Information School

A Decision Model for e-Procurement Decision Support Systems for the Public Sector Using Multi-Criteria Decision Analysis

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Information School

University of Sheffield

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January 2015

ACKNOWLEDGEMENTS

I would like to thank everyone who advised, helped and supported my PhD study.

More specifically, I would like to thank my sponsors and supervisors for their advice and support at different stages of this research.

I would also like to thank my fellow doctoral students for the helpful research discussions that we shared.

Finally, I would like to thank my family, especially to parents for their care and support to my education.

ABSTRACT

This PhD research aims to identify, analyse and evaluate a decision model for an e-procurement Decision Support System (DSS) for the public sector in Maldives, especially focusing on the Education Sector. The DSS uses Multi-Criteria Decision Analysis (MCDA) to evaluate procurement alternatives.

The features and characteristics of public sector procurement are based on major public sector principles, such as non-discrimination, equality, transparency and proportionality. This results in an organised step-by-step procedure for public sector procurement. However, this research focuses only on decisions that are based on the performances of the suppliers against a pre-set list of criteria where MCDA is applied to the evaluation.

This research studied the applicability of a comprehensive set of published MCDA methods identified in the literature to the problem context. The MCDA methods used in this research involves linear weighting methods, single synthesising criterion or utility theory, outranking methods, fuzzy methods and mixed methods.

This research adopted the Design Science Research (DSR) methodology, which is intended to design an artefact. The artefact in this case is the decision model. The methodology provides the artefact, explains how to use it, and how to evaluate the artefact. As these three components are of prime importance for the research project, DSR is chosen. The methodology follows a set of specific guidelines provided by Information Systems (IS) research scholars for such IS research projects. To support the process steps of the research project, literature reviews of public sector procurement and MCDA were undertaken, field research of focus groups was carried out, and selected documented data on procurement evaluations were collected for performance analysis of the MCDA methods in context.

The first part of the literature review provided the requirements and constraints of the public sector procurement in general and specifically in relation to

Maldivian public sector. The second part of the literature review identified MCDA methods and their procedures and characteristics.

The focus group discussions were conducted with public sector procurement evaluation officials of selected education institutions, to identify operational constraints and requirements of the procurement.

Criteria-based evaluation was conducted on the characteristics of MCDA methods compared to the public sector requirements gathered through literature review and focus groups. This analysis was to identify the applicable MCDA methods based on public sector requirements. The analysis filtered only two applicable methods namely, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) and COPRAS (COmplex PRoportional ASsessment).

Finally, performance analysis was done on the two methods by applying real life procurement data collected from selected public sector institutions. Congruence/incongruence analysis, variance analysis, stability analysis and MCDA were performed based on the results of the two methods, with real life data.

The performance analysis shows TOPSIS having higher variance and stability over COPRAS. However, congruence/incongruence analysis was inconclusive. Based on the results of criteria-based evaluation and performance analysis, MCDA was applied on TOPSIS and COPRAS. The current public sector procurement evaluation method, weighted sum and the two filtered methods are used for MCDA on TOPSIS and COPRAS. The MCDA also resulted in favour of TOPSIS. Therefore, based on this research, the recommended decision model for the public sector e-procurement DSS for the Maldivian context is TOPSIS.

The major research outputs are the identification of public sector requirements in context, the characteristics of the majority of MCDA methods in context, and strengths of performance of TOPSIS and COPRAS. In addition, the research identified the suitable decision model for the context, a theory of use of it in the context of the Public Sector of the Maldives and a framework to identify and evaluate the decision model.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Procurement objective is commonly defined as the acquisition of the right quality of material, at the right time, in the right quantity, from the right source, at the right price (Baily, Farmer, Jessop, & Jones, 1994; England, 1967; Leenders & Fearon, 1997; Weele, 2000). As procurement may turn out to be a complex and costly task (Monczka, Handfield, Guinipero, Patterson, & Waters, 2010), a procurement department needs to have the right system to make the right decisions on procurement. Availability of required materials and services are one of the prime factors for the smooth running of any organisation. Therefore, it is a vital responsibility for the procurement departments to select and provide the best materials and services to the organisation (England, 1967).

Procurement is challenging because making a fair judgment in selecting the right suppliers is never easy. The stakeholder theory by Freeman (1984) gives no room for negligence in selecting the best suitable supplier, because it makes a huge impact on the vast majority of the stakeholders.

In the context of the education sector, where this research is focused, the procurement of unsatisfactory materials and services may ruin the education of hundreds of students, the hopes of dozens of parents and the development of proficient citizens of the nation. Therefore the education authorities should pay particular interest to ensuring an effective procurement process.

Through Information and Communication Technology (ICT), the decision-making process of procurement can be assisted. Data and information from various suppliers can be analysed to suggest the best supplier for enabling the procurement decision makers to make sound judgements.

This design science research (DSR) aims to develop a design of a decision model for an e-procurement decision support system (DSS) for the public sector in Maldives, especially focusing on the education sector. The DSS uses Multi-Criteria Decision Analysis (MCDA) to evaluate procurement alternatives. The study uses published mathematical models to study and design a suitable decision model for a public sector e-procurement DSS.

1.2 Research background and context

This research focuses on the procurement of public sector education institutions in the Maldives. Acquiring materials and services for the education sector is a considerable job and involves a significant amount of funds and effort.

The education sector follows the *Dhaulathuge Maaliyyathuge Gavaaidhu* 2009 (literally, *Public Finance Regulation* 2009) on procurement published by Ministry of Finance and Treasury (MoFT), based on *Dhaulathuge Maaliyyathuge Gaanoonu* 2006 (literally, *Public Finance Act* 2006). In the education sector the procurement is a manual process done in three different hierarchies in different locations, namely at institutional level, at Ministry of Education level and at national tender board level.

Based on *Dhaulathuge Maaliyyathuge Gavaaidhu 2009*, if the procurement material or service cost is less than MVR1,000.00 (approximately GBP42.00), the institution can purchase it at a common market rate from any supplier. If the procurement material or service cost is from MVR1,000.00 to MVR25,000.00 (approximately GBP1,042.00), the institution should get quotations from three different suppliers and purchase it from the best supplier. If the procurement material or service cost is MVR25,000.00 or above, the institution has to go for public bidding or tendering. If the procurement material or service cost is from MVR25,000.00 to MVR1,500,000.00 (approximately GBP62,500.00), the institution forms a Bid Evaluation Committee (BEC) and the BEC evaluates the bids. If the procurement material or service cost is MVR1,500,000.00 or above, still the institution has to announce for public tender and the tenders are evaluated through National Tender Board (NTB) ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

The research focuses on the second last band, where procurement material or service cost is more than MVR25,000.00, which requires public bidding. This band is considered to be significant because, in this band, education sector BECs evaluate and decide the suppliers for education sector procurement and require careful evaluation of bids, based on legal and operational requirements for the benefit of the stakeholders.

Some institutions are allocated autonomous budgets and, with the approval of the Ministry of Education (MoE), the institutions take responsibility and do their own procurement. Budgets of other institutions are maintained by MoE, based on the needs of the institutions. For these institutions MoE does the tendering and BEC of MoE selects the suppliers. These tenders are sometimes group tenders for multiple institutions to lower procurement costs.

When procurement is required, the institutions announce a request for tender (RFT). In the announcement it specifies a date for an information session before the submission date. During the information session the evaluation criteria are provided to potential bidders.

Based on documented evidences and discussions with the BEC, the institutions evaluate bids using the weighted sum method on the pre-announced criteria. Different institutions have slight variations in representation of weighted sum method. However, these variations do not affect the final outcome of the weighted sum method. Depending on the material under procurement, the institutions allocate different criteria and weights for the criteria.

The supplier selection decision is made based on the supplier performances of the publicly announced criteria set for the procurement, as specified in Public Finance Regulation of Maldives. The final decision is taken by BEC in the research context. It is a legal requirement for the BEC to specify the reason for choosing a specific supplier ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

However, the weighted sum method which is currently used in public sector procurement in Maldives and many other countries has undesired outcomes according to literature (Luitzen de Boer, Linthorst, Schotanus, & Telgen, 2006; Keeney, 2002; Mateus, Ferreira, & Carreira, 2010). Luitzen de Boer et al. (2006) Boer et al. (2006) identified five distinct issues from the past public sector procurement cases that resulted unfavourable procurement outcomes. Similarly Keeney (2002) identified 12 mistakes of the method when applied to public sector procurement. Therefore, there is a need to identify a better decision making model for public sector. Any such decision model should meet the specific legislative requirements of the country (Falagario, Sciancalepore, Costantino, & Pietroforte, 2012; Leenders & Fearon, 1997). There are many decision models for procurement evaluations (Guitouni & Martel, 1998). However no literature provided a comprehensive study of the established decision models on public sector procurement evaluation. This study fills this gap focusing on Maldivian public sector procurement.

With developments in ICT, MoE is equipped with ICT infrastructure. However, the procurement evaluations are done manually, using desktop computers. The government of Maldives has established a National Centre for Information Technology (NCIT) to develop and promote ICT. NCIT has so far developed some

e-Government applications (NCIT, 2012) and it is expected that e-procurement services will be incorporated in the near future.

In light of these developments in ICT in the public sector of Maldives, the research focuses on the e-procurement decision model. However, though the decision model can be applied manually for the supplier evaluation, this would be time consuming and prone to errors. Therefore, the research project specifies the decision model for e-procurement where computerised processing is expected.

1.3 Research question and objectives of the research

Public sector procurement has a rigid structure enforced by law and regulations and follows a standard procedure for public sector procurement involving many activities at different stages. In the stage of supplier selection, decision-making is based on the performances of the suppliers against a pre-set list of criteria. These criteria allow public sector institutions to state differentiated priorities when they announce for bids or tenders. This situation creates a context in which MCDA techniques should be applied to the evaluation.

There are multiple MCDA methods. However, the applicability and suitability of these methods to the problem context is not known due to the multiple constrains and expectations of the public sector and there is no evidence of research conducted to answer the problem in this specific context. This research will study the applicability and suitability of a comprehensive set of published MCDA methods to the research context.

The primary aim of the research is to identify, analyse and evaluate MCDA methods to be applied as the decision model for an e-procurement DSS in the Maldives public sector, especially focusing on the education sector, to suggest the most preferred supplier, based on supplier performances of pre-set criteria.

Considering the primary aim of the research, the purpose of the study will be addressed through the following research question:

What is the most suitable MCDA method that can be used in public sector procurement in the Maldives education sector?

To answer this research question, the following research objectives were set:

i. To identify procurement characteristics, constraints and limitations of public sector procurement in general and more specific to the education sector in relation to local laws and regulations.
ii. To identify operational constraints, limitations and expected characteristics of public sector procurement from the education sector procurement decision-makers' perspective.
iii. To identify and analyse the characteristics of potential MCDA methods in the context of public procurement decision-making.
iv. To filter applicable MCDA methods by undertaking a comparative analysis of identified methods with the public sector procurement characteristics, constraints and limitations in relation to law and regulation and decision-makers' view.
v. To carry out a comparative analysis of the applicable MCDA method, based on the results of applying real procurement data sets as a proof of the model with the best performance.

1.4 Scope of the research project

The project is confined to a specific context. It is to have clear boundaries of the project to be completed. The scope of the project is listed below:

i. The research will focus on a decision model of e-procurement decision support system in the Maldives public education sector.

ii. The research will not cover tendering but uses tendering data and the information gathered as a result of tendering.
iii. The decision model will be based on the data received and generated for BEC to make decisions.
iv. The decision model will work on multiple selection criteria set by public sector institutions for procurement.
v. The decision model will suggest the best alternative, based on the supplied performance data of the pre-set criteria.
vi. The decision model is intended for the public procurements with value between of MVR25,000 and MVR1,500,000, where public tendering is required by law and evaluated by BECs of education sector. However, the decision model could be a potential model to apply for procurements of value more than MVR1,500,000, where NTB evaluates the suppliers.

1.5 Research methodology

The research adopted DSR methodology, as justified in Chapter 2. The process steps of the methodology involve an awareness of the problem at first, followed by suggestion and development of an artefact, and finally an evaluation and conclusion. The methodology used here follows a set of specific guidelines (Hevner, March, Park, & Ram, 2004) provided by information systems (IS) research scholars for IS research projects such as this.

To support the process steps of the research project, literature reviews undertaken, field research carried out, and selected documented data sets on procurement evaluations collected. For the field research, focus groups were conducted with public sector procurement decision-making officers to enhance awareness of the problem; to help to make more specific suggestions; and to support

the development of the artefact by identifying operational constraints and requirements of public procurement.

The reviews of literature concerning MCDA methods and the legal requirements for the public sector helped to compare public sector requirements and constraints against the characteristics of MCDA methods. This approach helped to filter and suggest alternative methods that are applicable.

The collected data sets are used to apply the filtered methods, in order to evaluate it. A set of performance analyses were undertaken on the results of these exercises in order to determine the performance of the artefact.

1.6 Structure of the thesis

The thesis is organised in the following chapters. Chapter two introduces DSR as the methodology used for this research, discussing the rationale for choosing it and comparing it to other common research approaches. The overall implementation structure of the research, with expected outputs are discussed in the chapter.

The third chapter discusses the research design. It provides detailed research implementation procedures. The chapter considers how the literature review was conducted, how focus groups are conducted and analysed, and how the performance analysis was carried out.

In chapter four, a review of the literature on procurement is presented. It covers public sector procurement in general and more specific to the research context. The chapter also deals with providing operational definitions and reviewing the literature for the specific issue of public sector procurement characteristics, guidelines, evaluation criteria, and modes of procurement in general, and in line with prescribed public sector legislations.

Chapter five presents the focus group findings in three major themes; preparation process, bidding process and evaluation process. Each has its sub-categories to represent the results.

Chapter six reviews major published MCDA methods and compares the characteristics of the MCDA methods with the public sector procurement characteristics, guidelines and constraints identified. Based on the comparative analysis, the chapter identifies the applicable MCDA methods in the public sector procurement decision-making.

Chapter seven discusses the performance analysis of the MCDA methods. Congruence analysis, variance analysis, and stability analysis conducted using real life procurement data are presented in this chapter. The chapter also presented the application of MCDA to the methods.

Finally, the concluding chapter presents a summary of the research and how the research question was addressed in the project. The chapter discusses contribution to knowledge and provides suggestion for the public sector and also discusses the limitations of the research project. In addition, future work is also discussed in this chapter.

1.7 Main findings and contributions

The framework to identify and evaluate the decision model is one of the major contributions. As presented in Section 2.3 and illustrated in Figure 2.2, the framework provided the most suitable decision model according to the legislative and operational requirements of Maldives public sector. The framework incorporated series of qualitative and quantitative evaluations including performance analysis using real life public procurement data sets. This research approach has yielded good results and research findings. This research design is easily transferable to other contexts and studies that aim at understanding the use of artefacts in complex human activity systems that share legal, operational and performance requirements.

Secondly, identification of the most suitable decision model for the Maldivian public sector procurement for the education sector for supplier evaluation is a major contribution. The research suggested that the most suitable decision model for the context is TOPSIS.

Third major contribution is identification of public sector procurement requirements and constraints in general and specific to Maldivian context. The requirements are gathered from literature and legislations. The research identified 29 requirements.

Fourth major contribution is identification of operational requirements and constraints in relation to procurement evaluations. The requirements are gathered through focus groups with Maldivian public sector procurement decision makers. The research identified 42 operational requirements.

Fifth major contribution is the outcome of the criteria-based evaluation. This study compared the identified characteristics of MCDA methods against the public sector procurement requirements of the research context. This analysis helped to identify the MCDA methods that are applicable to Maldivian context. It resulted in two applicable methods, TOPSIS and COPRAS.

Sixth major contribution is the finding of the relative strength of performance of TOPSIS and COPRAS. These evaluations measured the strengths of performance of the two methods in same scenarios. Based on the evaluation, TOPSIS has a higher performance than COPRAS.

Seventh contribution is the application of the identified decision model in practice. These sample applications, with segmented and staged results, will allow users to understand the application of the methods in procurement and its results in procurement context.

1.7.1 Publications

Based on the findings and contributions discussed in previous section, three journal papers and two conference papers are published and two more papers are under process. The publications are as follows.

Journal papers:

- Adil M, Nunes MB & Peng GC M (2014) Identifying Operational Requirements to Select Suitable Decision Models for a Public Sector E-Procurement Decision Support System. Journal of Information Systems and Technology Management, 11(2), 211-228.

- Adil M, Nunes MB & Peng GC M (2014) A three tier evaluation mixed method research model aiming to select an adequate MCDA method for public sector procurement. International Journal of Multiple Research Approaches, 8(2), 179–189.

- Adil M, Nunes MB & Peng GC M (2013) Selecting e-procurement decision models by evaluating MCDA methods according to the requirements of the Maldivian public sector. International Journal of Small Economies, 4(1), 9-22.

Conference paper:

- Adil M, Nunes MB & Peng GC (2014) Selecting suitable E-procurement decision models for the Maldivian public sector by evaluating MCDA methods. New Perspectives in Information Systems and Technologies, Vol. 1 (pp 455-465). Maderia, Portugal, 15 April 2014 - 18 April 2014.

- Adil M, Nunes MB & Peng GC (2013) Selecting Public e-Procurement MCDA Methods Using a Three Tier Evaluation Mixed Method (TTMM) Research Model.Proceedings of the 12th European Conference on Research Methodology for Business and Management Studies (pp 1-8)

CHAPTER 2

RESEARCH METHODOLOGY

2.1 Overview

The chapter describes the methodological approach used in this research, which aims at responding to the research question presented in Chapter 1 and represents a research focus on designing a decision model for e-procurement DSS using multi-criteria decision analysis.

The research adopts an overreaching Design Science Research (DSR) approach, which is chosen based on a review of different research approaches for this type of information system project. This chapter explains the choice of methodology and the reasoning behind the research approach and techniques used.

At first the chapter justifies the choice of DSR as well as the philosophical grounding of the approach when compared to other research approaches. The chapter also explains the implementation of the research project in terms of DSR adopted activities, such as field research and artefact evaluation.

2.2 Philosophical grounding and the basis for choosing DSR

According to the traditional perspective of IS research, Laws (2003) describes two major research approaches: positivist and interpretive approaches. Laws (2003) stated that research is all about the power of defining reality and research is undertaking systematic study with a view to making valid claims about the world.

However, different research traditions interpret this definition differently. Traditional scientific research claims that 'the scientist is disinterested, unbiased observer, who can produce objective truth about reality', a reality that is out there to be observed. Social science research which follows this tradition is called 'positivist' research (Laws, 2003:27).

Flick (2009) states that positivism is often attached to realism because "both assumes that natural and social sciences should and can apply the same principles to collecting and analysing data and that there is a world out there (an external reality) separate from our description of it" (Flick, 2009:69).

Recent social science approaches have disputed the view that a truly objective science is possible, showing how the observer's standpoint affects what is seen at every level. Reality is, to some extent, influenced by our own views of it. These traditions of research include social constructionism, phenomenology, critical theory, and grounded theory (Laws, 2003:27).

Design science research is a set of techniques that can be used alongside positivist and interpretive viewpoints in IS research (Vaishnavi & Kuechler, 2011). Table 2.1 summarises the philosophical assumptions of these three approaches of research.

Table 2.1: Philosophical assumptions of three research perspectives (Source: Vaishnavi and Kuechler, (2011)).

	Research Perspective		
Basic Belief	**Positivism**	**Interpretivism**	**Design Science**
Ontology	A single reality. Knowable, probabilistic	Multiple realities, socially constructed.	Multiple, contextually situated alternative world-states, socio-technologically enabled.
Epistemology	Objective: dispassionate. Detached observer of truth	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	*Knowing through making:* objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology	Observation; quantitative, statistical	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure artifactual impacts on the composite system.
Axiology: what is of value	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e. Improvement); understanding.

The three perspectives of research outlined in Table 2.1 are further discussed in the following sections explaining why DSR is adopted and other approaches are rejected for the research project.

2.2.1 Positivism

Positivism is the philosophical stance adopted by natural scientists and in social science, it is bounded with observable social reality producing research outcomes of 'law-like generalisations', like those of physical and natural scientists (Saunders, Lewis, & Thornhill, 2009). In contrast, this research project is confined to a specific context and specific group to design a solution valid to the research context only. It is the identification of the decision model for decision-making for the public procurement of Maldivian Education Sector.

The positivist approach involves using existing theory to develop hypotheses. These hypotheses are tested to be accepted as a whole or part, or proved false (Saunders et al., 2009). For this research, there is no clear hypothesis, but the objective is to reach a decision model to help in decision-making in the research context.

A significant part of the positivist approach, according to Saunders et al. (2009), is that the research is conducted in a value-free way. However, this research project cannot be value-free research, due to its context. It involves procurement culture, laws and regulations, expectations of the public and many other value incorporated factors that are unique to the context and cannot be generalised. In addition, the research project is employed in order to develop a decision model for public sector procurement which adheres to contextual constraints and requirements.

Due to ontological and epistemological conflicts between positivist research approach and this research context, as discussed above, a positivist approach cannot be used to answer the research question.

2.2.2 Interpretivism

Interpretivism, in contrast to the positivist stance, advocates that the social world is far too complex to be theorised by explicit ‘laws’, as in the physical sciences (Saunders et al., 2009). Interpretivists argue that important concepts of this complex world are nowhere to be found, if such complexity is presented as a sequence of law-like generalisations (Saunders et al., 2009).

Interpretivist researchers have knowledge of the difference between carrying out research among people and objects. Humans interpret their part in a particular way and it varies according to their set meanings (Saunders et al., 2009).

The ontology of the interpretivist research considers multiple realities (Vaishnavi & Kuechler, 2011) but this research aims to find a single most

appropriate MCDA model for the context, and the research context does not assume multiple alternatives.

The major output of this research, the decision model, is contextualised and applicable only to the context. However, the framework of identification and the evaluation of the decision model could be used in other similar problems.

"Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them" (Myers & Walsham, 1998:233). Interpretivists are not "reporting facts; instead, they are reporting their interpretations of other people's interpretations" (Walsham, 1995:79). However, the research question established in Section 1.3 required the identification, analysis and evaluation of MCDA methods, based on their inherent characteristics, linked to the contextual requirements. These inherent characteristics of MCDA methods are facts presented through analysis and evaluation, rather than people's interpretation attached to the MCDA methods. The analysis and tests on MCDA methods cannot be performed through an interpretivist approach to answer the research question.

"Central assumptions of interpretivism include that knowledge is gained through social constructions, that it does not include predefined dependent and independent variables, that it focuses on sense making in complex and emerging situations and that it attempts to understand phenomena through the meanings assigned to them by individuals in situations" (Stahl, 2014:2). However, MCDA methods require predefined variables to function. In addition, for the performance evaluation of the MCDA methods needed for this research requires predefined variables, as the performances should be evaluated based on the results of the MCDA methods when executed with required parameters. Therefore, the research is not in alignment with interpretivist approach.

Interpretivist approach interprets people's description of their surroundings, organisational structures, technological artefacts and their relations (Schultze & Leidner, 2002). However, the research question does not require people's interpretation of the MCDA methods and its relations, but requires a factual

description of the MCDA methods and its characteristics to evaluate the method's suitability as a decision model for the context.

As described above, interpretivist approach does not support the identification, analysis and evaluation of MCDA methods to answer the research question for the particular context. Therefore, interpretivist approach was not selected as the base approach for this research.

2.2.3 Design science

"Design science research is yet another "lens" or set of analytical techniques and perspectives (complementing the Positivist and Interpretive perspectives) for performing research in IS" (Vaishnavi & Kuechler, 2011:1).

DSR intends to design a man-made artefact opposed to natural science. Simon (1996) made a clear distinction between "natural science" and the "science of the artificial", also known as design science, bringing the design activity into the spotlight at an intellectual level. Design activity is the creation of an artefact, its components and their organization, which interfaces in a desired manner with its outer environment (Vaishnavi & Kuechler, 2011).

The science of the artificial is a body of knowledge about artificial or man-made objects and phenomena designed to meet certain desired goals (Simon, 1996).

Artefacts developed through design science research include algorithms, human computer interfaces and system design methodologies or languages, and many more. DSR can be understood as the analysis of the use or performance of the artefacts to enhance and recognise the behaviour of aspects of IS (Vaishnavi & Kuechler, 2011).

2.2.3.1 Basic principles

Design science research is carried out in various subject areas commonly in engineering and computer science, using a variety of approaches, methods and techniques. For the past several years, IS research has shifted from technological issues to managerial and organisational issues. However, many researchers are still supporters to return to an investigation of the "IT" that underlies IS research (Orlikowski & Iacono, 2001).

DSR is distinct in terms of their metaphysical assumptions. One of the distinct features of DSR is that the ontology, epistemology, and axiology of the paradigm cannot be developed from any other research approaches. The second distinct feature is that when the project runs, it goes through several refinements (Vaishnavi & Kuechler, 2011).

Alternative world-states are easily acceptable to design science researchers because DSR itself changes the state of the world by means of bringing the artefacts to it. The initial phase of DSR provides a tentative composition to develop an artefact which will have the functionality to solve the intended problem. For this process DSR keeps a natural-science-like belief in a single, fixed grounded reality (Vaishnavi & Kuechler, 2011).

However, as shown in Table 2.1, DSR considers a single stable physical reality with a multiplicity of world-states, unlike the multiple realities of the interpretive researcher.

Epistemologically, in the course of circumscription in DSR, the design science researcher identifies that the information is based on fact and understands more about what that information means. The descriptions of the result of interactions between the components or the behaviour of the artefact are information. The level of predictable behaviour of the artefact determines whether the information is true. The reliance on a predictably working artefact provides DSR with an epistemology that looks more akin to natural-science research than that of either positivist or interpretive research (Vaishnavi & Kuechler, 2011).

Design science is “fundamentally a problem-solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished” (Hevner et al., 2004:76).

Hevner et al. (2004), believe that artefacts are interdependent and coequal with organisational and social contexts in meeting business goals. Hevner et al. (2004), argue that the ability of the constructs, models, methods, and instantiations are as important as other elements of organisation, and that DSR work is required to create it.

2.2.3.2 Methods in DSR

Quantitative and qualitative methods are used in DSR. Quantitative analysis of artefacts is done using a mathematical basis such as optimization proofs, analytical simulation, and quantitative comparisons with alternative designs (Hevner et al., 2004).

Empirical and qualitative methods are used in the evaluation of the artefact, based on the research context. In such contexts, qualitative assessment of the interaction of people, organisation and technology would give a better understating of the phenomena for theory development (Hevner et al., 2004).

DSR provides the artefact, explains how to use the artefact, and how to evaluate it. These features are required in this research project. Therefore, DSR is extremely appropriate to respond to research question. As such, this research project applies DSR and uses qualitative and quantitative methods in evaluation of the artefact. The methods used in this research project are detailed in Sections 2.3.3.

2.2.3.3 Outputs of DSR

According to Hevner et al. (2004), DSR develops and assesses IT artefacts meant to solve identified organizational problems. These artefacts may include software, formal logic, and rigorous mathematics to informal natural language descriptions (Hevner et al., 2004).

The definition of artefact by Hevner et al. (2004), includes instantiations, constructs, models, and methods applied in the development and use of information systems. But it does not include elements of organisations and the evolving process of artefacts.

According to Hevner et al. (2004), the artefacts created in DSR are not often fully developed information systems implemented in organisations. They are new concepts that define ideas, practices, technical capabilities, and products.

March and Smith (1995) state that there are four types of DSR products. They are constructs, models, methods, and implementations. Constructs are the vocabulary of intended DSR domain. They represent the concept applied to explain problems within the domain and to state their solutions (March & Smith, 1995). Constructs come up during the conceptualization of the DSR problem and are enhanced and improved during the design cycle (Vaishnavi & Kuechler, 2011).

A model is “a set of propositions or statements expressing relationships among constructs” (March & Smith, 1995:256). In design activities, statements of condition as problems and solutions are representations of models. A model is basically a description or a representation of how things are (March & Smith, 1995).

A method is “a set of steps (an algorithm or guideline) used to perform a task” (March & Smith, 1995:257). Methods are developed on a set of constructs and a model of the solution. Even if methods are clearly not defined, the demonstration of activities and results are inherent to methods (March & Smith, 1995).

Instantiations operationalise constructs, models, and methods as the outcome of the realization of an artefact in its environment (March & Smith, 1995:258). An instantiation sometimes precedes a complete articulation of the conceptual vocabulary, models and methods that it embodies. Instantiations exhibit the possibility and usefulness of the models and methods they contain (March & Smith, 1995).

In addition to the four types of outputs by (March & Smith, 1995), based on the work of Rossi and Sein (2003) and Purao (2002), Vaishnavi and Kuechler (2011) stated that the fifth output of DSR is better theories.

There are at least two different ways that DSR contributes to better theories. Firstly, as the methodological construction of an artefact is an object of theorizing for many communities, the construction phase of a DSR effort can be an experimental proof of method or an experimental exploration of method, or both. The second way of contributing to better theories, as artefacts can show relationships between its elements. The relationships between elements of artefacts allow certain behaviours, and it restrains some, in order for its function to be as it should (Vaishnavi & Kuechler, 2011).

The outputs of DSR explained above are summarised in Table 2.2 providing the titles and descriptions.

Table 2.2: The outputs of DSR (Source: Vaishnavi and Kuechler (2011))

	Output	Description
1	Constructs	The conceptual vocabulary of a domain
2	Models	A set of propositions or statements expressing relationships between constructs
3	Methods	A set of steps used to perform a task – "how-to" knowledge
4	Instantiations	The operationalization of constructs, models and methods.
5	Better theories	Artefact construction as analogous to experimental natural science, coupled with reflection and abstraction.

The research project followed DSR guidelines and has generated the outputs listed in Table 2.2 and explained in Section 2.4.6. The implementation details of the research project with the outputs are discussed in Section 3.4.

2.3 Implementation of research project

The methodology of DSR proposed by Vaishnavi and Kuechler (2011) is adapted for the implementation of this research project as summarised in Figure 2.1. Originally, Vaishnavi and Kuechler (2011) shows the outcomes of Development, Evaluation and Conclusion looping back to awareness of the problem. However, the researcher is presenting it as findings and contributions of the research.

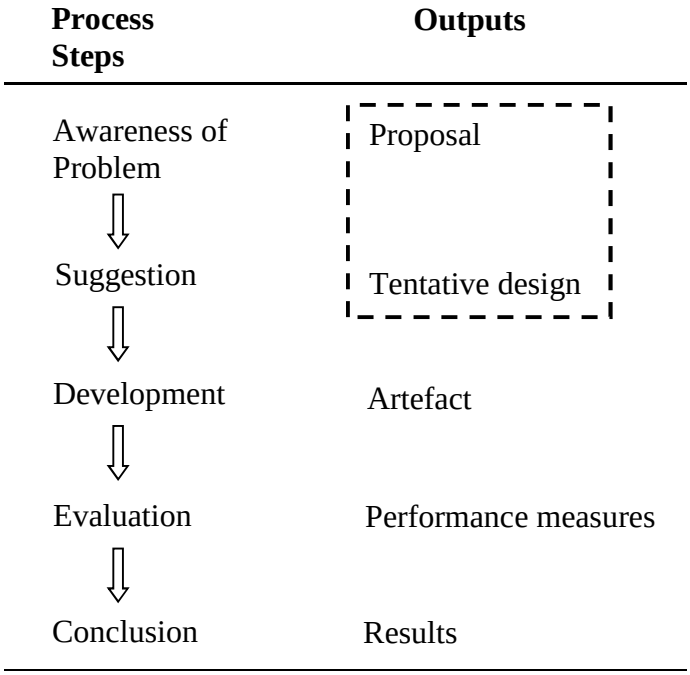

Figure 2.1: General methodology of DSR (Adapted from Vaishnavi and Kuechler (2011))

The process steps of the methodology involve awareness of the problem at first, followed by suggestion and development of an artefact, then finally its evaluation, to make a conclusion. The processed steps are further explained in the following sections.

For this research the last three steps of DSR; artefact development, evaluation, and conclusion, are implemented according to the model shown in Figure 2.2.

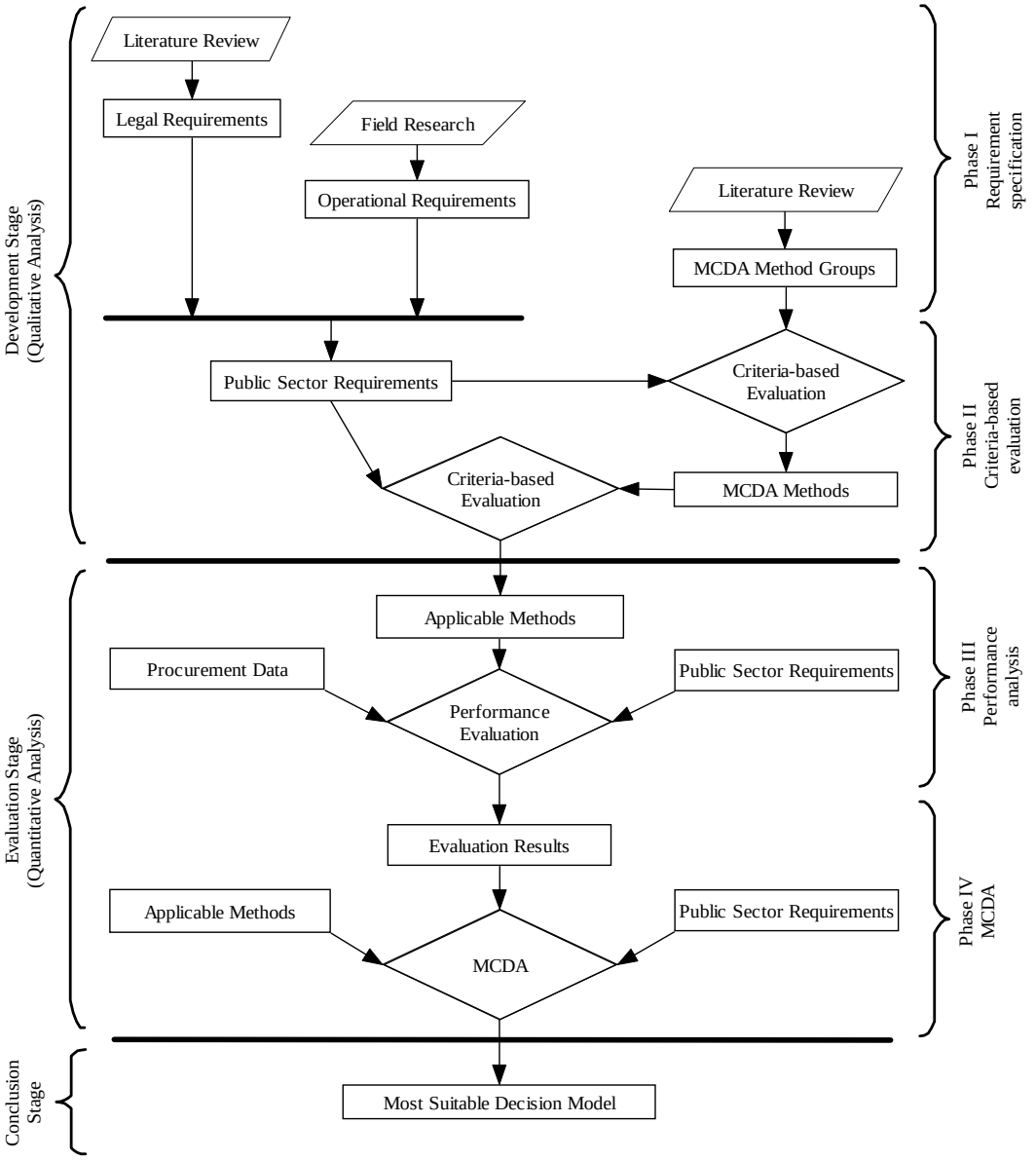

Figure 2.2: Artefact development, evaluation and conclusion model

For the development, in the first phase, at first, the literature review of public sector procurement was done in general but was more specifically related to research

context. This component is presented in Chapter 4. The second step was field research, involving focus groups conducted with public sector procurement decision-makers, in order to understand operational requirements. The focus groups are explained in section 3.4 and the analyses are presented in Chapter 5. The third step of the first phase was a systematic literature review of MCDA methods, in order to analyse their characteristics and requirements. This systematic literature review is explained in section 3.3.2 and the discussions are presented in Chapter 6.

For the second phase, firstly a criteria-based evaluation was conducted on MCDA methods at group level against public sector requirements. Secondly, another criteria-based evaluation conducted on individual MCDA methods that passed through the previous step, against public sector requirements. The MCDA methods filtered through the criteria-based evaluation are taken for the evaluation stage. The development stage is further explained in Section 2.3.3. The results of the evaluations are presented in Chapter 6.

For the evaluation stage, real life procurement data sets were collected from public sector institutions. These sets of procurement data were applied to the filtered methods from the development stage. In the third phase of the research, performance analyses are undertaken on the results of the application of the real life procurement data to differentiate the filtered MCDA methods in relation to public sector procurement requirements. The fourth phase is application of MCDA to select the best performing method, based on the performance results from the previous evaluations. The evaluation stage is further explained in Section 2.3.4. The results of the evaluations are presented in Chapter 7.

For the conclusion stage, results of the evaluation stage were used to make a decision on the filtered methods in the context of public sector procurement as is further explained in Section 2.3.5.

2.3.1 Awareness of problem

As described by Vaishnavi and Kuechler (2011), awareness of an attractive problem may result from developments in an industry or in a particular discipline. Reading in the discipline may also provide the chance to apply new solutions to the researcher's field. The output of this phase is a proposal for new research (Vaishnavi & Kuechler, 2011).

The government of Maldives in the research context has established a Nation Centre for Information Technology as the main government agency for the development, promotion and propagation of Information Technology (IT) in the Maldives (NCIT, 2012). NCIT is also currently working on e-Government project to ease government services to the public (NCIT, 2012). With the developments in public sector IT infrastructure and services, it is expected that e-procurement services will be available to the public sector.

Currently, the research context is using a manual weighted sum decision analysis model which has lots of drawbacks and undesirable outcomes (Luitzen de Boer et al., 2006; Keeney, 2002; Mateus et al., 2010). There are many decision models which could be used (Guitouni & Martel, 1998) and could potentially be better. However, no research has been done so far on this specific problem to identify the best applicable decision model for the research context.

The developmental changes in government services, as mentioned above, and better theoretical understanding of the procurement decision, has created an interest in researching a better decision model for procurement decisions. As a result, a research proposal has been developed.

2.3.2 Suggestion stage

As described by Vaishnavi and Kuechler (2011), the suggestion stage follows immediately after the proposal and the output is the tentative design, which is any formal proposal for design science research for a sponsor. It is basically a creative

step in which new functionality is figured out based on a novel configuration of either existing or new and existing elements (Vaishnavi & Kuechler, 2011).

Public services are being transformed to offer easy access to the public through e-services in the Maldives (NCIT, 2012). Procurement is one of the services which requires a significant amount of public funds, but no research in the problem context has been done to improve the procurement services, even though the developments in technology and infrastructure are developing in the research context.

Since there are many different multi-criteria decision analysis methods which could be used in public sector procurement (Falagario et al., 2012; Guitouni & Martel, 1998; Vaidya & Kumar, 2006), the proposal was to identify and suggest the most suitable MCDA method for public sector procurement decisions to incorporate the new technological developments of public services.

In light of the developments in the public sector services in Maldives, especially focusing on e-government services and the theoretical developments of the subject area, a formal research proposal for this research project was submitted to the sponsor. After considering the proposal with high importance, a team of experts for the sponsor accepted this research project and funded it.

2.3.3 Development stage

As described by Vaishnavi and Kuechler (2011), Tentative Design is implemented in this phase. Implementation techniques vary depending on the artefact to be constructed (Vaishnavi & Kuechler, 2011).

The development stage has two phases: requirements specification and criteria-based evaluation. The one the research activities in first phase is conducting literature reviews of public sector procurement and the area specific to the problem context, in order to understand the characteristics and constraints of public sector

procurement. It also covers the characteristics of MCDA methods to assess it in relation to public sector procurement.

The second research activity in first phase of development stage involved field research to identify operational issues and expected characteristics of the decision model for public sector procurement from decision-makers.

Finally, the outcomes of the literature reviews and field research results are analysed and compared against MCDA models for compatibility. This analysis is a criteria-based evaluation. The following sections provide further details of the three stages of development.

2.3.3.1 Literature reviews

A literature review of public sector procurement and more specifically public sector procurement of problem context was completed, followed by a second literature review to understand the characteristics of MCDA methods.

The literature review of public sector procurement was to identify procurement characteristics, constraints and limitations of the public sector in general and specifically related to procurement in the Maldivian education sector in relation to local laws and regulations. The outcome of the literature review is used for criteria-based evaluation as illustrated in Figure 2.2. This literature reviews are presented in Chapter 4.

A systematic literature review of MCDA methods are carried out in order to identify characteristics of potential MCDA methods in the context of public procurement decision-making. This literature review is presented and discussed together with criteria-based evaluation, in Chapter 6.

The literature reviews helped to compare the public sector requirements and constraints against the characteristics of MCDA methods. This approach helped the

filtering and identifying alternative MCDA methods to apply in the Maldivian public education sector. The design of the literature reviews are further explained in Chapter 3.

2.3.3.2 Field research

Field research was carried out mainly to answer the second research objective listed in section 1.3, which is to identify operational constraints, limitations and expected characteristics of public sector procurement from the education sector procurement decision-makers' perspective.

The field research was also to support the process steps (listed in Figure 2.2) for the research project, more specifically to enhance awareness of the problem, to help generate more specific suggestions and to support development of the artefact.

As discussed in section 3.4.3.1 and section 3.4.3.1, limited number of procurement decision-makers in education sector and they make decisions in groups as BECs. Therefore to fulfil the second research objective to understand decision-makers' perspective, potential methods were interviews and focus groups.

Interviews are useful for exploratory, explanatory and evaluation studies. However, it provides view of the specific interviewee and not all the people are equally articulate and perceptive (Creswell, 2009). As such, focus group discussions would minimise this drawback in interviews and supplement each other's view point (Barbour & Kitzinger, 1999). It is also more productive to discuss in pre-existing groups (Lloyd-Evans, 2006), like BECs, as the procurement decisions are done in groups.

Focus groups are being increasingly used in academia and the method is being followed in variety of social sciences (Barbour & Kitzinger, 1999) to gather information on public perceptions and viewpoints (Lloyd-Evans, 2006).

Even though focus groups have great potential, like any other research methods, they can be used incorrectly (Barbour & Kitzinger, 1999). However, focus groups have more strength, according to Morgan (1997), as two eight-person focus groups would generate as many ideas as 10 individual interviews and working with two focus groups clearly is more efficient. (Morgan, 1997).

"Focus groups are group discussions exploring a specific set of issues. ... Crucially focus groups are distinguished from the broader category of group interviews by the explicit use of group interaction to generate data. Instead of asking questions of each person in turn, focus group researchers encourage participants to talk one another" (Barbour & Kitzinger, 1999:4)

Focus groups are best applied to look for people's experiences, opinions, wishes and concerns (Barbour & Kitzinger, 1999). Group discussions match the ways in which participants' views are generated, spoken, and exchanged in everyday life. It also helps validate statements and views through corrections by the group concerning views that are agreed to be incorrect (Flick, 2009).

This field research involved focus group discussions with BEC members of public sector education institutions. Since the focus groups in this research project were used to find out how the current process works, including constraints and requirements, and the expected characteristics of an ideal evaluation method, it is expected that group members would contribute to refining and adding missed points by colleagues, as focus groups stimulate the respondents and help them to recall events, and more information than that obtained from individual interviewees can be gained (Flick, 2009). This field research design is further explained in Chapter 3.

2.3.3.3 Criteria-based evaluation

This activity involved qualitative comparative analysis of the suggested alternatives, with the results of the analysed field research and literature review used to confirm the compatibility of the artefact. It is a criteria-based evaluation, defined

by Chen, Osman, and Peng (2012) as an “evaluation that is conducted according to predefined checklists, heuristics or principles”. These same authors state that these criteria stem from “specific theories, as well as sets of guidelines, standards or even legal requirements”. In this step, the criteria-based evaluation of the MCDA methods is performed against legal and operational requirements of public sector procurement of the Maldives, gathered from the literature and results of the focus groups conducted.

For this purpose, at first, the MCDA methods are grouped into five categories as in the literature by some authors (Figueira, Greco, & Ehrgott, 2005; Guitouni & Martel, 1998; Ho, Xu, & Dey, 2010).The characteristics of the groups are then compared to previously identified public sector requirements. The individual methods of the groups which satisfy public sector requirements are further compared with legal and operational requirements to select suitable methods from the group. No individual methods are further considered if its parent group does not meet public sector requirements. The results and additional information gained from each comparison are noted and considered for the next round alternatives.

The aim of this criteria-based evaluation in the second phase of the research as illustrated in Figure 2.2 is to check which of the identified MCDA methods comply with public sector requirements and could become good candidates for the design and development of the new e-Procurement Decision Support System. These evaluations and its confirmations are discussed in Chapter 5.

The results of the criteria-based evaluation are the filtered MCDA models for the artefact which are in confirmation with the field research and literature are fed to third phase evaluation as shown in Figure 2.2.

2.3.4 Evaluation of artefact

As described by Vaishnavi and Kuechler (2011), once developed, the artefact is evaluated according to the evaluation criteria. Deviations from expected results,

both quantitative and qualitative, are carefully noted and explained. The evaluation stage includes an analytic sub-phase in which propositions are made about the behaviour of the artefact (Vaishnavi & Kuechler, 2011).

The final set of artefacts undergoes a series of evaluations. It has three major methods of performance evaluation and MCDA. These three methods are used because they are complimentary and analyse different performance aspects of MCDA methods namely: similarity of performance, distance of alternatives, and stability of results.

MCDA is applied using the outcomes of the criteria-based evaluation and performance analysis to identify the most suitable model in the research context.

2.3.4.1 Performance analysis

The research project also collected and included real life data sets and their results used in procurement evaluations by public sector education institutions. These data sets are used to apply the selected and filtered set of final artefacts, so as to evaluate and make a conclusion as in the process steps (listed in Table 2.2).

This quantitative analysis component of this study uses selected procurement data sets collected from three distinct public sector education institutions working at three different levels. The three different public sector education institutions are a primary school, a secondary school and Ministry of Education (MoE). Thirteen sets of previously evaluated procurement data, along with the results of the evaluation, are collected from the three levels of institutions, providing more diversity in the data from the education sector.

The data sets were applied to the MCDA methods, filtered by the qualitative comparative analysis undertaken. The evaluation became a comparative process where the competing MCDA methods were evaluated for the significance of the results, one against the other. The set of quantitative analysis methods used for

evaluation are the performance analysis methods used in the literature for such comparisons of MCDA methods (Antucheviciene, Zavadskas, & Zakarevicius, 2012; Podvezko, 2011; Raju & Pillai, 1999).

The first quantitative analysis method was congruence/incongruence of ranking analysis, following the approach used by Raju and Pillai (1999). Congruence/incongruence of ranking analysis is one of the analyses employed to compare MCDA methods in literature by calculating correlation coefficients (Antucheviciene et al., 2012; Raju & Pillai, 1999). For this analysis Spearman's rank correlation coefficients are calculated, as this reveals the degree of association between ranks generated by different MCDA methods (Raju & Pillai, 1999).

According to Raju and Pillai (1999), if the Spearman's rank correlation coefficients between the compared methods are high, then the choice of the methods would have minimum contention. That is, if two methods have higher correlation coefficients, the results of the two methods are more similar.

The second quantitative analysis was variance analysis on the results of the selected MCDA methods. Variance measures how far a set of numbers is spread out (Field, 2005). The smaller the variance the closer the data points to the mean and each other. Similarly, a high variance indicates that the data points are very spread out from the mean and from each other.

The aim of this variance analysis is to compare the three results to check which method spreads the data points more, with the real procurement rankings. The higher the variance of the rankings, the farther the alternatives are from each other. Therefore the method which provides the higher variance would make alternatives more distinct from each other, for better selection by the BECs.

The third quantitative analysis took the form of a stability analysis, following the method used by Podvezko (2011). Stability analysis or robustness of results of MCDA methods is judged based on the effect of changes in the parameter values (Podvezko, 2011; Raju & Pillai, 1999).

Stability is higher if the higher changes in parameter values change the ranking results. Similarly, stability is lower if lower changes in parameter values change the ranking results. This test is to analyse and identify the method which provides higher stability.

The detailed activities in the performance analyses are explained in the following chapter, research design in Section 3.6. The analyses are presented and discussed in detail in chapter 6.

2.3.4.2 MCDA evaluation

The performance evaluation results are analysed to check the best performing MCDA method following the approach used by Raju and Pillai (1999). This analysis involved applying MCDA on the filtered methods. The current method used by the public education sector institutions to evaluate the suppliers and the filtered applicable methods are used as MCDA for the evaluation. The filtered methods are chosen because it is provided by the second phase of research with criteria-based evaluation which selects the MCDA methods that adhere to the public sector procurement requirements of the Maldives. In addition, the current method in practice, weighted sum, is chosen to evaluate the preference results based on the current system. Therefore, the methods used for the MCDA evaluation are in line with the public sector procurement.

This MCDA evaluation will provide the best method from the available alternative methods.

The detailed evaluation procedure is discussed in Chapter 3 and the evaluations and results are discussed in Chapter 7.

2.3.5 Conclusion of research

As described by Vaishnavi and Kuechler (2011) the conclusion stage is the finale of a specific research effort. “Typically, it is the result of satisfying, that is, though there are still deviations in the behaviour of the artefact from the (multiply) revised hypothetical predictions, the results are adjudged ‘good enough’” (Vaishnavi & Kuechler, 2011:9).

To satisfy the decision model’s requirement of ‘good enough’, the performance evaluation given above is carried out. Based on the results of the evaluation the best performing MCDA method is selected.

2.3.6 Outputs and its realisation

The research project created the artefact which can identify the best alternatives in a given context in line with public sector constraints, fulfilling the major aim of the research.

The outputs listed by March and Smith (1995) and Vaishnavi and Kuechler (2011), shown in Table 2.2, are also realised, as the project discussed the conceptual vocabulary of a domain in the literature review chapters (Chapter 4 and 6), giving the first outcome of constructs. The second outcome is the models created, as the artefact provides the relationships between the constructs for the DSS model in Chapter 4 and 6. The third outcome involves methods, which are explained as the artefact provides the steps and procedures for applying the DSS model in Chapter 6 and 7. The forth outcome, instantiation, is achieved as the research project analysed and identified the decision model for the context. The realisation of the fifth outcome, better theories, is achieved through providing the methodological construction and evaluation of the decision model in the particular context.

In addition to the outputs of DSR, the research project identified public sector requirements and constraints in the Maldivian context, as discussed in Chapters 4 and

5. It also has gathered the characteristics of major MCDA methods and its applicability in the context of public sector procurement. Finally, it has also evaluated and gathered the performance strengths of the two MCDA methods: TOPSIS and COPRAS.

2.4 Conclusion

This chapter has discussed the detailed methodology applied to the research project. The philosophical aspects of the DRS in relation to positivism and interpretivism have been discussed in relation to the outcomes of DSR research.

This chapter has also discussed the DSR research activities conducted for the research project, and the artefact evaluation methods and level of checks completed.

The chapter has explained and justified the research methodology used and techniques adopted for the research project.

CHAPTER 3

RESEARCH DESIGN

3.1 Overview

As mentioned in the previous chapter and illustrated in Figure 2.2, literature reviews, a field research, quantitative analysis was conducted as major components of the research project. This chapter presents and discusses the research design for these major areas.

This chapter discusses in detail the approach, procedures and activities conducted for the literature reviews, field research and performance analysis. The chapter is divided into these major sections, representing the the components as presented in Figure 2.2.

3.2 Introduction of the research design

Research design is defined as the “science (and art) of planning procedures for conducting studies so as to get most valid findings” (Vogt, 2005:276). As such, the research design for this research project provides a detailed action plan to direct data collection and analysis.

The literature review was targeted on two major areas: public sector procurement and MCDA methods. The literature review design is presented in Section 3.3. In this study, firstly public sector procurement constraints and requirements, based on the literature, were gathered. This literature review is presented in Chapter 4. The second area of the literature review gathered families of MCDA methods and its characteristics. Finally, the procedures and characteristics of specific MCDA methods from the applicable families of MCDA methods were studied and are presented together with comparative analysis in Chapter 6.

The field research was targeted at public sector education institutions, where public bidding is done for procurement. For the study, there were two major data collection activities: focus groups and collection of real life procurement data sets with evaluated results from the research context. The details of this study are provided in Section 3.4.

The real life procurement data sets collected in field research are used to do quantitative comparative analysis of the suitable MCDA methods filtered through the comparative analysis, based on the previous two studies: literature review and field research. The real life data were collected from the same institutions where focus groups were conducted. The details of this study are provided in Section 3.5.

The research design is based on the development, evaluation and conclusion model presented in Chapter 2 and illustrated in Figure 2.2.

3.3 Literature review

The literature review was conducted in two major components of the first phase of the research, as illustrated in Figure 2.2. The first component was public sector procurement, specifically identifying constraints and requirements of public sector procurement in the Maldives context. The procedure and the rigid structure of public sector procurement generally come from public laws and regulations.

The second component of the literature review is undertaken in relation to the MCDA methods. The requirements for the methods and characteristics of these methods are gathered through a systematic literature review for the purpose of comparative analysis as described in the previous chapter. The literature review structure is presented in Figure 3.1, as follows.

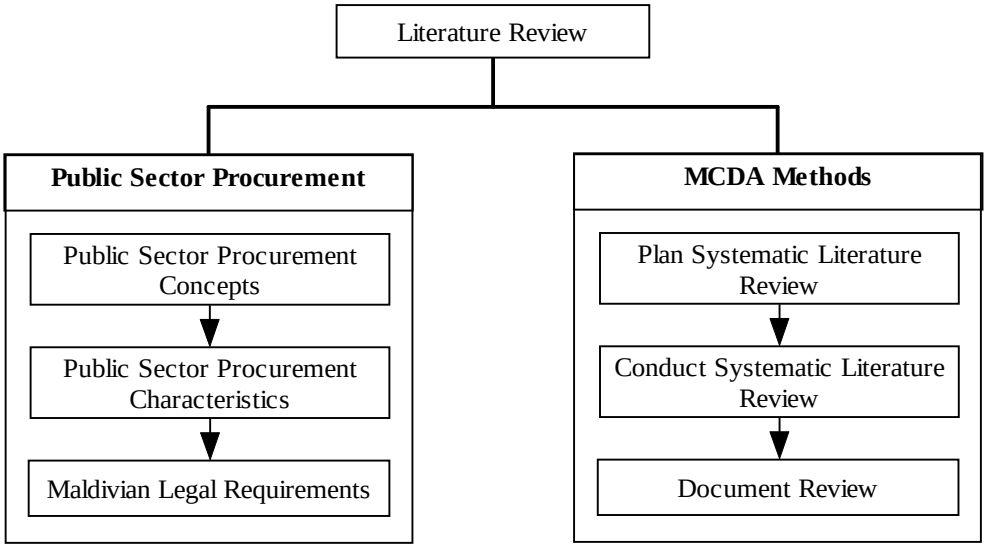

Figure 3.1: Structure of literature review

As shown in Figure 3.1, the literature review has two major components and each component has a sequence of activities. The literature review of public sector procurement involved a review of grey literature on legal and fiscal aspects of procurement specifically focusing on the Maldives Public Sector.

The literature review of MCDA methods is a systematic literature review involving structured procedures as shown in Figure 3.1. Further steps of the structured approach are discussed in Section 3.3.2 and illustrated in Figure 3.2.

3.3.1 Public sector procurement

The initial literature review was performed on public sector procurement, identifying and choosing definitions for the public procurement related terminologies

for the research project. This process described purchasing, procurement, tendering, tendering process, tender evaluation, e-procurement and public sector procurement.

The next stage discussed procurement objectives in the public sector; characteristics of public sector procurement; modes of procurement in public sector; guidelines for public sector procurement; and tender evaluation criteria for public sector procurement.

The final stage of the procurement related literature review involved focusing on the research context, the Maldivian public sector, identifying government guidelines for Maldivian public sector procurement, public tendering in the Maldives and tender evaluation criteria set for the Maldivian public sector.

3.3.1.1 First stage: Understanding public sector procurement concepts

The first stage of the literature review was to understand the general concept of public sector procurement. This was achieved with the available academic materials online and in the university library to study concepts and definitions of:

- purchasing,
- procurement,
- tendering,
- tendering process,
- tender evaluation,
- e-procurement and
- Public sector procurement.

This part of the literature review identified and discussed concepts and definitions of the terminologies for the context of the research in general, and specific to the study. This understanding provided the foundation of concepts for carrying the research forward to the next stage.

3.3.1.2 Second stage: Understanding public sector procurement characteristics.

The second stage of the literature review was to understand the characteristics and constraints of public sector procurement. Similar to the first stage, this literature review was also executed via the available academic materials in the university library and beyond to study:

- objectives of public sector procurement,
- characteristics of public sector procurement,
- mode of public sector procurement,
- guidelines for public sector procurement, and
- evaluation criteria for public sector procurement.

This part of the literature review provided the fundamental principles involved in public sector procurement. This understanding helped the research to be focused and to limit the boundary to accommodate decision models that cover the basic principles. Along with the identified fundamental principles of public sector procurement, there are country specific regulations for public sector procurement. The next stage studied the regulations specific to the research context, the Maldivian public sector.

3.3.1.3 Third stage: Understanding Maldivian public sector procurement.

The third stage of the literature review was to understand the characteristics and constraints of public sector procurement in the Maldives, based on the regulatory documents of public sector procurement in Maldives, involving the study of the Maldivian constitution, its laws and regulations. More specifically, public sector procurement related legal documents are studied. They are as follows:

- Constitution of Maldives
- Dhaulathuge Maaliyyathu Gaanoonu 2006 (*Public Finance Act 2006*)

- Dhaulathuge Maaliyyathu Gaanoonunah 1 vana islaahu genaumuge gaanoonu 2010 (*Public Finance Act 1st Amendment Act 2010*)
- Dhaulathuge Maaliyyathuge Gavaaidhu 2009 (*Public Finance Regulation 2009*)
- Dhaulathuge Maaliyyathuge Gavaaidhah genevey furathama islaahu 2009 (*First Amendment to Public Finance Regulation 2009*)
- Anti-Corruption Commission ge Gaanoonu 2008 (*Anti-Corruption Commission Act 2008*)

This part of the literature review provided the characteristics and constraints of public sector procurement in relation to Maldivian regulations. The study identified guidelines and criteria for public sector procurement within the research boundary.

To identify the appropriate decision-making models for public sector procurement in Maldives, as described in the previous chapter, the next major component of literature review was to study MCDA methods. The following section describes the design of the systematic literature review carried out for MCDA methods.

3.3.2 MCDA Methods

The second major component of the literature review was a systematic literature review to identify characteristics of MCDA methods. In this literature review more than 80 MCDA methods were found. The literature categorises MCDA methods into groups, based on their characteristics (Figueira, Greco, et al., 2005; Guitouni & Martel, 1998; Ho et al., 2010). Therefore, at first, the MCDA methods were identified and categorised into five groups based on their characteristics according to the literature. These categories are:

1. Elementary methods,
2. Single synthesizing criterion or utility theory,
3. Outranking methods,

4. Fuzzy methods, and
5. Mixed methods.

Based on the characteristics of these categories of MCDA methods, a criteria-based evaluation, as described in the previous chapter, was conducted against public sector requirements gathered. This evaluation resulted in identifying applicable group of MCDA methods. This MCDA group-based evaluation process helped to eliminate unsuitable groups of methods from further literature review at the individual method level. Individual MCDA methods that belonged to the resulting filtered categories of methods were further studied for their procedures and characteristics.

The following sections describe the systematic literature review.

3.3.2.1 Systematic literature review design

According to Brereton, Kitchenham, Budgen, Turner, and Khalil (2007:572), "systematic literature reviews are primarily concerned with the problem of aggregating empirical evidence which may have been obtained using a variety of techniques". For this literature review, the aim is to understand the procedures and characteristics of the existing MCDA methods.

The literature explains that, to conduct a systematic literature review, there are some distinct activities (Brereton et al., 2007; Nunes, McPherson, Annansingh, Bashir, & Patterson, 2009). These activities are group into major three phases: planning the review; conducting the review; and documenting the review (Brereton et al., 2007). The activities for this systematic literature review are grouped into three major phases, as described by Brereton et al. (2007). Figure 3.2 illustrates the overall activities.

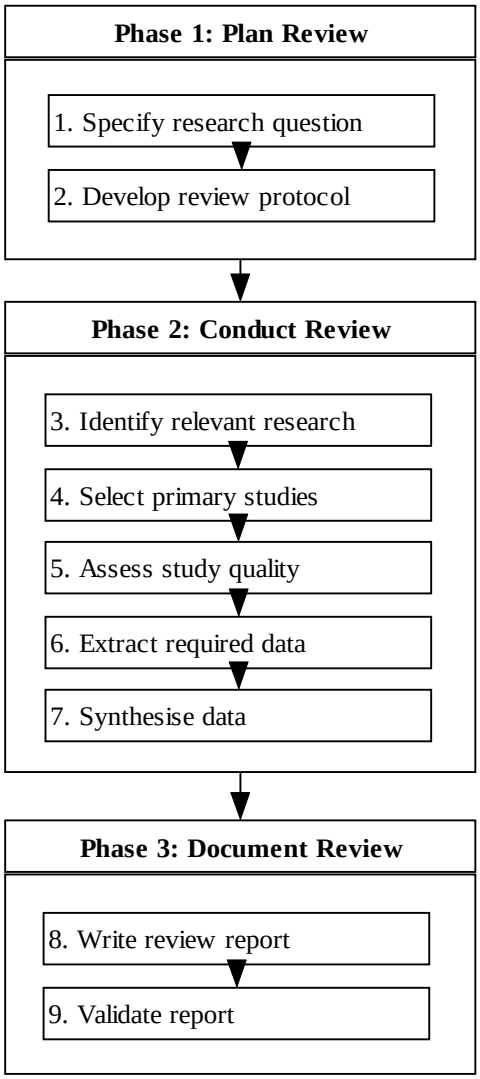

Figure 3.2: Systematic literature review process based on Brereton et al. (2007)

The activities and procedures for the three phases of the systematic literature review are described in the following sections.

3.3.2.2 Step 1: Specify research question

Based on the methodology of this research project as described in the previous chapter, a primary activity is to do a comparative analysis to match the characteristics of public sector procurement with the characteristics of MCDA methods. For this criteria-based evaluation, understanding characteristics of MCDA

methods are essential. So, the aim of this literature review is to understand characteristics of MCDA methods. Therefore, the research question at first was:

Question 1: What are the characteristics of the specific MCDA methods?

After studying some well-known literature on MCDA methods, the researcher found a significant amount of MCDA methods categorised in to groups. This finding led the researcher to change the criteria-based evaluation to be executed at first group level then at individual method level. Therefore, the next initiative was to understand the characteristics of the groups of MCDA methods. Based on the grouping as explained previously, the additional research questions were:

Question 2: What are the characteristics of the linear weighting and elementary methods?
Question 3: What are the characteristics of the single synthesizing criterion or utility theory methods?
Question 4: What are the characteristics of the outranking methods?
Question 5: What are the characteristics of the fuzzy methods?
Question 6: What are the characteristics of the mixed methods?

Since then, the first initiative has become to understand group level characteristics. After the first level of criteria-based evaluation at the group level, the filtered methods literature review was continued with research question 1.

3.3.2.3 Step 2: Develop review protocol

The review protocol was to plan the details the literature review process. This involved specification of the activities in the steps ahead for the literature review. For instance, specifying inclusion and exclusion criteria for studies, assessment of the literature for quality, and so on. These protocols are explained for every activity discussed below.

3.3.2.4 Step 3: Identify relevant research

The search strategy was based on the approach suggested by Brereton et al. (2007):

- The individual elements of the research question related to MCDA were used as the main search terms.
- Potential main terms are assessed and taken from known studies in the same area.
- Similar terms for the main terms were identified.
- Search strings used Booleans to join main terms and include similar terms.

Using these strategies, for instance, it became evident that some authors refer to MCDA as multi-criteria decision making (MCDM), Multi-objective decision making (MODM) and multi-attribute decision making (MADM). So, the search strategy was to use these combinations.

Several electronic resources were searched through University library. Primo Central search utility offered by University library was used to search literature. According to University of Sheffield Library (2014), Primo Central covers 249 indexing resources as listed in Appendix V.

Based on the search strategy the general search string was created using Booleans to join main terms and include similar terms as follows:

> (characteristics OR feature OR strength OR weakness OR advantage OR disadvantage) AND (MCDA OR "multi-criteria decision analysis" OR MCDM OR "multi-criteria decision making" OR MODM OR "multi-objective decision making" OR MADM OR "multi-attribute decision making") AND Method

The initial search resulted in 9,837 documents which included articles, conference proceedings, reviews, books, dissertations and legal documents published even before 1961 written in English and other foreign languages. Therefore, an inclusion and exclusion strategy was used as follows:

- Include only articles.
- Use only peer reviewed papers.
- Use only English language publications.
- Exclude articles published before 1996
- Exclude papers published in natural science domains (E.g. biology, chemistry, etc.).

With the inclusion and exclusion criteria, the search resulted in 1,940 documents. However, there were still irrelevant articles listed in the search results, such as ones which mentioned ‘features’, ‘MCDA’ and ‘methods’ in other contexts. For this purpose and to select primary studies, a manual process of selection was done as explained in Section 3.3.2.5.

The same search strategy explained above was used to search for the characteristics of the individual MCDA methods filtered through the group level criteria-based evaluation. However, the search string was modified to include the procedure, the name of the method in full, and as acronym. For instance, the search string for TOPSIS (technique for order preference by similarity to an ideal solution) would be as follows:

> (procedure OR characteristics OR feature OR strength OR weakness OR advantage OR disadvantage) AND (TOPSIS OR "technique for order preference by similarity to an ideal solution")

These searches brought up some of the papers that had been studied before. However, relevant papers for the specific method were considered for the primary studies, according to a selection process explained in the following section.

3.3.2.5 Step 4: Select primary studies

A two stage process suggested by Brereton et al. (2007) was used to select primary studies. The two strategies are as follows:

- Study titles and abstracts of the papers listed by the search and reject irrelevant papers.
- Review full copies of the papers not rejected in the previous step and assess for relevance to research.

For instance, this process checked whether the paper provided characteristics, procedures or features of the MCDA methods.

This process also prompted the researcher to study some specific papers outside the inclusion protocol with regard to the specific date. For instance, to understand SMART (simple multi-attribute rating technique) methods well, the researcher needed to study papers by the original SMART methods developer, which was written before 1996. Such specifically identified papers are included as primary studies for the literature review, irrespective of the generic exclusion criteria for better understating of the characteristics of the methods.

3.3.2.6 Step 5: Assess study quality

Study quality is not universally defined, but quality is linked to minimising bias and maximising external and internal validation (Brereton et al., 2007). The selected primary studies are checked for their quality. For the purpose, at the very initial stage of inclusion and exclusion strategy, articles were filtered for peer-reviewed and published papers from journals. This filtration minimised bias and maximised validation.

In addition to the filtration, papers were assessed for completeness. For instance, a paper may claim that TOPSIS had a narrow gap between the performance

measures when normalized, and so would have to support the claim with verifiable data used with TOPSIS.

3.3.2.7 Step 6: Extract required data

Data extraction was precisely focused on the research question. Statements made on the characteristics of the MCDA methods were gathered. This included studying the requirements, procedures, features, strengths, weaknesses, advantages and disadvantages of MCDA methods.

In this process, for many cases, a similar characteristic from multiples sources emerged. However, instead of presenting the same characteristic from multiple sources, highly referenced papers from better ranking journals among the group were chosen.

3.3.2.8 Step 7: Synthesise data

The data synthesis must be suitable for answering the review question (Brereton et al., 2007). The objective of this review was to understand the characteristics of the MCDA methods. Therefore the data synthesis should be able to cater to fulfil the need.

The extracted data was organised in a logical manner. For instance, procedures of a method were organised to step by step process. The characteristics are structured in a way that presents the features, procedures, strengths, advantages, weaknesses and disadvantages of the specific method. So that it would help to present discussion of the review report.

3.3.2.9 Step 8: Write review report

This activity documents the systematic literature review. This includes documenting the procedures for the review and the resulting answers for the review questions (Brereton et al., 2007).

The systematic literature review design presented here is the first component of the documentation. The second component is written as the MCDA methods discussion chapter in this thesis. The review report is presented, together with the criteria-based evaluation. This was done to make the study compact and easy for the readers.

In addition to the thesis chapter, two conference papers and two journal articles were written incorporating the results of the literature review. However, the conferences and journals had page limits, making it difficult to fit in every detail of the literature review. Therefore, the publications presented a summary of the reviews.

3.3.2.10 Step 9: Validate report

Brereton et al. (2007) suggested that a systematic literature review should be independently reviewed. This study was reviewed by the two supervisors and internal examiner at upgrade stage. In addition, four peer-reviewed papers were published based on the literature review.

3.4 Field research

The field research was conducted in the capital of Maldives, Male'. Public sector schools under MoE were the target institutions for the research. There are 213 government schools under MoE (MoE, 2012). According to an email communication

with a director of MoE, only 19 schools may carry out their own procurements, while MoE procures for the rest. MoE allows certain procurements to be handled by those 19 schools.

MoE and the schools which undertake their own procurement through public tendering are required to have a BEC by regulation, to evaluate the procurement proposals. BECs evaluate public tendering procurements that cost more than MVR25,000, and are announced publicly for proposals.

The focus groups were conducted with the BECs of the education sector institutions. Existing procurement evaluation data was also collected from the same group of institutions. This data was collected for use in the performance analysis phase discussed in Section 3.6.

3.4.1 Obtaining access

Obtaining access to the study site has been considered to be one of the crucial issues which determine the final success of the research project (Saunders et al., 2009). Gaining access to participants varies from study to study, however, the use of 'gatekeepers' to obtain access to potential participants is important in many research studies (King & Horrocks, 2010). For this research project, initial communication was made with a Director of MoE, Maldives, through email, after which the researcher went to the Maldives and had various meetings with the Director of MoE and School Principals to arrange focus groups and to collect previously evaluated procurement data.

As King and Horrocks (2010) state, the main challenge may be that finding the participants with the kind of experience that the researcher is interested in is very difficult. Similarly, for this research, there were only a limited numbers of participants who made procurement decisions. Each BEC had five members and procurement evaluation can be done with a minimum of three members.

During the meetings with the Director of MoE and School Principals, the research information was provided and the pre-prepared information sheet, and a sample consent form were provided, for additional information. After the meetings the Director of MoE and Principals contacted the BECs of the institutions and arranged the date and time for the focus groups at their convenience. However, for one of the schools, the Principal was unable to gather minimum requested number of participants, even after several attempts, due to limited number of members in the BEC. Therefore, another school of similar nature was used to conduct the focus group.

3.4.2 Translation

Based on the Director of MoE and Principals many BEC members preferred their local language, Dhivehi, to be used in the focus groups and there is also possibility that some of the participants may not have the ability to understand and speak in English. Similarly, when the researchers had informal discussions with some of the individual BEC members, they said that they preferred to use Dhivehi in the focus groups. Therefore, the focus groups had to be conducted in Dhivehi. In addition, Marshall and While (1994) also suggested that, in order to maintain the reliability and validity of the data, it is more appropriate to use the native language of participants.

The focus group questions were originally developed in English and the focus group results needed to be reported in English. This created a potential risk, due to two translation processes that took place: firstly, the translation of the focus group questions from English into Dhivehi; secondly, the translation required to report the theoretical narrative of the data collected and analysed in Dhivehi.

The focus group questions were designed in English initially instead of Dhivehi, because the questions were based on the literature review, which mostly involved English language sources, and used terminologies from the literature as proposed by Strauss and Corbin (1990). In addition, Peng and Nunes (2008)

proposed discussing and validating the design of the questions with colleagues and advisors. Therefore, as this research project is in an English university and colleagues and advisors use English language, the initial design of the questions was developed in English.

This translation risk was mitigated, as the native language of the researcher is Dhivehi and he is fluent in both English and Dhivehi. However, for further refinement, the translated questions were given to two lecturers from the home institution of the researcher in Maldives to verify the translation. This exercise removed potential ambiguities and errors in the Dhivehi language translation. Finally, the focus group questions pilot tested with two School Principals who were BEC members. Based on the feedback, further corrections were made to the focus group questions.

As mentioned before, the data need to be collected and analysed in Dhivehi, but the results of the analysis needed to be presented in English. There were mainly two reasons to adopt this approach. Firstly, translating the large amounts of focus group discussion material from Dhivehi to English would be difficult because, as some researchers have stated, there can be a different interpretation of narratives and also unavailability of the similar words from one language to other (Carlson, 2000; Twinn, 1997, 2000). Therefore, using the original language would effectively minimise the probability of mistakes in translation, misinterpretations and inaccuracies, in turn strengthening the reliability and validity of the data and the credibility of the findings.

Secondly, this approach maintains the dynamic and natural connections between data collection and analysis, which are ideally practised simultaneously (Esposito, 2001). The relationship between data and analysis could break if the translation is made early, before analysis causing misinterpretation. According to Carlson (2000), supported by Peng and Nunes (2008), literal word-by-word translation can often result in awkward sentence structure and incomprehensible meanings in the target language version. Such cases can cause incorrect coding of data and result in misinterpretations of analysis. In addition, it may lead the

researcher to overlook the nuances and deeper meanings of data (Marshall & While, 1994), which are important to the analysis and interpretation of the results.

3.4.3 Data collection

Focus group interviews were used as one of the major data collection activities, according to the research design, as discussed in Chapter 2. Based on the understandings and set-up arranged by the Director of MoE and Principals of the selected schools the researcher conducted the focus group interviews on dates agreed by the institutions. The data collection process is explained in the following sections.

3.4.3.1 Sample size and sampling strategy

Barbour and Kitzinger (1999) state that focus group studies range from three or four groups to more than fifty. "The appropriate number of focus groups will depend on the research question, the range of people you wish to include and, of course, time and resource limitations" (Barbour & Kitzinger, 1999:7).

Barbour and Kitzinger (1999) believe that statistical representativeness is not necessary for most focus group research projects. Focus groups use structured sample rather than random sample based on the research question (Barbour & Kitzinger, 1999; Morgan, 1997).

MoE represents 213 schools, for which most procurements are handled by their procurement department. However, as mentioned previously, depending on the procurement, MoE decides to have procurement processed at 19 different schools. So, there are 20 distinct BECs for 213 schools and MoE.

During the initial meeting, the Director of MoE said that the procedures and expectations of evaluation of procurement are the same throughout all public sector institutions and it would not be necessary to have the focus group discussions with

other schools if it was conducted with BEC of MoE. However, the researcher requested to have at least three focus groups in three distinct institutions to verify and enrich the data. Therefore, the focus groups were conducted with BECs from MoE, a secondary school and a primary school to cover the major spectrum of institutions under MoE. It covered BEC members who make procurement decisions for 196 schools out of 213 schools, covering 92.02 percent of the schools under MoE, and the procurement decisions of the MoE itself.

3.4.3.2 Group size and composition

The didactic nature of existing guides for focus groups providing advice on group size can badly impact on good application of focus group methods. Many focus group method contributors prefer five, or six or even as few as three participants in a group (Barbour & Kitzinger, 1999).

Since the main advantage of focus groups is group interaction, careful consideration of the focus groups' composition, such as people with shared interest, helps to facilitate it (Lloyd-Evans, 2006). In addition, Barbour and Kitzinger (1999) state that many researchers prefer to work with pre-existing groups who are already working together and having the shared experiences is more productive. Therefore, the focus groups were conducted with members of the same BEC together without mixing BEC members from more than one institution.

The participants of the focus groups in the research context involved the senior officials of the MoE and other government institutions represented as BEC. Since the participants were the senior officials and every BEC had a limited number of representatives, the target was to have the maximum number of BEC members in each focus group, with the least possible number of focus groups.

Procurement evaluation requires a minimum of three BEC members to be present for evaluation. In consideration of this, the size of the focus group was set at a minimum of three members and a maximum of the whole BEC of the specific

institution. In addition, as mentioned before, the BEC had a limited number of members and they were senior staff, having multiple responsibilities other than their BEC function, so it is not practical to get every member of the BEC into the focus group. As a result the size was set to a minimum three and a maximum of all BEC members of the target focus group.

3.4.3.3 Recruitment and research setting

As there are no defined rules for the recruitment of focus groups participants (Lloyd-Evans, 2006), the recruitment initially involved a meeting with a director of the MoE, followed by formal meetings arranged with heads of the chosen institutions, to arrange focus group meetings with the BECs of the institutions. The institutions allocated meeting times based on the availability of at least the minimum requested number of BEC members.

The sessions were held in meeting rooms of the institutions where focus groups were conducted making it easier for the participants to attend. As suggested by Barbour and Kitzinger (1999) it is important to provide a suitable room, so the meeting rooms of the institutions were chosen, as they were quiet and comfortable, free from interruptions.

3.4.3.4 Recording and transcribing

Focus group recording ranges from the most basic level of note-taking to audio and video recording. Some researchers recommend video recording because it can provide additional information, but it can also be difficult to handle and may provide a misleading illusion of comprehensiveness (Barbour & Kitzinger, 1999).

This research used video recording as it helped to easily identify individual speakers and so simplifies the transcription process. It also helped to retain the sequence of the conversation in transcription. Focus group transcription can be

difficult because of sudden leaps and interruptions by participants (Barbour & Kitzinger, 1999), so video recording is a good choice, since it can help the researcher to overcome such difficulties.

These focus groups were also to discuss some technical information and a video recording can help to recap the verbal and non-verbal explanations made during the conversation.

3.4.3.5 Question design

The focus group questions were designed in advance and corrections were made, as mentioned in Section 3.4.2. It involved a series of open-ended questions, constructed so as to generate meaningful data for the research.

The questions were designed together with trigger questions to get better responses and to indicate to the focus group participants the expected level of response. All the questions were written in English as well as in Dhivehi, as shown in Figure 3.3. The questions written in English were to help the researcher to understand the original intention of the question and the Dhivehi translation was used for the participants.

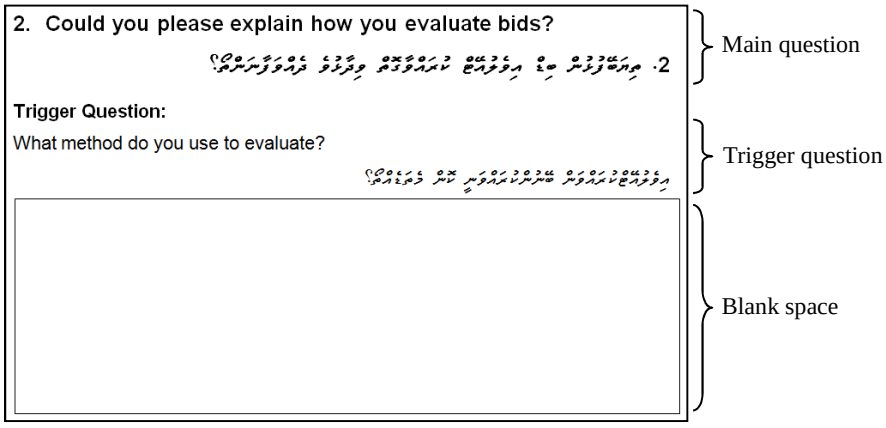

Figure 3.3: Example of focus group question design

Finally, the design has an empty space after every main question, used to make quick notes of emerging issues, new thoughts, potential probing for additional explanations, etc.

The questions slightly evolved with the process of data collection and analysis from one group to other. The initial version with the required documents underwent an ethical review process in the Information School of the University of Sheffield, and was approved as discussed in Section 3.8.

3.4.4 Data analysis

Analysing focus group data has the same process as any other qualitative data analysis. However, group context is referenced by an analysis of groups rather than individuals, and keeping the balance between the concepts provided by the group and individual ideas within it (Barbour & Kitzinger, 1999).

The analysis involves comparing discussion of similar themes and examining how these vary between groups (Barbour & Kitzinger, 1999; Lloyd-Evans, 2006) and between individuals (Barbour & Kitzinger, 1999).

Krueger (1998) states that focus group analysis is complex, as it occurs at several levels. For one question, two members may answer using different words which have the same meaning. Sometimes respondents may change their positions later in the discussion. The analysis of focus groups is like detective work (Krueger, 1998).

For the focus group data, thematic analysis is used, as proposed by King and Horrocks (2010). The steps of the thematic analysis involved are:

- Transcribing data,
- Descriptive coding,
- Interpretive coding,
- Naming themes,

- Writing the report.

The following sections describe the detailed process of the thematic analysis conducted for the focus group.

3.4.4.1 Transcribing

All focus groups were conducted in Dhivehi and transcribed in the same language. However, all the coding was done in English. The transcripts included gestural information (e.g. “left member nods in approval” or “centre member looks surprised and doubtful”). This information was kept as part of the quotation, in order to illustrate the discussion, but the object of coding was the verbal information. For the purpose of formulating the narrative that forms the proposed inductive theory, important and supporting quotations were translated into English.

3.4.4.2 Coding and naming themes

The transcripts were coded, in a three tier approach, starting with descriptive coding, followed by interpretive coding and finally defining overarching themes.

Descriptive coding was done by going through the entire data set by identifying data relevant to each code. A new code was created if a new concept was identified in the data set.

Descriptive codes were analysed and grouped to form interpretive codes. These interpretive codes were further grouped in to related themes.

A code definition list was created, showing the descriptive codes and their definitions. The code definition list also showed interpretive codes and themes for the descriptive codes, as shown in Table 3.1.

Table 3.1: A section of the code definition list

Themes	Interpretive Codes	Descriptive Codes	Definition
Bidding process	Pre-bid meeting	Announcement of pre-bid meeting	Informing the public through public announcement for pre-bid meeting and bidding when public procurement is necessary.
		Compulsory pre-bid meeting	Obligatory requirement to have an information session for bidders before bidding.
		Provision of specification	Requirement to provide specific details of the required procurement to the bidders before bidding.
		Provision of marking criteria	Requirement to provide evaluation criteria of the required procurement to the bidders before bidding.
		Recoding of pre-bid attendants	Recording of the attendees of the pre-bid information session.

The code definition list attached in Appendix III provides all the descriptive codes, with definitions, along with interpretive codes and themes.

This code definition list helped the researcher to clearly present the meaning of each descriptive code and know where it should be located. As such, when a new code is emerged from the data, it was compared to the codes in the list to check if it could be merged with any of the existing codes or if not, a new entry is added to the list.

The interpretive codes and themes are validated through multiple assessors. As such, the analysis was rechecked and assessed by the two supervisors of this research project and amendments are done based on the assessment.

As shown in Figure 3.4, coding of the first focus group provided 57 descriptive codes and all (10) interpretive codes and themes. The second focus group analysis revealed three additional descriptive codes. Finally, no new descriptive codes emerged in the third focus group. Therefore, these results are in line with what the MoE stated in the preliminary meetings: that all institutions follow the same procedures and have the same expectations for procurement evaluation.

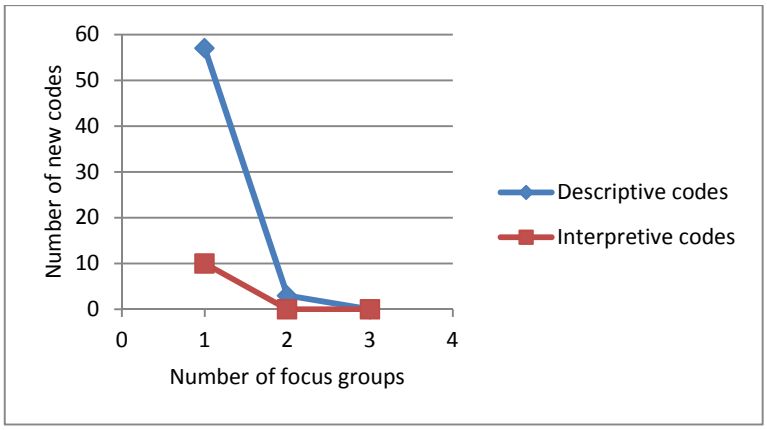

Figure 3.4: Emergence of new codes

3.4.4.3 Writing the report

The analysis report is presented in Chapter 5, providing an analytic narrative of the data, codes and themes in relation to the research question. In addition to the explanation, sample extracts from the data are provided in the report as evidence to support the findings.

To help to write the report with evidence from the data, a quotation list was created and used to record selected quotations for each descriptive code in the code definition list. A section of the quotation list is shown in Table 3.2.

Appendix IV provides the translated quotation list used. If a new quotation is identified based on a particular descriptive code, the new quotation is compared with the existing quotations in the list attributed to the particular code to check if it provided a similar meaning. If the quotation provided a different meaning than that of the list, then a new code was applied to the quotation.

Table 3.2: A section of the quotation list

Themes	Interpretive Codes	Descriptive Codes	Quotations
Bidding Process	Pre-bid meeting	Compulsory pre-bid meeting	"It is an obligation to have a pre-bid meeting if the value is more than MVR25000" ML2
			"Yes, if we announce for bids, we have to have the information session" DL1 & DL2
			"A pre-bid meeting is compulsory. That is the time information is provided. Otherwise it is missed."IL3
		Provision of specification	"an information sheet is provided during the [pre-bid] meeting" ML2
			"When information is provided, the information sheet will have criteria and specific details of the work to be done" DL1
			"The information is provided in writing" DL2. "Both verbal and written" DL3. "Explained verbally and given in writing" DL1

The quotation list also provided the indicator for each quotation which specified the focus group and the member of the focus group. For instance, ML2 in first quotation illustrated in Table 3.2 represents the focus group 'M' and the participant 'L2'. This identification helped in analysis to locate the data and analyse individual differences of opinion in the group context for the same topic.

King and Horrocks (2010), stated that it is easier to understand the levels of coding and how they are related to each other if presented diagrammatically. As such, Figure 3.5 shows the three-layered concept model for the study.

This model supported the data analysis, enabling the researcher to visualise the interrelationships between the descriptive codes, interpretive codes and the themes. This in turn helped in comparative analysis between components within the same layer, and within other layers as well.

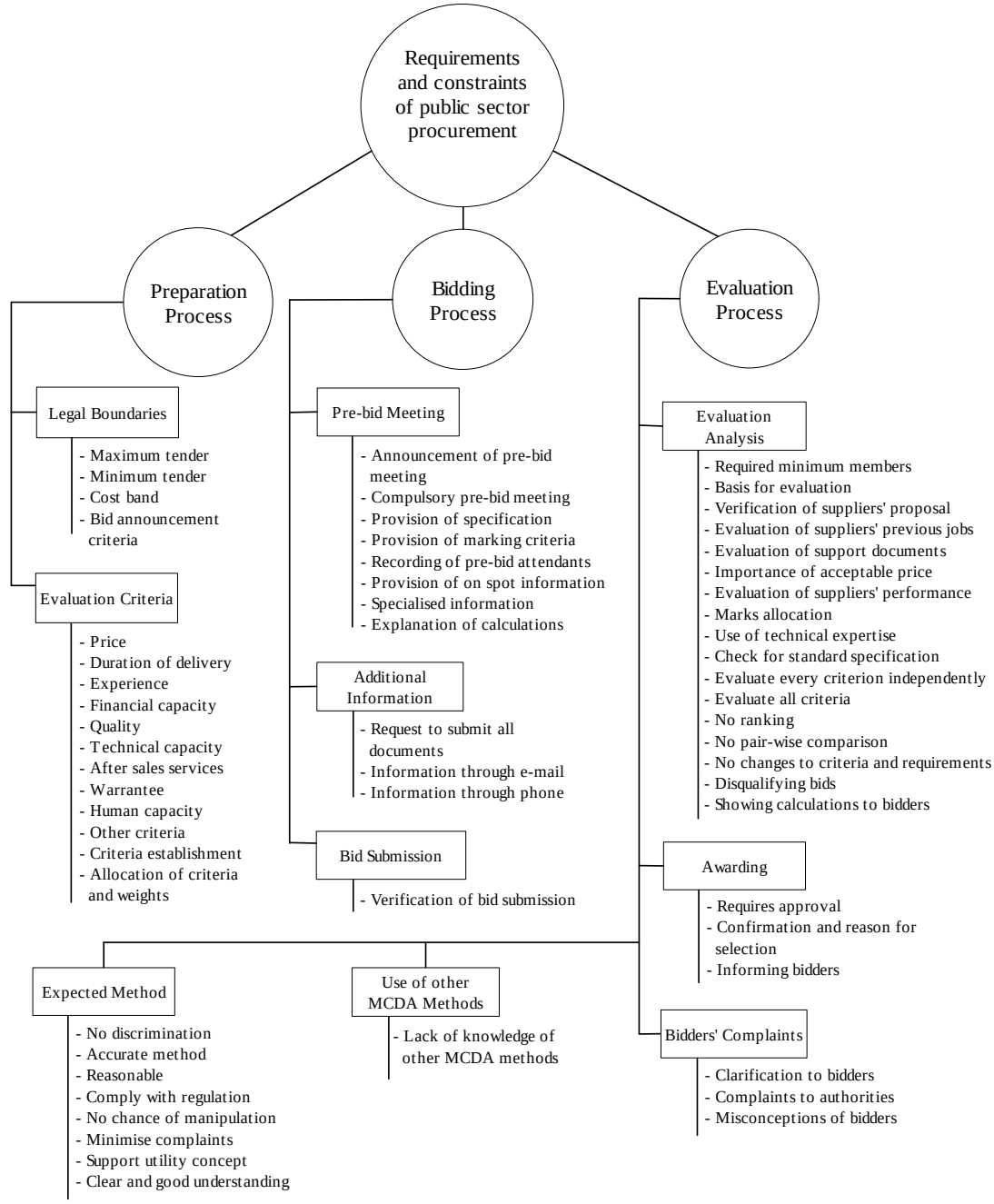

Figure 3.5: Three-layered concept model

The analysis is structured based on the concept model illustrated in Figure 3.5 and presented in Chapter 5.

3.5 Criteria-based evaluation

The second phase of the research as explained in the methodology chapter, Section 2.4.3.3 and illustrated in Figure 2.2 is criteria-based evaluation. This analysis is a comparative analysis of the suggested alternatives with the results of analysed field research and literature review. The aim of the analysis is to identify the MCDA methods that are compatible with public sector requirements.

This analysis studied the characteristics of MCDA methods against the public sector constraints and requirements gathered through the literature review and field research.

The results of the criteria-based evaluations are discussed together with MCDA methods in Chapter 6.

3.6 Performance analysis

The third phase of the research, as explained in the methodology chapter and illustrated in Figure 2.2, is the performance analysis of the filtered individual MCDA methods by the quantitative comparative analysis. This performance analysis aims to differentiate the identified suitable MCDA methods, based on their performances, and to select the most suitable MCDA method for the Maldivian context. The performance was measured using the real life procurement data collected from the Maldivian public education sector.

3.6.1 Data collection

Data collection was executed during the field research on the public education sector institutions where focus groups were conducted, as described previously in Section 3.4 and Section 3.4.1. Therefore, obtaining access and other necessary communications were completed as explained previously.

The past real life procurement data sets were collected from three institutions: MoE, a primary school and a secondary school. This data included public announcements for procurement, pre-bid meeting records, pre-bid information sheets, bid submission sheets, suppliers' proposals, bid evaluation sheets with allocated marks identifying the selection. Only one institution provided the suppliers proposals. The quantitative analysis requires only the allocated marks for the criteria to feed the MCDA methods under evaluation. However, the additional data was collected to familiarise the researcher with the context and holistic understanding of the procurement decision-making process.

Thirteen data sets were collected from the three institutions. Five of them are responses for five distinct bids from a single announcement for a single institution, having same selection criteria. These five data sets are evaluated independent of each other, as well as collectively, as one data set by the institution. For the performance analysis, the data sets were considered the same as those carried out by the institution.

3.6.2 Data processing

The data sets were implemented with the individual MCDA methods under evaluation. Each data set was given a unique identifier by the researcher for anonymising the real procurement names for ethical purposes. Suppliers' names were also replaced with A1, A2… A*n*, where *n* is the maximum number of suppliers for each set of data, to represent alternatives. However, the data remained unchanged. No transformation factor and no normalisation was applied to data before implementing the methods.

At first all 13 data sets were recorded on a spreadsheet. Then the weighted sum was applied, as by the institutions. Up to this point in the process it represented the original data with original results as prepared by the institutions. Along with the original results, a new set of results was generated by applying TOPSIS, one of the

selected methods. The formulae and steps for TOPSIS are presented in Section 5.3.2.1. Each step of TOPSIS was calculated using a spreadsheet and documented. A sample of the calculated spreadsheet is shown in Figure 3.6, and a summary of the documented data are presented in Chapter 7.

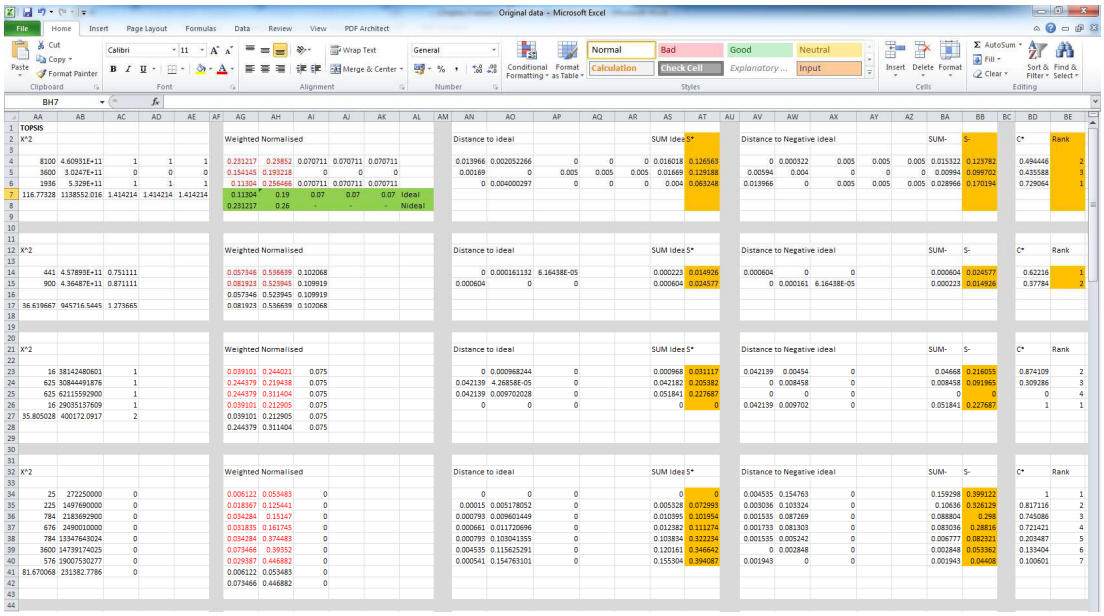

Figure 3.6: Spreadsheet sample for TOPSIS

Similarly, additional calculations were done with COPRAS (COmplex PRoportional ASsessment), another selected method from second phase. This process also used the original data and applied formulae and steps required for COPRAS, as presented in Section 5.3.2.8. It also recoded and documented the results of all the steps of COPRAS.

Based on the calculations and results of TOPSIS and COPRAS, as well as the results of the institutions, three different analyses were made. They are variance analysis, congruency analysis and stability analysis. The aim of these analyses is to compare the results of the MCDA methods. The designs of the analysis are discussed in the following sections.

3.6.3 Congruence/incongruence analysis

For this analysis Spearman's rank correlation coefficients are calculated, as explained in Section 2.3.4.1.

If x_j and y_j denote the ranks of two different MCDA methods for the same alternative j, then Spearman's rank correlation coefficient r is calculated as follows (Antucheviciene et al., 2012):

$r = 1 - \frac{6\sum_{j=1}^{n} d_j^2}{n(n^2-1)}$, where $d_j = x_j - y_j$.

Spearman's rank correlation coefficients are calculated for the ranks resulted from every pair of MCDA methods (TOPSIS, COPRAS and Weighted Sum).

The calculated rank correlation coefficients are presented and discussed in Chapter 7.

3.5.4 Variance analysis

Variance measures illustrate how much data points are spread. The results provided by the weighted sum, TOPSIS and COPRAS were used to find the variances of the three independent results from the same data sets.

For this analysis the variance is calculated using the following formula (Field, 2005):

Variance = $\frac{\sum(x_i-\bar{x})^2}{N-1}$, where $\bar{x}$ is the mean and *x* is the ranking for the alternative *i* till the last alternative *N*.

The results of the variances are presented and discussed in Chapter 7.

3.6.5 Stability analysis

Stability analysis or robustness of results of MCDA methods is based on the sensitivity of the methods to changes in data and in terms of variances of ranking alternatives. For the stability analysis of the selected MCDA methods, the approach used by Podvezko (2011) was applied. Podvezko (2011) changed two data parameters each by a value of 5 for a single set of data to show changes in the results by the MCDA methods used.

For this research, the applied data sets for selected MCDA methods were changed to evaluate the changes in the results of the MCDA methods. For each test of the stability analysis, two parameters were either increased or decreased by a value between 1 and 20 for every MCDA method under evaluation. The choice of this range of numbers is arbitrary. Even with this limited set of values, all possible permutations of changes in data are not practical for this research. However, the study focused to apply the minimum possible values that could change the outcome.

The resulting stability analysis for the selected MCDA methods are presented and discussed in Chapter 7.

3.7 MCDA Evaluation

The fourth phase of the research, as explained in the methodology chapter and illustrated in Figure 2.2, is MCDA evaluation. As discussed in research methodology, MCDA is performed to identify the highest ranking method from the public sector compliant methods identified by the criteria-based evaluation. Therefore, in this research project, the two methods identified, TOPSIS and COPRAS are evaluated on the performances of the major analyses discussed above, in order to calculate the highest ranking method.

As explained with the rationale in previous chapter, Section 2.3.4.2, the two methods (TOPSIS and COPRAS) are evaluated by TOPSIS and COPRAS and by WS using the performance measures from the previous analyses, namely criteria-based evaluation, congruence/incongruence analysis, variance analysis and stability analysis, as the criteria for evaluation. Equal preference weights were allocated for every criterion. The following four criteria are set each with a 25% weighting:

1. **Adherence to requirements:** This criterion is based on the results of the criteria-based evaluation done. If the method passes through the criteria-based evaluation as an applicable method, the highest performance score is given. In this case, the two methods passed through the evaluation. Therefore, both methods are allocated the highest performance score for this criterion.
2. **Average correlation coefficients:** This criterion is based on the congruence/incongruence analysis. The average correlation coefficient score for the 13 samples are calculated and the value is used as the performance score for the methods.
3. **Average variance:** This criterion is based on the variance analysis. The average variances for the 13 samples are calculated and the value is used as the performance score for the methods.
4. **Average threshold:** This criterion is based on the stability analysis. The average threshold values for the tested cases are calculated and the value is used as the performance score for the methods.

These evaluations and results are discussed in Chapter 7.

3.8 Research ethics

This research project was approved through University of Sheffield's ethical procedure (letter of ethical approval is attached in Appendix VI). The implementation of the research was monitored by the Information School of the University of Sheffield.

In additional to the ethical approval from the university to conduct the focus groups, meetings were held with MoE of the Maldives explaining the procedure with information sheets (attached in Appendix I). In the next stage the researcher met with the institutions to arrange focus groups with the BECs, in which information about the research and the information sheets (Appendix I) were again provided. Based on a date and time agreed by the institutions, the focus groups are conducted in the institutions' premises. Before the start of the focus groups, the members are informed about the research and focus group as in information sheet verbally and written form (Appendix I). In addition, a consent form was filled and signed by every attendant and moderator (attached in Appendix II).

The focus group questions were carefully designed not only for the purpose of collecting research data, but also with the intention of protecting the privacy of the participants. For instance, consideration was given not to form any question which might be culturally, politically or religiously sensitive.

The focus group interviews were immediately transcribed. Particular importance was given to anonymising the participants in the transcript, so that the information could not be traced back to any particular participant. The focus group recordings and transcripts were kept securely in password encrypted and protected computer system. The printed copies of transcripts were securely locked and were used only for this research purpose.

3.9 Conclusion

This chapter has discussed the details of the research activities for this research project, including of data collection, data analysis and the ethical procedures of the research.

The first phase of the research involved major three research activities. At first a literature review of public sector procurement mainly focused on the

Maldivian context. Secondly, a systematic literature review of MCDA methods was conducted to understand the characteristics of MCDA method for the purpose of criteria-based evaluation to select applicable methods for public sector procurement in Maldives. Thirdly, in the first phase the research involved three focus group interviews with a minimum of three BEC members each, in three distinct public sector education institutions. The focus groups were conducted and transcribed in Dhivehi. Data analysis was done using thematic analysis. During the analysis process, descriptive codes, interpretive codes and themes were developed, based on the data. All the analysis was systematically recorded and presented.

The second phase of the research was criteria-based evaluation on MCDA methods, carried out under the constraints and characteristics of public sector procurement gathered through literature review and focus groups. The MCDA methods that meet public sector procurement constraints and requirements are further analysed in third phase of research.

The third phase of the research was performance analysis on MCDA methods that are resulted from criteria-based evaluation. Three sets of quantitative analysis were done on the MCDA methods with 13 collected real life procurement data sets from public sector education institutions. These analyses involve congruence/incongruence analysis, variance analysis, and stability analysis.

The fourth phase of the research was the application of MCDA on the selected methods using the results of the previous analyses as the performance measures for the evaluation criteria. The method currently being practiced in the research context and the filtered methods were applied, in order to identify the rankings.

Finally, the chapter discussed the ethical procedures used to conduct the research. The research was approved by the University of Sheffield and conducted according to the university's ethical guideline.

Overall, the procedure for the research was presented in this chapter. The next chapter discusses the literature review of public sector procurement.

CHAPTER 4

PUBLIC SECTOR PROCUREMENT

4.1 Overview

As the research focus is on e-procurement DSS using multi-criteria decision analysis in the public sector, the literature review of the research covers two major areas of the research project, as discussed in previous chapter: procurement and multi-criteria decision analysis. Therefore this chapter is focused on the literature on procurement and its related literature highlighting the fundamental literature on definitions; objectives; methods; guidelines; and the characteristics of procurement in public sector in general, and more specifically, in public sector procurement in the Maldives.

At first the chapter provides a general introduction of procurement, then a specific investigation of public sector procurement, and finally the last section is based on public sector procurement in the Maldives.

4.2 Introduction to procurement

"The function of purchasing is almost as old as the history of man" (England, 1967:3). It happened since when man bartered one of his belongings for another property of a man. Purchasing has been an important function for everyone's life. (England, 1967). Every organisation buys material and services from suppliers and uses these in their operations (Monczka et al., 2010).

The purchasing function has evolved (Leenders & Fearon, 1997; Monczka et al., 2010) and purchasing terminologies like purchasing, procurement, supply, supply-chain, materiel, materials management, sourcing and logistics are all used as similar terms (Leenders & Fearon, 1997; Leenders, Johnson, Flynn, & Fearon, 2006; Weele, 2000). There is no agreement on the definition of any of them (Leenders & Fearon, 1997; Weele, 2000) and all the definitions of purchasing are open to criticism (Lysons & Gillingham, 2003). However, authors have given definitions for these different terms. I will try to explore some of the definitions of the terms purchasing, procurement, e-procurement or electronic procurement, and tendering in the following sections.

4.2.1 Purchasing

As we all know, in general, buying means going to a shop and getting an item we want by giving money (Monczka et al., 2010). Purchasing is more precise as defined by (Monczka et al., 2010) and also by (Leenders & Fearon, 1997) as follows:

> "Purchasing is responsible for acquiring all the materials needed by an organisation. It consists of related activities that organise flow of goods, services and other materials from suppliers into an organisation." (Monczka, et al., 2010:10)

> "Purchasing describes the process of buying: learning of the need, locating and selecting a supplier, negotiating price and other pertinent

terms, and following up to ensure delivery." (Leenders & Fearon, 1997:6)

Both these definitions state the issue of getting materials and its related activities till it is received by the organisation, suggesting a systematic approach to source required materials or services to the organisation.

A wider definition covering the supply of capabilities and knowledge, in addition to goods and services, is provided by Weele (2010), and it is as follows:

> "The management of company's external resources in such a way that the supply of all goods, services, capabilities, and knowledge which are necessary for running, maintaining and managing the company's primary and support activities is secured under the most favourable conditions." (Weele, 2010:8)

Lysons and Gillingham (2003) provided a simpler definition for purchasing, in line with procurement, stating that it "implies acquisition of goods or services in return for a monetary or equivalent payment." (Lysons & Gillingham, 2003:5)

Since all the definitions listed above indicate a systematic approach to acquiring required materials or services, all these definitions are applicable to the research purpose. However, for this research project the definition by Lysons and Gillingham (2003) is chosen because it is simple and covers acquisition of goods or services in return for payment.

When the purchasing function grew, different terminologies began to be used, often interchangeably (Weele, 2000). The term commonly used in the next level is procurement, the definition of which is discussed next.

4.2.2 Procurement

For this research purpose the term procurement is used because the research context, the Maldivian public sector, uses the term. It is also a more precise term and, as such, often job titles of the purchasing department come with the word procurement like ‘procurement manager’ (Lysons & Gillingham, 2003).

However there are variations in the definitions provided by different authors. Some people believe that purchasing expresses real buying and procurement has a broader meaning (Monczka et al., 2010). Monczka et al. (2010) and Leenders and Fearon (1997) provide the following definitions of procurement:

> “Procurement has a broader meaning which includes different types of acquisition (leasing, rental, contracting, etc.) as well as the associated work of identifying and selecting suppliers, negotiating, agreeing term, expediting, monitoring supplier performance, analysing orders, material administration, developing purchasing system and so on.” (Monczka et al., 2010:11)

> “Procurement is a somewhat broader term and it includes purchasing, stores, traffic, receiving, incoming inspection, and salvage.” (Leenders & Fearon, 1997:6)

Based on above two definitions, procurement is a broader term than purchasing and purchasing is a subset of procurement. It also indicates that procurement is more structured and contains critically responsible functions. Lysons and Gillingham (2003), provided an even wider definition, covering the process of getting materials or services even by force, as follows:

> “Procurement, however, is the process of obtaining goods or services in anyway including borrowing, leasing and even force or pillage.” (Lysons & Gillingham, 2003:5)

However the research focuses on the procurement decisions, based on the analysis of the data for evaluation criteria received though tendering from suppliers which is a voluntary process. Therefore, the definition of procurement provided by Lysons and Gillingham (2003) is not applicable in this research context if the choice is not made through analysing data using evaluation criteria.

The definition of procurement provided by Monczka et al. (2010) is more appropriate for this research context as it indicates the processes of acquisition of goods and services, as well as types of acquisition, such as rental. The processes of acquisition in definition of Monczka et al. (2010) indicate the selection of suppliers, which is the core interest of the research area. However, it is not specifically covered in the definition of procurement provided by Leenders and Fearon (1997). Therefore, the definition of procurement provided by Monczka et al. (2010) is more suitable in this research context and it is considered for this research.

Based on the research context, the procurement decision is taken based on data received through tenders from suppliers. Tendering itself is a separate process of procurement. Supplier selection is a later process than tendering because the outcome of the tendering process will be used for evaluation of the suppliers for selection. Tendering is not the focus of this research. However, it has direct relationship with supplier selection. Therefore, the next section explains tendering.

4.2.3 Tendering

One of the important processes of procurement is to look for potential suppliers (Leenders et al., 2006). Tendering is one of the common procedures to search for suppliers (Weele, 2010), especially for high price products and services. Tendering process is used to create competitive bidding by potential suppliers for particular goods or services, and to make the procurement process more transparent (Lysons & Gillingham, 2003).

Several authors have provided definitions for tendering. One of them is provided by Weele (2010), and another one by Lysons and Gillingham (2003) as follows:

> "Situation where a buyer asks for bids from different suppliers, creating a level playing field (identical to competitive bidding)." (Weele, 2010:35)

> "A purchasing procedure whereby potential suppliers are invited to make a firm and unequivocal offer of price and terms which, on acceptance, shall be the basis of the subsequent contract." (Lysons & Gillingham, 2003:651)

Both definitions indicate an approach which involves inviting potential suppliers and getting a quotation for procurement. However, the definition of Lysons and Gillingham (2003) is more precise indicating the outcome of the acceptance as the contract. Therefore, the definition of Lysons and Gillingham (2003) is preferred and used in this research.

Tender and competitive bidding are identical (Weele, 2010). However, for the research context a bid and a tender are differentiated through value. If a procurement costs between Maldivian Rufiyaa (MVR) 25,000.00 to MVR1,500,000.00, it is regarded as a bid and evaluated by the Bid Evaluation Committee (BEC). If a procurement costs MVR1,500,000.00 or more, it is regarded as a tender and evaluated by National Tender Board (NTB). However, the tendering and bidding processes are the same as described in Maldivian Public Finance Regulation 2009 ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). More details on the breakdown, BEC and NTB are discussed in Section 4.4.

Tendering has a very specific procedure to follow, especially when it comes to public sector tendering, to make it more competitive and transparent. The next section highlights the tendering process.

4.2.3.1 Tendering process

In the context of this research, the tendering process and bidding process is the same. Tendering is done if the procurement exceeds the cash limit prescribed in procurement procedures (Leenders et al., 2006; Lysons & Gillingham, 2003). In the context of this research the cut-off limit is MVR25,000.00. If any procurement costs MVR25,000.00 or more it should be announced for public tender ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

Lysons and Gillingham (2003:653) provides the following procedures for tendering:

- The issue of a public advertisement inviting tenders.
- Full and identical specifications given to potential suppliers, who have to submit the tender in a sealed and identifiable envelope by a specific date.
- On the date arranged for opening of tenders, appoint officers from the purchasing department and an external department, e.g. treasurer's department, will attend.
- Tenders will be initialled, listed and entered on an analysis sheet, showing details of prices, rates, carriage charges, delivery settlement terms and other information necessary for their evaluation.
- Late tenders are not considered and are usually returned unopened.

Leenders et al. (2006) provide a similar procedure, listed below:

- Advertise the purchase needs
- The bidder will receive:
    - a complete list of specifications that the supplier must meet;
    - a list of instructions to the bidder specifying how, when, where and in what form bids must be submitted;
    - general and special legal conditions that must be met by the successful bidder; and

    - a bid form, in which the supplier will submit price, discounts, and other required information.
- The bidder must submit any bid on or before the specified date and hour.
- At the hour and date specified in the bid instructions, the buyer or designated person will open all bids and record the bids on a bidder spreadsheet.
- Late bids are returned, unopened, to the bidder.

Based on the two studies, Leenders et al. (2006) and Lysons and Gillingham (2003), we can say that there is a standard procedure for tendering which includes advertising for tenders, issuing specifications, receiving and opening tenders on a specific time.

However the major issues as addressed in the research are evaluation method. The current evaluation method in public sector, which is weighted sum, mainly with its inherent compensatory behaviour makes undesirable outcomes (Mateus et al., 2010). Therefore, the research focuses beyond receiving and opening tenders, but minimising such undesirable outcomes which results from the evaluation method.

4.2.3.2 Tender evaluation

Tender or bid evaluation is the main focus of the research project, because the supplier selection is based on the tender evaluation. As described in the tendering process above, a specification is provided to the potential suppliers about the tender and the same document details the evaluation criteria as well. A reasonable set of criteria are used for tender evaluation (Leenders et al., 2006).

In most of the tender evaluation cases, one supplier is more superior to the others. However, the preference is not so apparent (Dobler & Burt, 1996). In such cases a mathematical model can be used to evaluate the tenders to identify the best choice (Dobler & Burt, 1996; Monczka et al., 2010; Rowlinson & McDermott, 1999). An example of a common tender evaluation model is numerical weighted

factor rating system, which can help the decision-making process (Dobler & Burt, 1996). Details of evaluation models are discussed in Chapter 6.

Tenders are evaluated based on selection criteria set out for the tenders, and the criteria are prioritised in evaluation by allocating weights to each criteria (Dobler & Burt, 1996; Leenders et al., 2006; Monczka et al., 2010; Rowlinson & McDermott, 1999). In the majority of the cases, the criteria and weights are set by a committee of individuals assigned to procurement (Dobler & Burt, 1996). However, there are evaluation methods, such as Data Envelopment Analysis (DAE), which do not require manual assignment of weights for criteria (Falagario et al., 2012; Lorentziadis, 2010).

The evaluation committee assigns rates for each criteria of each tender. It is a collective decision by the evaluation committee, arrived at after an analysis of all the data and information provided in the tenders and also information gathered in the field investigation (Dobler & Burt, 1996).

In most of the procurement cases, suppliers expect that the lower bid will win the procurement. However, it is almost impossible to evaluate tenders based only on price, due to the fact that very few suppliers are equally competent for a specific procurement. Most of the time, decisions on suppler selection other than low bidder is rationalised by this condition (Dobler & Burt, 1996). There are procurement guidelines for tender evaluation, which will be discussed in later sections.

With the development of modern technology, especially internet technology, procurement has taken a major leap in fulfilling its functions including tender evaluation. Mainly, it involves using electronic communication between supplier and buyer, and technological advancements in selecting suppliers to track procurement. The next section will provide a brief explanation of electronic procurement, or e-procurement.

4.2.4 e-Procurement

E-procurement is a short form of electronic procurement and both terms are interchangeably used in practice and literature. Lysons and Gillingham (2003) define e-procurement, cited in the Chartered Institute of Purchasing and Supply (CIPS), Policy Statement on Procurement, as follows.

> "The combined use of information and communication technology through electronic means to enhance external and internal purchasing and supply management process." (Lysons & Gillingham, 2003:172)

Boer, Harink, and Heijboer (2002) and Croom and Brandon-Jones (2007) provide the following definitions for electronic procurement.

> "E-procurement can be defined as using Internet technology in the purchasing process" (Boer et al., 2002:26)

> "Electronic procurement refers to the use of integrated (commonly web-based) communication systems for the conduct of part or all of the purchasing process; a process that may incorporate stages from the initial need identification by users, through search, sourcing, negotiation, ordering, receipt and post-purchase review" (Croom & Brandon-Jones, 2007:295)

These definitions depict the involvement of electronic communication making it e-procurement. Therefore suppliers and buyers should be able to request and respond to tenders, and other necessary communications should take place, through electronic means.

For this research context, the definition provided by Lysons and Gillingham (2003) is chosen because it not only mentions the use of communication technology but also information, and it also focuses on enhancement of the purchasing process. The research project is focused on e-procurement because the decision model is

expected to use ICT to minimise processing time and eliminate manual processing errors.

As in the definition of Lysons and Gillingham (2003), ICT is used in purchasing process, which is also supported by Croom and Brandon-Jones (2007). Choosing a supplier is one of the most important processes in procurement. This research focuses on the specific process of selecting suppliers in public sector procurement. As public sector procurement has its own unique features, the next section will explain the context of public sector procurement.

4.3 Public sector procurement

Public sector procurement is also referred to as government procurement. Arrowsmith and Anderson (2011) state government procurement, based on the perspective of the World Trade Organisation (WTO), as "the purchase of goods, construction service and other services required by government bodies" (Arrowsmith & Anderson, 2011:1)

There are four major principles in public procurement: non-discrimination, equality, transparency and proportionality (Weele, 2010). The features and characteristics of public sector procurement are based on these principles.

However, there are cases in which current practice of public sector procurement evaluation providing undesirable outcomes. There are many such cases even provided through media as public news (Boer et al., 2006). Some of these issues are due to the compensatory nature of the evaluation method (Mateus et al., 2010). One of the undesired outcomes presented by Boer et al. (2006) is a real life case from Netherlands as follows.

> "One of the uniformed services in the Netherlands needed new uniforms. Price and delivery time were both considered equally important. Price was awarded a score of 100 points up to a price of

€550. For every €10 above €550 1 point is deducted from the maximum score of 100. Delivery time scored 100 points up to 8 weeks; for every week above 8 weeks 25 points are deducted from the maximum score of 100" (Boer et al., 2006:3).

Based on the above requirements suppliers proposals are evaluated as shown in Table 4.1.

Table 4.1: Evaluation results of proposals

	Price (in €)	**Delivery time (in weeks)**	**Score on price**	**Score on delivery time**	**Total score**	**Ranking**
Supplier 1	650	13	90	0	45	3
Supplier 2	750	13	80	0	40	4
Supplier 3	825	12	73	25	49	2
Supplier 4	1550	9	0	100	50	1

In this case the supplier 4 wins. This means that the uniform service has to pay almost twice as much for a lead-time improvement of only 33 percent. The purchasing manager thinks this is strange as he gave the two criteria the same weight (Boer et al., 2006).

Similarly, Mateus et al. (2010) provided such undesiable issues with Portugal public sector procurement. In literature there are many known public sector procurement evaluation problems (Boer et al., 2006; Keeney, 2002; Mateus et al., 2010). This research is intended to identify an evaluation method that minimises these issues currently identified in literature and adheres to the local legal and operational requirements.

There are substantial features specific to public sector procurement which needs to be discussed. The following sections are based on those features, explaining public sector procurement objectives; key characteristics of public sector procurement; methods of procurement in the public sector; guidelines for public sector procurement; and evaluation criteria for public sector procurement.

4.3.1 Procurement objectives in public sector

The objectives of public sector procurement are the same as in the private sector (Leenders & Fearon, 1997) and many authors define the procurement objective as purchasing the right quality of material, at the right time, in the right quantity, from the right source, at the right price (Baily et al., 1994; England, 1967; Leenders & Fearon, 1997; Weele, 2000). Leenders and Fearon (1997:539) provides the following objectives for government procurement:

- Assurance of continuity of supply to meet service needs.
- Avoidance of duplication and waste through standardisation.
- Maintenance and improvement of quality standards in goods and services purchased.
- Development of a cooperative environment between supply agencies and departments served.
- Obtaining maximum savings through innovative supply and application of value analysis techniques.
- Administering the supply function with internal efficiency.
- Purchase at the lowest life cycle cost, consistent with quality, performance and delivery requirements.

These objectives given by Leenders and Fearon (1997), re-confirm that public procurement is about what is in the best interests of the organisation as in private sector. However, even if the objectives are of the same, there are some unique characteristics for public sector procurement which will be highlighted in the next section.

4.3.2 Key characteristics of public sector procurement

Public sector procurement has a rigid structure and it is difficult to make changes in public purchasing as it is established by law or regulation (Leenders & Fearon, 1997). Public procurement must adhere to the guidelines provided by public

authorities. In every country, public procurement must comply with specific legislative requirements (Falagario et al., 2012).

Public purchasing laws require a contract to be awarded to the lowest capable bidder who fits the requirements laid by invitation for bid (Brown, Wright, Cloke, Morris, & Trumper, 1984; Falagario et al., 2012; Leenders & Fearon, 1997). Public procurement has limited flexibility and narrow evaluation criteria when dealing with bid evaluation, as it has legal bindings (Leenders & Fearon, 1997).

The public sector spends on a planned and approved budget (Leenders & Fearon, 1997; Weele, 2000) and any changes need to be approved by legislative body making it time consuming, resulting in difficulties in taking advantage of spot buys of high quantity price deals (Leenders & Fearon, 1997).

Public procurement funds come from taxpayers. Being a taxpayer, a supplier may attempt to influence the political process to give themselves preference in procurement of materials, as they have been paying a higher amount of tax (Leenders & Fearon, 1997).

Reports on how public sector institutions spend their fund are open to the public (Weele, 2000). More specifically, all information on prices submitted by suppliers, and the amount ultimately rewarded to the supplier, must be provided to any taxpayer who wants it (Leenders & Fearon, 1997). Because of the issue of confidentiality, as the competitors can get the information, the suppliers are cautious about providing price deals to the public sector (Leenders & Fearon, 1997).

Clear and accurate specification is required to provide information to bidders to get competitive bids, without varying interpretations (Leenders et al., 2006; Lysons & Gillingham, 2003). The development of good specifications requires much time (Leenders & Fearon, 1997).

Public sector procurement emphasises the bid process with a rigid structure from invitation for bids to bid opening, evaluation and award (Leenders & Fearon,

1997). The extensive authorization process makes procurement a dull, difficult and time-consuming process (Weele, 2000).

Maldivian public sector procurement also incorporates the characteristics discussed above. Further explanations and more characteristics specific to the Maldives context are explained in Section 4.4.

4.3.3 Mode of procurement in public sector

Although there are unique issues in purchasing by public sector, procurement officials in this sector must give as much serious consideration to spending on procurement as private sector procurement managers (Leenders & Fearon, 1997). The mode of procurement in the public sector varies, depending on the product, value, urgency, location, and the suppliers capability (Brown, Wright, Cloke, Morris, & Trumper, 1984). Therefore, the mode of procurement depends on the situation of the procurement at the specific time for the public sector institution.

The following modes are described by Brown et al. (1984:7) and are still applicable in the Maldives public sector as well, according to Public Finance Regulation of Maldives ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

- Purchasing low value goods from local shops or stockists by cash or other arrangements.
- Obtaining oral quotations.
- Obtaining written quotations.
- Inviting tenders from a range of suppliers against a formally issued specification.
- Extensive formal tendering such as the letting of a contract for a stretch of motorway or a major computer installation.

Similar acquisition procedures, with additional explanations, are described by Leenders et al. (2006) as follows:

- Small-dollar purchases for items below the threshold for competitive bids or quotes.
- Request for quotations (RFQ) for items below the threshold for issuing a formal bid but high enough to require competitive quotations.
- Invitation for bids (IFB) for the items above the threshold to issue formal bid solicitation, normally for a product or contractual (nonprofessional) service.
- Request for proposal (RFP) for professional services or high-tech needs when formal bid solicitations are required.
- Emergency purchases for unplanned needs to protect public health and security.
- Sole-source purchases for a supply, service, or construction item when the purchase has been determined in writing and there is only one source.
- Negotiated acquisition, usually part of an RFT or sole-source purchase, or to acquire exempted services, such as utilities, power or landfills.

As is evident from the above methods described by both Brown et al. (1984) and Leenders et al. (2006), it includes all types of purchasing activity, from very simple cash and buy methods to sophisticated tendering. The amount of procurement effort changes, based on the significance of the material (Leenders & Fearon, 1997; Monczka et al., 2010). For small, common items, preference of supplier is comparatively unimportant. However, detailed evaluation processes and resource dedication are required for high-priced items (Monczka et al., 2010)

The Maldivian public sector procurement also practices different modes of procurement for different level of goods and services, as discussed above. Further explanations specific to the Maldives context are explained in Section 4.4.

The research focuses on the evaluation model for supplier selection for tendered materials and services. Therefore the next section discusses guidelines for evaluation for supplier selection.

4.3.4 Guideline for public sector procurement

It is evident that the procurement function can have a critical impact on the security of an organisation, an industry and a national economy as a whole (England, 1967). Therefore countries have developed guidelines for public sector procurement or government procurement which can be general guidelines for specific countries or work categories, developed through best practice (Rowlinson & McDermott, 1999).

In public sector procurement, some countries have industry specific guidelines, like GOSIP (Government Open Systems Interconnection Profile) in the UK. GOSIP provides a procurement handbook which is intended to simplify the procurement of OSI-based products by the UK government civil administration (GOSIP, 1994).

The guidelines provide systematic approaches to tender evaluation. Rowlinson and McDermott (1999) discouraged the design of a universal evaluation system of tenderers, due to the complexity and range of the potential performance criteria and indicators of tenderers. On the other hand, Rowlinson and McDermott (1999) believe that a basic model and guidelines can be established, based on which specific criteria and indicators could be identified for every specific case.

As explained by Falagario et al. (2012), European Directives state that either the Lowest Price (LP) or the Most Economically Advantageous Tender (MEAT) approach should be used. LP is used when features of the material or service other than price are identical to differentiate suppliers, otherwise tenders are awarded using MEAT (Falagario et al., 2012). Similarly, in the UK it is to maximise the ‘value for money’ (Brown et al., 1984) and in USA it is the lowest responsible and responsive bidder (Leenders et al., 2006) which is the approach used in choosing a supplier.

All these approaches of supplier selection are based on one or more evaluation criterion. There are fundamental criteria and procurement specific criteria for tender evaluation. The next section will highlight tender evaluation criteria.

4.3.5 Tender evaluation criteria for public sector procurement

Price, quality and delivery are the three primary criteria used by most organisations to rate suppliers (Liu, Ding, & Lall, 2000; Luo, Wu, Rosenberg, & Barnes, 2009; Mahdi, Riley, Fereig, & Alex, 2002; Monczka et al., 2010; Rowlinson & McDermott, 1999). It has also been shown in the results of the review of literature implemented by Ho et al. (2010) on evaluation criteria, in international journals from year 2000 to 2008, that price, quality and delivery are the three most commonly used evaluation criteria. However, there are several other criteria used by organisations and listed in theory, depending on the type of procurement. Different criteria can be applied in the selection of suppliers in different procurements. There are numerous evaluation criteria discussed by different authors and it is almost impossible to list every one as these changes over by time, and based on the specific procurement context. Monczka et al. (2010:170) described some of the criteria in general categories that can be applied, as follows:

- **Management capability**: involving criteria like management's mission and long term capability, investment in research and development, and whether this is enough to sustain growth, commitment to Total Quality Management (TQM), continuous improvement and so on.
- **Employee Capability:** such as the extent to which employees are committed to supplying high quality products, employees' views and responses to continuous improvements, worker flexibility, and so on.
- **Financial Stability:** such as the Current ratio, Quick ratio, Inventory turnover, Fixed asset turnover, Net profit margin, Return on assets and so on.
- **Quality management:** Management commitment, Number of defects, Variability, Process control, ISO 9000 certification, Continuous improvement and so on.

Process design and technology, production scheduling and control systems, environmental regulation compliance, e-commerce capability, supplier's sourcing

policy, and potential for long-term relationship are other categories described by Monczka et al. (2010).

Based on the fact that different procurements need different criteria for selecting suppliers, this research project does not specify a set of criteria to be applied to the decision model. However, as seen in literature, there are contemporary criteria like cost and delivery (Luo et al., 2009; Mahdi et al., 2002; Monczka et al., 2010; Rowlinson & McDermott, 1999) which could be used for evaluation.

Since the project is based on public sector procurement in the Maldives, more specific details of Maldivian public sector procurement is discussed in the next section.

4.4 Public sector procurement in Maldives

Dhaulathuge Maaliyyathu Gaanoonu 2006 (literally, *Public Finance Act* 2006) and *Dhaulathuge Maaliyyathu Gavaaidhu 2009* (literally, *Public Finance Regulation* 2009) are the governing laws and regulations for public sector procurement in the Maldives ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). The responsible body for governing public sector finance is assigned by the President of Maldives ("Dhaulathuge Maaliyyathu Gaanoonu," 2006) and it is the Ministry of Finance and Treasury (MoFT) ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). As MoFT is the assigned body for public finance regulation it creates and amends Public Finance Regulation requirements ("Dhaulathuge Maaliyyathu Gaanoonu," 2006).

In alignment with (Brown et al., 1984), in the Maldives too the method of procurement in public sector varies depending on the product, value, urgency, location, suppliers capability ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

In normal circumstances the method of procurement mainly depends on the value of procurement product as described by Leenders and Fearon (1997) and also

based on public finance regulations of Maldives ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009)

As described in Introductory chapter Section 1.2, based on the *Dhaulathuge Maaliyyathu Gavaaidhu 2009*, if the procurement material or service cost is less than MVR1,000.00 the institution can purchase it at the common market rate from any supplier. If the procurement material or service cost is from MVR1,000.00 to MVR25,000.00, the institution can get quotations from three different suppliers and purchase from the best supplier. If the procurement material or service cost is MVR25,000.00 or more, the institution has to go for public tendering. If the procurement material or service cost is from MVR25,000.00 to MVR1,500,000.00, the institution forms a Bid Evaluation Committee (BEC) which evaluates the bids. If the procurement material or service cost is MVR1,500,000.00 or more, still the institution has to announce for public tender and the tenders are evaluated through the National Tender Board (NTB) ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

The research focuses on the second last band, where procurement material or service cost is more than MVR25,000.00, thus requiring public bidding. The following sections will cover public bidding or tendering and its guidelines with regard to the procurement of materials and services above MVR25,000.00 and supplier selection.

4.4.1 Government guidelines for procurement

Dhaulathuge Maaliyyathu Gavaaidhu 2009 (literally, *Public Finance Regulation* 2009) prescribes a standard guideline for public sector procurement. The main points in the guidelines provided by *Public Finance Regulation* 2009 in the context of this research are as follows:

- Public procurement should be a transparent process.

- To create competitive bidding, fair opportunities should be provided to capable suppliers.
- The procurement process should be the same for all bidders.
- To ensure the procurement process runs smoothly according to the regulations, modern technology can be used.
- There must be a responsible person for the procurement.
- Imported products should be purchased from the suppliers who have a licence and are in continued business. The suppliers need to agree to support public procurement.
- If a supplier has any family or business relationship with a senior official, the details should be submitted in a signed document along with the bid documents. Failure to this condition cancels the bid.
- In the case of bulk buying of materials, an organisation should not buy at the retail rate but at the wholesale rate provided by the supplier.
- Every public department should submit their annual budget in advance for the next year and the procurements should be listed and approved in the budget.
- Anything outside the approved budget should be procured only if it risks a person's life or if it stops any basic public service.

Dhaulathuge Maaliyyathu Gavaaidhu 2009 provides very specific and copious guidelines to be followed in Maldives public sector procurement. However, not every guideline that it provides has significant importance to this research project. The important guidelines only are discussed here.

A major importance is given to public tendering under *Dhaulathuge Maaliyyathu Gavaaidhu 2009* of Maldives. The following sections describe public tendering in Maldives and the criteria imposed for supplier selection in public procurement in the Maldives.

4.4.2 Public tendering

The public tendering procedure is same as described in Section 4.2.3.1. However, there are some country-specific regulations in public sector tendering. The major points of the regulation with regard to public sector tendering, based on the research context, are described as follows:

Dhaulathuge Maaliyyathu Gavaaidhu 2009 prescribes that any procurement of material or service which amounts to more than MVR25,000.00 should be announced for public tender. The procurement should be made based on the bids or tenders submitted ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

Procurement specifications should be provided in writing to the potential bidders. This information should also provide information on the selection guide by providing the evaluation criteria including weights and how points will be allocated ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

There must be a Bid Evaluation Committee (BEC) in every public office that does procurement. The BEC members are senior officials from different departments. The names, with job titles, of the BEC members should recorded in writing and also passed on to individual BEC members in writing. The minutes of BEC meetings should be recorded in writing ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). If the procurement value is more than MVR1,500,000.00, the tender is evaluated by NTB under MoFT and the same procedure is applied.

The BEC or NTB need to have a justified reason for choosing a particular supplier and it should be signed by an authorised person ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). The justification is the evaluated result of the tenders by the BEC or NTB.

For the tender evaluation there are enforced criteria by law and regulation. The country-specific criteria for the research context are discussed in the next section.

4.4.3 Enforced tender evaluation criteria

Even though there are a number of criteria used in public sector procurement, there are compulsory criteria that must be used in supplier selection in public sector in the Maldives ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). *Dhaulathuge Maaliyyathu Gavaaidhu 2009* assigns the responsibility to BEC or NTB to evaluate the bids or tenders, based on price and duration. In addition, it prescribes to look for the following criteria:

- Financial capability of the supplier.
- Technical capability of the supplier.
- Justifiability of the prices submitted by suppliers, compared to estimated price of the procurement material or service.
- Similar past experiences of the suppliers, in terms of size and execution.
- Any other important criteria perceived by the public sector department.

The bids or tenders should cover the above mentioned information requested by tender announcement through a bid or tender submission form. The bids or tenders should also cover a summary of the current work undertaken by the supplier and its value ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

According to *Dhaulathuge Maaliyyathu Gavaaidhu 2009* there must be minimum of three bids or tenders for any public procurement tendering for evaluation. If minimum three bids or tenders are not received, it should be re-announced for tendering. If the second attempt fails to receive three tenders, procurement should be negotiated with the suppliers ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009).

Like every public sector institution, BEC and NTB is bound to follow these criteria and guidelines for public sector procurement.

Since the public sector procurement requires more than one criterion to be considered in the evaluation of bids or tenders, a multi-criteria decision analysis (MCDA) method needs to be used for evaluation.

4.5 Conclusion

Decisions on procurement involve more than balancing a variety of technical considerations. The chapter discussed the essential issues that need to be considered in public sector procurement.

Public sector procurement uses a structured procedure governed by public finance law and regulations which enforces non-discrimination, equality, transparency, and proportionality. In accordance with the regulations, public sector procurement sets criteria for tender evaluation. It involves compulsory criteria and optional criteria based on the procurement. Public tender evaluation approaches seek to select the best tender, based on the collected information.

The education sector where the research is focused is fully under the public sector. Therefore, the same public sector procurement rules and regulations are applied to the education sector.

Based on the literature, it is evident that procurement decisions in the public sector need to consider the best choice, based on the information gathered. For this purpose, multiple evaluation criteria are used to evaluate the bids or tenders.

From the literature review the following criteria are identified for the purpose of criteria-based evaluation, as described in Research Methodology, Section 2.4.3.1 and Section 2.4.3.3.

1. Bids should be identifiable and received on a specific date.

2. Bids should have specified information requested in the bid invitation, such as price, delivery duration and so on.
3. A procurement process should follow four major principles: non-discrimination, equality, transparency and proportionality.
4. Evaluation should be in line with the procurement objective to purchase the right quality of material, at the right time, in the right quantity, from the right source, at the right price.
5. Selection decisions to be made by considering the following:
    a. Assurance of continuity of supply to meet the service needs.
    b. Avoidance of duplication and waste through standardisation.
    c. Maintenance and improvement of quality standards in goods and services purchased.
    d. Obtaining maximum savings through innovative supply and application of value analysis techniques.
    e. Purchase at the lowest life cycle cost, consist with quality, performance and delivery requirements.
6. Selection decision should be in the best interests of the public sector organisation.
7. Evaluation procedures should follow the procurement guidelines and rules provided by the authorities.
8. Contract should be awarded to the lowest capable bidder who fits in to the requirements laid down by the Invitation for Bid.
9. An evaluation process should consider that the public sector spends on its planned and approved budget. For instance, it is difficult to take advantage of spot buys of high quantity price deals.
10. There should be no political, organisational or personal influence on preference for any supplier.
11. Requirement specifications are provided to potential bidders.
12. Evaluation criteria with weights, and how points are allocated, should be given to potential bidders.
13. Evaluation criteria and weights cannot be changed after the bid submission.
14. Announcement of the invitation for bids should be made public.

15. The value of procurement should be between MVR25,000.00 and MVR1,500,000.00.
16. Public procurement should be a transparent process.
17. To create competitive bidding, fair opportunities should be provided to the capable suppliers.
18. The procurement process should be the same for all bidders.
19. There must be a responsible person for the procurement.
20. Imported products should be purchased from the suppliers who have licence and are in a continuing business. The suppliers need to agree to support public procurement.
21. In the case of bulk buying of materials, these should not be bought at the retail rate but at the wholesale rate provided by the supplier.
22. Every public department should submit their annual budget in advance for the next year, and the procurements should be listed and approved in the budget.
23. Anything outside the approved budget should be procured only if it is not acquired risks a person's life or if it stops any basic public service.
24. Procurement should be from the bids submitted.
25. There must be a bid evaluation committee to evaluate bids.
26. For the selection of any supplier, there must be a justified reason.
27. There must be a minimum of two criteria: price and duration of delivery.
28. There can be as many criteria as required by the organisation relevant to the procurement.
29. There must be a minimum of three bids for evaluation to select a supplier.

The above mentioned criteria will be used for criteria-based evaluation as legal requirements, as illustrated in Figure 2.2. In addition, operational requirements are used for criteria-based evaluation. The next chapter discusses operational requirements in detail.

CHAPTER 5

FIELD RESEARCH FINDINGS

5.1 Overview

Field research was to achieve the second research objective presented in Section 1.3 and also as illustrated in research implementation model in Figure 2.2. The field research was to conduct focus groups with education sector procurement decision-makers and to collect real life procurement data sets with their evaluated results.

This chapter presents the research findings of the focus group interviews. The focus group findings are in three major themes: preparation process, bidding process and evaluation process. The findings of constraints and requirements for public sector procurements for this study are in these three stages of procurement. Each theme has sub-categories to represent the results.

This chapter discusses the emerged results of the data analysis, based on the field research conducted in public sector education institutions in the Maldives.

5.2 Introduction to research findings

The following sections are indented to present the research findings of the context emerging from the data analysis. The findings are presented under three major themes with their related constraints and requirements under consideration, in context of public sector procurement, as shown in Figure 5.1.

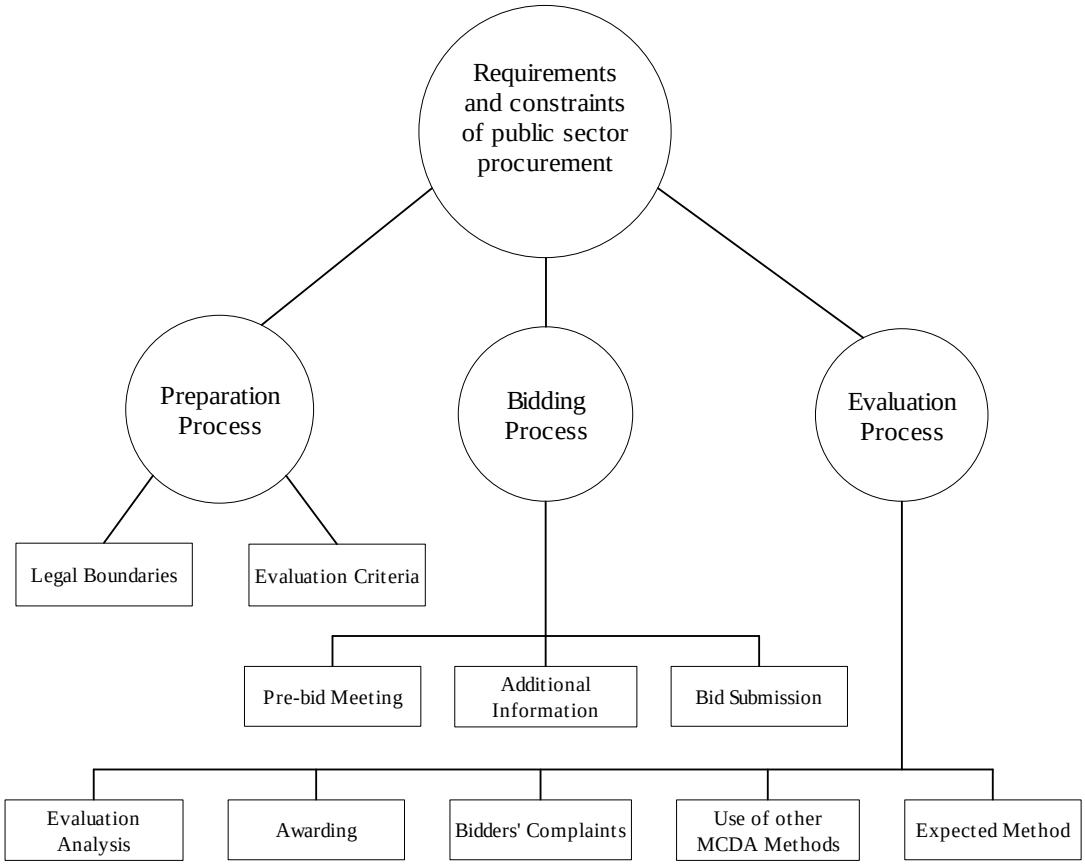

Figure 5.1: Structure of presentation of findings

The presentation of finding is themed to the major processes involved in public sector procurement in relation to bid evaluation context. The first theme presented is the ‘preparation process’ where the requirements and constraints with regard to the theme are discussed, followed by ‘bidding processes and finally ‘evaluation process’.

As illustrated in Figure 5.1, the findings are presented with main themes aggregated from interpretive codes, which are derived from descriptive codes, as shown in Table 5.1. The descriptive codes are derived from the focus group transcripts for every new concept discussed by the BEC members. These concepts are categorised to interpretive codes.

Table 5.1: Presentation of findings

Main themes	**Interpretive codes**	**Descriptive codes**
Preparation process	Legal boundaries	Maximum tender
		Minimum tender
		Cost bands
		Bid announcement criteria
	Evaluation criteria	Price
		Duration of delivery
		Experience
		Financial capacity
		Quality
		Technical capacity
		After sales services
		Warrantee
		Human capacity
		Other criteria
		Criteria establishment
		Allocation of criteria and weights
Bidding process	Pre-bid meeting	Announcement of pre-bid meeting
		Compulsory pre-bid meeting
		Provision of specification
		Provision of marking criteria
		Recoding of pre-bid attendants
		On the spot information provided
		Specialised information
		Explanation of calculations
	Additional information	Request to submit all documents
		Information through email
		Information through phone
	Bid submission	Verification of bid submission
Evaluation process	Evaluation analysis	Required minimum members
		Basis for evaluation
		Verification of suppliers proposal
		Evaluation of suppliers previous jobs
		Evaluation of support documents
		Importance of acceptable price

		Evaluation of suppliers' performance
		Marks allocation
		Use of technical expertise
		Check for standard specification
		Evaluate every criterion independently
		Evaluate all criteria
		No ranking
		No pair-wise comparison
		No changes to criteria and requirements
		Disqualifying bids
		Showing calculations to bidders
	Awarding	Requires approval
		Confirmation and reason for selection
		Informing bidders
	Bidders complaints	Clarification to bidders
		Complaints to authorities
		Misconceptions of bidders
	Use of other MCDA methods	Lack of knowledge of other MCDA methods
	Expected method	No discrimination
		Accurate method
		Reasonable
		Comply with regulations
		No chance of manipulation
		Minimise complaints
		Support utility concept
		Clear and good understanding

The descriptive codes are the operational criteria required to conduct criteria-based evaluation to achieve the fourth research objective. These descriptive codes represent operational requirements, characteristics, limitations and constraints of procurement from the BECs. In a focus group if any BEC member mentions any of such operational requirements, it is treated as one of the criteria for the analysis, because such requirements need to be in line with any chosen decision model. Therefore, even if any such requirement is mentioned by one or many BEC members, it is treated equally because the frequency of the requirement mentioned in focus groups does not weaken or strengthen the requirement for the criteria-based analysis. A requirement remains as one single requirement irrespective of its frequency or number of BECs mentioning it.

The following sections are organised to present the results according to the structure provided in Table 5.1 and illustrated in Figure 5.1. Themes are presented at first followed by interpretive codes under the themes and then the descriptive codes with its related quotations.

5.3 Preparation process: requirements and constraints

Based on the findings, there are multiple constraints and requirements in the preparation process which would influence the supplier selection in public sector procurement. The requirements and constraints are grouped into two sub-categories, as shown in Figure 6.2.

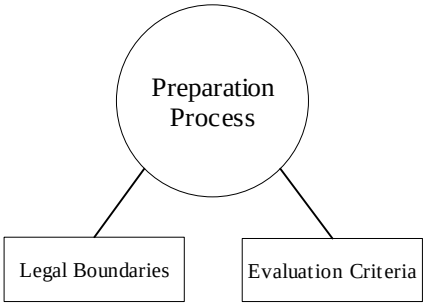

Figure 5.2: Sub-categories of preparation process

The sub-categories are legal boundary and evaluation criteria. The following sections will discuss the findings in the two sub-categories in details.

5.3.1 Legal boundaries

As discussed in Chapter 4, public procurement is regulated by laws and regulations. It remains the same in the public education sector context under study. Participants of the focus group mentioned at different times in discussions related to different questions that they had to follow rules and regulations. With regard to the practice of regulation, in discussion related to pre-bid meetings a participant mentioned that “in addition to pre-bid meeting, information is provided through

different means. But we have standard regulations to follow" (IL4). Furthermore, in another focus group the following was mentioned:

> "When bidding is done, even if we need to a bear loss [on quantity discounts] there is Public Finance Act and Public Finance Regulation, which should not be violated. If we take advantage of such discounts, it violates the regulations." DL3

There are several constraints and requirements related to legal boundaries in the preparation process of the public education sector procurement. The following sub-sections discuss the requirements and constraints.

5.3.1.1 Maximum tender

According to the Public Finance Regulation, the public sector education departments can handle procurements that cost less than MVR1.5 million (approximately GBP60,000). Any public sector procurement which costs more than MVR1.5 is evaluated by NTB under MoFT. During the focus group interviews participant ML2 stated that "we handle procurement value less than MVR1.5 million" (ML2).

5.3.1.2 Minimum tender

Similar to having a maximum tender limit, according to the Public Finance Regulation, the public sector education departments request for bids and evaluate by their BEC if the procurement costs are more than MVR25,000 (approximately GBP1,000). A participant in the focus group stated:

> "If [the cost of] procurement is greater than MVR25000 we have to gazette it." ML2

5.3.1.3 Cost bands

In normal circumstances, Public Finance Regulation has a varied mode of public sector procurement, based on the cost of the procurement under consideration, varying from over the counter to public tendering.

> "Items less than MVR1000 would be purchased after checking prices from three vendors. Items between MVR1000 to 25000 will be purchased after getting quotations from three vendors. If [the cost of] procurement is greater than MVR25000 we have to gazette it." ML2

The lowest band, which is less than MVR1,000 (approximately GBP40) requires public sector institutions to check costs from three shops before purchasing. The second band, which is more than MVR1,000 and less than MVR25,000, requires three formal quotations from three sellers. Finally the last band, which is more than MVR25,000, requires a public announcement requesting bids.

The selection of supplier is based on the lowest cost supplier when a public announcement for bidding is not required.

> "If [cost] is less than MVR25000, we award to the lowest cost supplier. Otherwise, there are cases we don't award to the lowest price but to the most competitive bidder." ML2

5.3.1.4 Bid announcement criteria

The bid announcement criteria are also regulated by Public Finance Regulation. The request for a bid to the public is based on the cost of the procurement as well. According to the regulations, if the cost of the procurement is more than MVR25,000, it has to be publically announced to potential suppliers.

> "If [the cost of procurement is] greater than MVR25000 we have to gazette it; publically announce it. Nowadays, we usually gazette it." ML2

The evaluation of such publically announced bids are undertaken by BEC, according to the publically announced evaluation criteria.

5.3.2 Evaluation criteria

Public Finance Regulation of the Maldives specifies two compulsory criteria; cost, and duration of delivery. It also provides guidance to look for other criteria. The same two criteria were mentioned by all the focus groups, along with several other bid evaluation criteria, as stated by a participant thus "points are allocated for price, duration and experience too" (ML2).

The commonly used criteria for the public education sector procurement, based on the focus groups are given below.

5.3.2.1 Price

Price has been the major evaluation criterion for all procurements. For all the focus groups, the first criterion mentioned is cost: "Generally price is a criterion" (ML2). In the third focus group a participant said that "mainly, price, duration and experience are evaluated" (IL4). Price is checked in most cases for evaluation, as mentioned by a participant in the second focus group, who stated that "price, duration, technical capacity, financial capacity is checked" (DL1). Similar expressions are noted for price as a criterion as follows.

> "There are mainly 4 criteria. They are: price, duration of supply, their financial capacity and experience." ML2

> "Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria)." IL3

5.3.2.2 Duration of delivery

Duration of delivery is another major evaluation criterion for all the procurements. Delivery as a criterion was mentioned in all the focus groups. "Points are allocated for price, duration and experience too" (ML2).

Generally, the duration of delivery was used together with price criterion, as mentioned by a participant, who stated "price, duration, technical capacity, financial capacity is checked" (DL1). Similar expressions are noted for price as criterion as follows:

> "There are mainly 4 criteria. They are: price, duration of supply, their financial capacity and experience." ML2

> "Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria)." IL3

> "Mainly, price, duration and experience are evaluated." IL4

5.3.2.3 Experience of supplier

Experience of the supplier is also a prominent evaluation criterion. In bid evaluation, BEC "look for bidders experience as well" (DL1). "Points are awarded for duration [of delivery], experience [of the suppler] and financial capacity [of the supplier] as well" (ML2).

Use of personal knowledge about the supplier also indirectly helps BEC in evaluation. However, the experiences are evaluated based on information gathered for the bid.

> "Then we look for experience, right? In everyday life, we also know some of them. But experience of the bidder is based on submitted documented evidences." IL3

The experiences of the bidder within the particular public sector department are counted in the evaluation of the experiences of the bidder. This experience may inflict reduced marks if the performances are not acceptable.

> "We look into the bidders' previous level of performances for us, if they have ever done any job for us. If it is bad, it will be considered [in evaluation]." DL3

5.3.2.4 Financial capacity

Financial capacity of the supplier is also used as an evaluation criterion for bid evaluation. As stated in a focus group, "points are awarded for duration [of delivery], experience [of the suppler] and financial capacity [of the supplier] as well" (ML2). The same focus group also stated:

> "There are mainly 4 criteria. They are: price, duration of supply, their financial capacity and experience." ML2

In addition the same criterion, the financial capacity of the supplier, was also repeated in the second focus group as well.

> "Price, duration, technical capacity, financial capacity is checked." DL1

5.3.2.5 Quality

Quality of work is used as an evaluation criterion for bid evaluation as well. This criterion is evaluated based on the work done by the particular supplier.

> “As such [we] give higher importance to bidders' experience. Need to think about quality of work. Based on experience, it is evaluated.” DL1

> “We assess similar work done by the bidders in other places to check for their quality of work.” DL2

5.3.2.6 Technical capacity

The technical capacities of the supplier is also used a criterion for bid evaluation. It involves the evaluation of "number of qualified people for the job and number of available machineries for the job as well" (DL3). In addition, technical capacity was mentioned by a participant while listing some of the evaluation criteria, as follows:

> “Price, duration, technical capacity, financial capacity is checked.” DL1

5.3.2.7 After-sales services

After-sales services are also considered to be one of the criteria for bid evaluation, used for long term use products, like machinery, as illustrated by a participant, who stated that "there may be, for instance, after sales services as a criterion for things like machinery" (IL3).

> “Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria).” IL3

5.3.2.8 Warrantee

Warrantee is also considered as a criterion for bid evaluation for some cases of procurement. Use of the criterion depends on the item to be procured.

While listing some of the criteria for bid evaluation, a participant mentioned warrantees as one of the criterion as stated bellow.

> "Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria)." IL3

5.3.2.9 Human capacity

The human capacity of the supplier is also used as a criterion for bid evaluation. Based on the product or services to be procured, it is important to see if the supplier has staff who are sufficiently qualified to handle the product or service.

> "[Criteria include] number of qualified people for the job and number of available machineries for the job as well." DL2

5.3.2.10 Other criteria

Other criteria are used, depending on the product or services being procured.

> "Depending on the procurement there may be other allocated points (weights)." ML2

However, there are fundamental criteria used for any procurement, like price and delivery period. Additional criteria are contextual to the procurement.

> "Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria)." IL3

> "Some jobs have additional criteria other than the major 4 [criteria], but in most of the cases, these 4 criteria are used." ML2

5.3.2.11 Criteria establishment

According to the procurement regulations, criteria need to be established. The criteria is identified and informed before any purchasing is done. For instance, a BEC member stated:

> "Points are allocated for price, duration and experience too. The Public Finance Act says to use these criteria. Need to ensure before ordering." ML2

Specific criteria are identified and established based on the needs of the particular procurement. In addition, the situation where procurement is needed is considered in establishing the criteria. A BEC member mentioned this as follows:

> "Criteria are established based on the work and situation analysis." DL2

For instance, if classroom repair work is to be completed before the end of the school holidays, having the time to complete the work is highly important as it would disrupt the classes during school days if it were to take place then.

> "Duration is highly considered when the work needs to be done in a short period of time. In some projects we may not assess the component. But it (duration) is considered for all the work which needs to be done during the school annual holidays. Some jobs are given ample time to be done to higher quality standards." DL3

5.3.2.12 Allocation of criteria and weights

The allocation of criteria and their weights are prioritised, based on the need. A highly important criterion for a particular procurement could be preceded by another criterion in a different procurement situation. As such, one of the focus groups of a school stated:

> "Compared to price, quality, duration, if there is less time [to get the job done], priority is given to duration. Otherwise it may cause disruption to the education of many students." DL2

For instance, if the institution had no urgency to procure a certain item, the allocation of weights to duration of delivery will be lower. More weights may be allocated to other important criteria.

The highest priority is usually given to the cost of the item by allocating the highest weight to the cost criteria. However, in a school situation it is common to give almost equally higher priority to the duration of delivery and cost.

> "If we need the item to be delivered urgently, allocated points for delivery can be almost equal to that of cost. Otherwise if we have enough time, we do not allocate higher weight to the item." ML2

> "There may not be a standard to allocate weights. The norm is as DL2 mentioned, since we are a school we have a limited time to get the work done. So we pay attention to duration." DL1

The allocation of criteria and its weights is also influenced by past experiences of similar procurements. For instance, if suppliers get an advantage from putting more weights on duration, but cannot deliver within the required time-frame, the weight for the duration may be reduced next time for similar procurement. On the other hand, the weights can be increased based on the suppliers' expected performances on the criteria for a similar procurement. As such, a BEC member stated:

"Before it comes to evaluation, during information sessions it will be thought out. For instance, we may have had a bad experience with duration. The winning bidder for a job may have had a short duration for the job and could not deliver within the time. Next time, we will know that we need to allocate less weight to the duration for such jobs. Similarly, based on our experiences, weights increase for other criteria." IL3

5.4 Bidding process: requirements and constraints

Bidding process involves several constraints and requirements that would influence the supplier selection in public sector procurement. The requirements and constraints are grouped into three sub-categories, as shown in Figure 6.3.

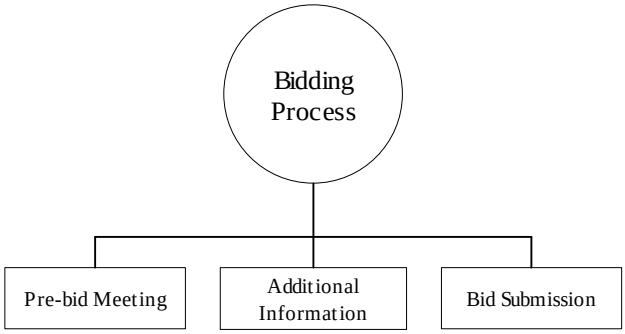

Figure 5.3: Sub-categories of bidding process

The sub-categories are pre-bid meeting, addition information and bid submission. The following sections will discuss the findings in the three sub-categories in details.

5.4.1 Pre-bid meeting

A pre-bid meeting is compulsory for public sector institutions for procurements that exceed the cost limit of MVR25,000, which is where the study is focused. It has been confirmed in the focus groups, as follows.

> "It is an obligation to have a pre-bid meeting if the value is more than MVR25,000." ML2

The pre-bid meeting is announced through the invitation for bids (IFB) in public. The date, time and place of the pre-bid meeting are stated in the same announcement.

> "Public announcement made for the bids will have a specified date and time for an information session." ML2

There are several constraints and requirements with related to pre-bid meeting during the bidding process. The following sub-sections discuss the constraints and requirements.

5.4.1.1 Announcement of pre-bid meeting

The announcement of a pre-bid meeting is important for the potential bidders to attend and receive information on the specific procurement. The pre-bid announcement goes together in the same announcement for IFB.

As mentioned by participants, "at first it is publically announced" (DL2) and the "public announcement made for the bids will have a specified date and time for an information session" (ML2). Additionally, the following statements were made during the focus groups.

> "First it is announced and when information is provided, it will state the point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points." IL3

> "An announcement will state a time for information session, right? We have only small jobs which could be managed internally. An information sheet with the details is provided to attendees of the information session." IL4

IBF for every procurement is specific to a particular product(s) or service(s). The bids will be accepted for only those stated and as stated. For instance, a member of BEC stated:

> "An announcement is made for specific jobs. It states we want these jobs to be done and bid submissions are open only for those jobs. First it will be an invitation to attend information session." DL1

5.4.1.2 Compulsory pre-bid meeting

It is compulsory to have a pre-bid meeting according to Public Finance Regulation and also reconfirmed in focus groups.

> "It is an obligation to have a pre-bid meeting if the value is more than MVR25,000." ML2

A pre-bid meeting is also crucial because the relevant information about the procurement is provided during the meeting. Failing to give the information to potential bidders may mean good proposals to the institution being lost.

> "A pre-bid meeting is compulsory. That is the time information is provided. Otherwise it is missed." IL3

It is also generally accepted among BEC members that, if the public announcement for bids are done, then it is the responsibility of the institution to provide information to potential bidders about the procurement.

> "Yes, if we announce for bids, we have to have the information session" DL1 & DL2

5.4.1.3 Provision of specification

Specification of the procurement is given during the pre-bid meeting. Usually "an information sheet is provided during the [pre-bid] meeting" (ML2) with specifications including the details of the product(s) or service(s) required, with the quantity needed. For instance a BEC member mentioned:

> "When information is provided, the information sheet will have criteria and specific details of the work to be done." DL1

During the pre-bid meeting, required information with details for the procurement are discussed and provided to the attendants in writing. Three BEC members in a group explained it as follows.

> "The information is provided in writing" DL1 & DL2. "Both verbal and written" DL3. "Explained verbally and given in writing." DL1

It has always been the case that, if a public sector institution announces for a bid then an information sheet is provided to the potential bidders.

> "If we announce for bids, we provide an information sheet." DL1 & DL2

> "An information sheet with the details is provided to attendees of the information session." IL4

5.4.1.4 Provision of marking criteria

A set of marking criteria is also provided during the pre-bid meeting. This specifically states the evaluation criteria and their allocated weights. This information is also provided in writing to the attendees of the pre-bid meeting.

> "The information sheet will have marking criteria. It states the allocated points for price, allocated points for delivery, and how many points for their

> [suppliers'] experience. In some cases there are other allocated points. Point allocation standards should be stated in the information sheet. [...] The information sheet should state how (many) points (weights) are allocated (for each criteria) for marking. [...] That [marking criteria] is provided with the information sheet during the information session on the same day." ML2

According to a BEC member "previously the [bid] announcement was with marking criteria but now it is not provided with the announcement but with the provision of information." (IL3).

Provision of marking criteria with the information sheet is the custom followed now. It has been stated by members of BEC that:

> "A set of criteria is given while providing information [on specification] saying that those criteria are the ones to be used for marking. It is given to them [attendees of pre-bid meeting]. Evaluation is based on it [given set of criteria]." DL1

> "We must provide [marking criteria] in the information sheet when we provide information." DL1 & DL2

> "First it is announced and, when information is provided, it will state the point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points." IL3

5.4.1.5 Recoding of pre-bid meeting attendants

Pre-bid meeting attendants are recorded, as in some cases bids are accepted only from the potential bidders who attend the pre-bid meeting. There are some practical reasons for the BEC to record pre-bid meeting attendants, which was explained by a BEC member as follows:

> "Without attending the information session, when someone takes the information sheet to a bidder, based on that, those who did not attend

> information session submit bids. After winning the bid, they may say that we were not clear about it. Therefore, we a have a list of attendees to the pre-bid information session." DL2

The pre-bid meeting attendees list "have name, signature and time" (DL1 & DL3).

5.4.1.6 On the spot information provided

During the pre-bid meeting queries from attendees are answered during the meeting. This is the opportunity for potential bidders to get further clarification on the procurement. For instance, a member of BEC stated:

> "They will get the opportunity to get answers for misunderstood information. They will also be given the opportunity to ask for additional information or questions. That is how it goes." DL3

If the answers to the queries are not readily available, the public sector department provides the information later after the meeting, when the requested information is gathered. This was confirmed by a BEC a member:

> "Questions raised in the information session will be answered at the time. If answers are not available, they are provided later, either by email or by phone." ML2

5.4.1.7 Specialised information

The public sector department responsible for procurement brings the people who request the item or service to a pre-bid meeting to provide specialised information about the particular procurement to potential bidders.

> "The procurement unit handles jobs for many different sections. Therefore, in the pre-bid session a person from the requested department will attend to provide information." ML2

The procurement staff are generally capable of providing information on procurement to bidders. These staff have experience in handling procurement in the education sector. However, for specialised products or services, people with the knowledge of the products and services are brought in to provide specific information to potential bidders. A member of the focus group stated:

> "Some of them (procurement staff), by experience, have good knowledge to provide information to bidders. However, for IT, we bring a person from the IT section because IT is critical." ML2

5.4.1.8 Explanation of calculations

For some cases, calculations used in the evaluation process are explained to potential bidders during the pre-bid meeting. BEC expects that the bidders would know how the calculations are done. The following statements were made during the focus groups:

> "Sometimes (calculation) are also explained. Generally bidders know how it is calculated [...]. [calculations are] explained rarely." ML2

How the calculations are done was explained to the researcher during the focus group discussions by showing examples from previously evaluated procurement results. However, generally this explanation is not provided to potential bidders during the pre-bid meeting, mainly for three reasons. Firstly, BEC believes that procurement is a routine job and the potential bidders would have the experience to know how evaluations are done. Secondly, potential bidders do not usually ask for an explanation of the calculations for evaluating bids during the pre-bid meeting. Finally, potential bidders do not complain about not receiving information on how

the calculations are to be done. A set of focus group members jointly explained the issue, as follows:

> "We don't really explain how the calculations are done. Marking criteria is there, but how the calculations carried out are not" DL1. "We assume that they know how the calculations are done." DL1 & DL2. "Since it is routine and it is seen in papers." DL1

Additional explanations were provided by another focus group, thus:

> "How the calculations are done is not explained as such [in the pre-bid meeting]. Attendees of the information session don't make any complaints about it [not explaining how calculations are done]. All of them will see the prices and other information submitted. When they see, they don't ask questions about it. So we also don't explain [calculations]. But if anyone complains we will provide that information. They would know how calculations are done. Everybody does these calculations in the same way." IL3

However if any bidder wants to see the calculations after evaluation, the public sector department shows it. But education sector institutions do not face the issue commonly. For instance, a focus group member stated:

> "After evaluation, if bidders want to see the calculations, we provide it." IL3
> "But hardly, anybody wants it." IL4

5.4.2 Additional information

After the pre-bid meeting, there is still provision for additional information to bidders, if there are issues which need to be cleared before bidding. In addition, bidders are also requested to submit additional information to support their bid, including any documentation that would count as evidence of their performance towards the bid.

The additional information is exchanged through different means. However, care is taken to adhere to the laws and regulations of public sector procurement, such as provision of the same information to all the potential bidders. As such a BEC member mentioned:

> "In addition to pre-bid meeting, information is provided through different means. But we have standard regulations to follow." IL4

5.4.2.1 Request to submit all documents

For the advantage of bidders and to check for evidence of supplier by evaluators, the potential bidders are informed to submit all relevant documents related to the bid which could help the bidders to gain even the slightest evidence of their performances.

> "During information session bidders are requested to submit every document to support the bid." DL1

Submission of the all relevant documents would reduce the time taken to evaluate the performance of the bidders as there may be reliable evidence from the documents submitted. In addition, this will help the bidders to gain marks for their performances, if any document gets counted by the evaluators.

5.4.2.2 Information through email and telephone

Additional information after the pre-bid meeting is generally provided through email or telephone. Some cases, informed by telephone and specific details are emailed to the potential bidders.

> "Questions raised in the information session will be answered at the time. If answers are not available, they are provided later, either by email or by phone." ML2

In the case of informing by telephone, procurement administrative staff call all the potentials bidders who attended the particular pre-bid meeting and provide identical information to all. The other case, when informing by email, procurement administrative staff send same email to all the potentials bidders who attended the particular pre-bid meeting with the information.

5.4.3 Bid submission

Bid submission is done according to the initial announcement on the specific data and time by the bidders. The bids are opened at the same time at the presence of the bidders.

> "In the presence of all the bidders, bids are received and the submission sheet is signed by all the bidders and a photocopy of the sheet is provided to every bidder." ML2

All the bids are verified for acceptance. At first, if stated initially, bids are verified to see if the bids are from the same bidders who attended the pre-bid information session for the particular bid. Such bids which require pre-bid attendance must have the bidders attendance recorded in the pre-bid attendance sheet. Otherwise, the bid will not be accepted as explained below by a member of BEC.

> "Therefore, we have list of attendees to the pre-bid information session. We accept bids from them." DL2

The basic details of the bids are recorded during bid submission in the presence of all the bidders. The details involve name of supplier, contact details, cost, and duration of the supply. This record is signed by every bidder and a copy of the sheet is provided to all bidders.

"On the day (when bids are submitted) qualified bids with their figures [cost and duration] are given to all the bidders. So they know who will probably win." ML4

According to the BEC, based on the basic performance information, especially cost and duration, bidders are normally able to estimate who will win the bid.

5.5 Evaluation process: requirements and constraints

The bid evaluation process also involves several constraints and requirements that would influence supplier selection in public education sector procurement. The requirements and constraints are grouped into five sub-categories, as shown in Figure 6.4.

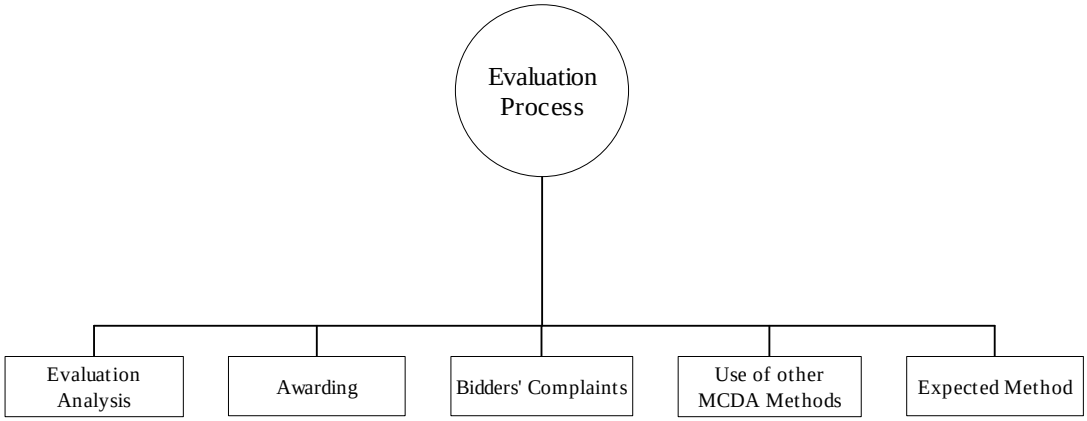

Figure 5.4: Sub-categories of evaluation process

The sub-categories are evaluation analysis, awarding, bidders' complaints, use of other MCDA methods and expected method. The following sections will discuss the findings in the three sub-categories in details.

5.5.1 Evaluation analysis

One of the important functions of public sector procurement is bid evaluation. Therefore, the bid evaluation analysis is a dedicated and professional exercise abiding by the procurement laws and regulations. As such, the evaluation has several constraints and requirements in the public education sector procurement. For instance, to evaluate a public education sector bid, there is a need for a minimum set number of BEC members during the evaluation analysis. According to a BEC member, "three people need to evaluate" (ML2) the bids. More constraints and requirements in evaluation analysis are discussed in the following sub-sections.

5.5.1.1 Required minimum members

There is a requirement to have a minimum number of members to evaluate bids. This was explained by a member of BEC as follows.

> "Three people need to evaluate." ML2

The bid evaluation requires a minimum of three members on the bid evaluation committee. These BEC members are experienced senior staff from the public sector.

5.5.1.2 Basis for evaluation

The basis for evaluation solely depends on the information provided in the pre-bid meeting.

> "[evaluation is] based on provided information during the information session. Based on the provided information, sometimes, even a higher cost bid can win." IL3

The information session provides the specification for the procurement and evaluation criteria for selection. The criteria provided in the pre-bid meeting to the potential bidders are always the basis for evaluation of the particular procurement.

> "A set of criteria is given while providing information [on specification] saying that those criteria are the ones to be used for marking. It is given to them [attendees of pre-bid meeting]. Evaluation is based on it [given set of criteria]." DL1

Therefore, the evaluation analysis requires confirmation that it is done according to the evaluation criteria provided to the bidders during the pre-bid information session.

5.5.1.3 Verification of suppliers' proposal

There is a thorough process of verifying of suppliers' proposal. Sometimes the bidders are contacted to ask for additional verification. For instance, "when lowest cost bidders are to be awarded, the board [BEC] will check whether they can do the job" (ML2) and "sometimes calls are made to bidders to verify whether they can do [the job], while the board [BEC] is in sitting" (ML3).

Important information related to the evaluation criteria is checked against suppliers' performances. Internal estimation of the cost, duration and other relevant criteria for the particular procurement are undertaken in order to compare the same in proposed bid. A focus group member stated the following.

> "Sometimes, when we announce for bids to paint the outer walls of this big school, we get bids priced for MVR5000. Painting all around the fence of the school [repeated with sarcastic expression to show that it is impossible to do the job for the said cost]. So we check for the market price of the paint and other items required. When we work it out MVR5000 is not enough for a single wall. So the committee analyses these issues to verify whether the

> work could be done [by the bidder]. We assess similar work done by the bidders in other places to check for their quality of work." DL2

BEC considers that there could be unrealistic proposals to win the bid. As such the bids are analysed for the possibility of fulfilling the requirements based on the proposed figures. A set of examples illustrated by BEC members are stated bellow:

> "Some bidders put a shorter duration, unrealistic [duration], to win the bid. [Bidders are] trying to win [the bid] by allocating shorter duration to finish the work. We analyse whether it is possible to finish the work for the said period of time. All committee members analyse and then decide on it." DL2

> "The price of shifting a container [full of goods] may be stated as MRV9000, but based on the committee analysis we don't find it possible. If the price is too low we ask before [awarding]." ML2

However, when it comes to beneficial attributes of suppliers, evaluation is based on the submitted documents by the bidders for the particular procurement. For instance, some of the suppliers are well known and BECs have some knowledge of the suppliers' experiences. However, the experiences of the suppliers are based on the documents submitted by the supplier for the bid, as mentioned below by a BEC member.

> "Then we look for experience, right? In everyday life, we also know some of them. But experience of the bidder is based on submitted documented evidences" IL3

5.5.1.4 Evaluation of suppliers' previous jobs

Bidders' previous jobs done for the institution and others are evaluated during the evaluation process. Similar jobs to the proposed procurement executed by the

bidders are checked for quality, delivery and any other issues with relate to the job. With regard to the same, a member of BEC stated as follows:

> "We assess similar work done by the bidders in other places to check for their quality of work." DL2

The past performance of the suppliers on similar jobs affects the marks that they gain. If the bidders have a good performance record from other customers based on the evaluation, the bidders would get better marks. Otherwise, the marks would be reduced relatively. Two members of a focus group jointly explain the issue as follows:

> "Previous jobs are considered in evaluation" DL2. "Based on previous work, there may be reduced points [for the bidder]. Such concerns are considered by us" DL3

In addition to this, every job carried out by the supplier to the specific public sector institution, whether similar or unrelated, is considered in evaluation. The BEC takes note of the suppliers who have misled the institution in previous cases.

> "We take note of suppliers who misled us too. [...] we look into the bidders' previous level of performances for us, if they have ever done any job for us. If it is bad, it will be considered." DL3

Past experiences of suppliers to the particular institution also affect the marks the supplier gets. In particular, suppliers with a bad history with the institution get lower marks.

5.5.1.5 Evaluation of support documents

BEC evaluates the support documents submitted by bidders. The support document is the primary source of information to evaluate the bidders for a particular procurement. Fundamental documents, such as profiles of the companies, audit

reports, the documents showing the resources of the bidders are studied for evaluation. For instance, a member of BEC stated:

> "In first attempt we check company profiles, audit reports and their tools and so on." DL2

Studying the basic documents helps the bid evaluators to understand the bidders better and gain knowledge of the credibility and capability of the bidders in general. The information that is required to submit for any bid must be provided by the bidders. The completeness of the bid is verified for evaluation according to the information provided in the pre-bid meeting.

> "Bids will be checked for the presence of all required documents. If the documents are not complete [in a bid], the bid will be disqualified" DL1 & DL2

These documents are very important for evaluation, since the allocation of marks is based on the documents provided after verification. For instance, a member of BEC mentioned that even if they know the bidder's capability personally, they would still require the proof of documents, in order to allocate marks to the bidder. A BEC member stated:

> "… In everyday life, we also know some of them. But [evaluation of the] experience of the bidder is based on submitted documented evidences." IL3

5.5.1.6 Importance of acceptable price

In bid evaluation BEC gives importance to acceptable price. "Generally [bids] are awarded to the lowest bidder" (ML2). This is because, most of the time, a higher priority is given to the cost criteria and it is allocated more weight. The provision of priority to price was stated in a focus group as follows:

> "Yes, not to the cheapest bid. But price takes bigger chunk [of points]. When points are allocated, price is given a higher priority." IL3 &IL4

Even if the price is given a higher priority in most of the cases, BEC compares the bid price to the procurement announced, to see if it could be done with the proposed cost. The comparison of the price to the real job was stated in a focus group as follows:

> "We verify the price of the job, and check whether the job could be done with the stated cost [by the bidder] or not." ML2

Based on the comparative analysis of the bid price to the BEC's estimate, if the bid price looks unrealistic the bid is not awarded to the bidder. However, a higher cost bidder may win the bid, as it is competitive bidding. The competitive bidding approach where lowest bid does not win was explained by a focus group as follows:

> "There are cases we don't award to the lowest price but to the most competitive bidder. It is done when we see the price of the lowest cost bid is too low to complete the job." ML2

Therefore, the lowest price bid is not necessarily the winning bid, as the BEC checks for the acceptable price during the evolution. It could be the case that the product or service proposed by the lower priced bid may not be the best expected product or service the institution is looking for. In that case, evaluators look for a suitable product or services rather than the lower price as sated bellow.

> "The lowest cost bidder is not taken [for granted]. Most important is to look for acceptable price. For instance, a cheaper bid may have an item that may not well fit the purpose. In such cases we cannot consider it". DL1

For all such cases, BEC members who take part in the evolution of the particular bid analyse it and a collective decision is taken on the matter. For instance, an illustration of such a case was stated by a member of BEC as follows:

> "Some bidders put a shorter duration, unrealistic [duration], to win the bid. [Bidders are] trying to win [the bid] by allocating shorter duration to finish the work. We analyse whether it is possible to finish the work for the said period of time. All committee members analyse and then decide on it. It is the same for price too." DL2

5.5.1.7 Evaluation of suppliers' performance

Evaluation of suppliers' performance is one of the most important requirements in the bid evaluation process. Issues in multiple angles are considered in the evolution. Performance of suppliers for every evaluation criterion provided initially for the procurement is assessed to allocating points to the suppliers' bid.

> "Based on delivery, experience and financial capacity, the higher cost bid may gain more points. But lower cost bidder will get higher marks for the cost criteria." ML3

"Mainly, price, duration and experience are evaluated" (IL4) as they are the generic criteria for most public sector procurements. But if there are other criteria, then they will be evaluated as well according to a BEC member, as stated below.

> "… But price is not only the criteria, there are several other criteria. All those criteria are considered and the bid which gets the maximum marks is offered [the job]." DL1

However, most importance is given to the price criteria. For different procurements, for instance repair jobs, the criteria are different and the public sector institutions do considerable background checks for performance evaluation, as a member of BEC mentioned.

> "Most consideration is given to price. Cheap, look for the cheapest. But for repair jobs, several things are considered: the machinery used, the number of workers, and some information is collected by contacting other parties, like the bidder's previous performance, and whether the bidder has misled others,

> etc. Such hidden agendas are there too. Bidders don't expect that we would gather that information. But we do. We check for bidders who cheat. We had a loss in the year before previous year (2 years back) when the bidders left without fixing the doors. Still the doors are not fixed. Chairs are not supplied. So these [issues] are considered priorities for the second attempt [bid evaluation]." DL3

In addition to background check on suppliers, the viability of the bid proposal is also assessed, as mentioned before. For instance, a member of BEC stated:

> "Sometimes, when we announce for bids to paint the outer walls of this big school, we get bids priced for MVR5000. Painting all around the fence of the school [repeated with sarcastic expression to show that it is impossible to do the job for the said cost]. So we check for the market price of the paint and other items required. When we work it out MVR5000 is not enough for a single wall. So the committee analyses these issues to verify whether the work could be done [by the bidder]. We assess similar work done by the bidders in other places to check for their quality of work." DL2

Similar to price, experience of the supplier is also considered during performance evaluation. The quality of work is also evaluated, based on the experience of the supplier, as stated by a member of BEC, as follows:

> "As such [we] give higher importance to bidders' experience. Need to think about quality of work. Based on experience, it is evaluated." DL1

BEC also evaluates suppliers experience in handling similar jobs to the procurement. To explain the scenario, a BEC member provided the following illustration:

> "For instance, we wanted plastic chairs. We may have a bidder who has no experience in working with [supplying] plastic chairs. So they will get zero [marks on experience]. Even if their cost is the lowest, another bidder may win by gaining points [from other than cost]." ML2

As mentioned above by the BEC member, a supplier who has no experience in the expected procurement field would get no marks for their experience for that particular procurement.

5.5.1.8 Marks allocation

Marks allocation is critical to the evaluation process too. The marks are allocated based on the criteria and weights provided during the pre-bid meeting in relation to the performances of suppliers for the particular bid. The aggregated marks for all the criteria give the final value for every bid. The bid with the highest aggregated marks wins the procurement. This was confirmed by a member of focus group as follows.

> "First it is announced and when information is provided, it will state the point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points." IL3

For the input criteria, such as cost, where the target is to reduce the performance value of the supplier, the highest marks are allocated to the bid with lowest value on the specific input criteria. The highest mark is the pre-set maximum weight for the specific criteria for the particular procurement. The following statements by a focus group member provide an illustration of marks allocation:

> "It is the same case for duration too. For instance, we have bids with duration of delivery within 20 days, 15 days and 10 days. So the shortest period will get the highest marks. Bids are awarded based on the total calculated by addition of all such marks." DL2

Another illustration of the marks allocation was provided during the focus group interview by a BEC member pointing to a previously evaluated marks sheet, as follows:

> "For instance, this bidder states 5 days to deliver, the other 7 days. The shortest period will get the best marks." ML2

For the output criteria, such as warrantee period, where the target is to maximise the suppliers' performance value, the highest marks are allocated to the bid with the highest performance value of the output criteria. Similar to the input criteria, the maximum marks will be the pre-allocated weight for the output criteria for the particular procurement.

For quantitative input criteria, such as cost, or duration of delivery, the suppliers will get some marks in proportion to their performance values on the criteria. The highest mark for every quantitative criterion will be for the highest performing supplier for that criterion. The worst performing supplier for the criterion will not get zero but a mark in relation to their performance. This proportional allocation of marks was explained by a member of BEC as follows:

> "For instance, if the total marks for price is 35, the lowest cost bid will get 35 marks for the price. Others will get lesser marks based on the proportion. No bid gets zero, because it is proportional to submitted price. For instance, the highest cost bid may get 7." DL2

Another focus group illustrated the same proportionality, as follows.

> "Submitted price and other criteria are evaluated to allocated points. If MVR1000 and MVR500 are there, then the one with MVR500 will be in the first position. Based on the calculations, there will be marks for it [highest cost]. However, highest marks will be for the one with MVR500." IL3

However, the application of proportionality to the worst case is different for quantitative output criteria compared to quantitative input criteria. For quantitative output criteria, such as the warrantee period, suppliers' experience, the bidders will get no marks if the performance values on the criteria are nil. This situation was explained by a BEC member as follows:

> “For instance, we wanted plastic chairs. We may have a bidder who has no experience in working with [supplying] plastic chairs. So they will get zero [marks on experience].” ML2

5.5.1.9 Use of technical expertise

BEC use technical expertise during the evaluation of procurements that need technical guidance. BEC members may not have knowledge in every technical field where procurement is required. As such, for the bid evaluation for technical products or services, relevant technical people are brought in to advise, during the evaluation process. The use of technical advice was illustrated by a member of BEC as follows:

> “For instance, when buying computers, there will be an IT person in the bid committee. [Bids are] evaluated based on the IT person's advice” ML2

For instance, the IT person would provide the technical information for the specification provided by bidders. The advice could be informative, like the effects on changes in certain elements of the specifications from different suppliers.

5.5.1.10 Check for standard specification

It is important to purchase the item intended be bought. Therefore, during the bid evaluation process, all bids are checked against the given specification for the procurement. If the specification mentions even a component standard, that will still be checked. A member of BEC explained this as follows:

> "Some products have specific standards. If it is up to standard, marks are allocated. [...] At first we check if it fits to our provided criteria (specification). For instance, there may be an item requested with standard 992 [...] if the item fits the standard, it is fine for us.” ML2

Irrespective of other criteria, such as cost, every specification provided, such as expected quality, should be met with a proposed bid in order to select the bid. If a supplier's proposal does not meet the specification, then it cannot be considered the item requested. The importance of the specification was illustrated by a member of BEC as follows:

> "If we bring something, check for quality, we check for alignment with our spec [...]. For instance, a supplier whose delivery is fastest may not meet our spec. But the highest cost bid may exactly meet our spec. In such cases, we go for the one which meets the spec." ML1

Another member of the same focus group added another illustrated example, as follows:

> "To illustrate, if we get a short-sleeved shirt when we announced [the requirement] for a long-sleeved shirt, will not be fine. We have specific requirements." ML2

In the case of quantity, when the bidders offer quantity discounts for bulk buying, still the BEC cannot consider the quantity discounts by purchasing more than the specified amount, even if it is highly advantageous, because of the need to align with the requirement specifications announced initially. Bids are "evaluated as the prescribed requirements given in the information session" (IL4). A member of BEC explained it as follows:

> "An announcement should be followed, right? For instance announcement is for 100 chairs. So we have to follow that requirement given. Otherwise, it is a change. It never happens." DL1

Another focus group mentioned the similar situation where they cannot change the quantity announced for procurement as follows:

> "In that case, if we announce and buy 100 chairs, then we can buy only 100 chairs, even if we get cheaper by buying 150. If we want, we need to

announce again for 150 chairs. We cannot change [pre-announced quantity]" IL3

5.5.1.11 Evaluate every criterion independently

BEC evaluates every criterion independently. One criterion should not influence the other criterion's evaluation. The independence of criteria in evaluation was discussed in a focus group as follows:

> "Every criterion is evaluated on its own. No influence to one criterion from other criteria [are allowed] to allocate marks." ML1
> "Each and every criterion is evaluated independently in isolation [from other criteria]." ML2

For instance, it could be generally expected that higher quality comes with a higher price "but marks for quality will not be influenced by the price" (IL2) of a bid. Further confirmation of the independence of criteria in evaluation was provided by another member of the BEC thus:

> "Each criterion gets its own points. Nothing else, no other criteria is influenced by it" IL3

The "evaluation is based on the submitted information for the specific bid" (DL2). No case-based reasoning is used or acceptable. A member of BEC stated this point thus:

> "No marks differentiation can be done based on previous bids [no case based reasoning]. Information is provided with that understanding. We have to evaluate all the criteria and cannot put aside some of it. But if there are inappropriate issues and if there are warnings issued to the bidder, it may be considered, otherwise the announcement is followed." IL3

No marks are allocated to a particular supplier based on previous cases of experience by the public sector institution. However, the previous experiences are used to set criteria and its weights as described above with regard to allocation of criteria and weights.

5.5.1.12 Evaluate all criteria

It is compulsory for BEC to evaluate all the criteria provided for the particular procurement. A member of BEC stated the same at different times of the focus group interview, as follows:

> "All the criteria are evaluated." ML2
> "The committee checks all the areas." ML2
> "Each and every criterion is evaluated." ML2

Similar expressions were made in other focus groups. Some of the statements from other BEC members are as follows:

> "Everything needs to be evaluated." DL2
> "Every criterion of everything (bids) needs to be evaluated." DL1 & DL2

The only case where any criteria are not evaluated is when the bid is not submitted according to the information provided. But an incomplete bid gets rejected, according to a BEC member:

> "If a bid is not submitted with requested information, then it will be disqualified. Otherwise everything will be evaluated." IL3

There are cases where BEC feels that it is worthless to evaluate the bid due to poor supplier performance values in the proposal for the evaluation criteria. It is because in any case the bidder would not win. However, such bids also need to be evaluated by the BEC. This compulsory evaluation of all the criteria, even when

supplier performances are below expectation, is explained by a member of BEC as follows:

> "We have to evaluate every criterion for every bid. Even if the supplier submits unreasonable value, the bid should be evaluated." ML2

5.5.1.13 No ranking

Ranking methods are not practiced in public sector procurement. Rather than ranking, a relative proportional value for the supplier's performance against the criteria is given in bid evaluation. Some of the BEC members commented on this:

> "The committee checks all the areas. [We] cannot do ranking [in evaluation of criteria]." ML2

> "We cannot even do ranking [within a criteria]." IL4

> "Based on suppliers' submitted values for a criterion, we cannot position it by giving first, second and third." DL2. "Yes [in agreement]" DL1

However, ranking can be used when only one evaluation criterion is used for the procurement because, even after allocating relative marks for a single criterion, the selection results will be the same as a ranking. The use of ranking could even be the case previously, when one criterion is used according to a BEC member:

> "Ranking may have used earlier when only cost criterion is used but not anymore. Even now, price is a criteria but ranking is not used." IL3

In addition to the rejection of ranking criteria, outranking is also not acceptable in public sector procurement. Three BEC members from distinct focus groups mentioned the following disagreements regarding outranking in the evaluation of procurement.

"No outranking also used. If they meet all the criteria, we cannot do outranking. We follow our procedures of marking." IL3

"No outranking. Evaluation is done proportionate to all the criteria." DL1

"[Outranking] cannot be used. Everything needs to be evaluated." DL2

As seen above the BECs felt that one of the major principles of public sector procurement, proportionality, is not fully guaranteed in outranking.

5.5.1.14 No pair-wise comparison

Comparing the performance of a criterion of one supplier to the same criterion of another supplier in relation to marks allocation is also not considered in public sector procurement by BECs. When asked if pair-wise comparison could be used in bid evaluation, a member of BEC rejected the pair-wise comparison by stating the following.

"No, we cannot do pair wise comparison." IL3

Pair-wise comparison can be time-consuming, especially for qualitative criteria, when BEC need to compare each and every pair of criteria. Based on the number of bids under evaluation, timescale may vary to evaluate the bids.

5.5.1.15 No changes to criteria and requirements

BECs cannot change the pre-announced evaluation criteria and their weights during evaluation. Once the criteria and weights are publicly announced, this is fixed, and no more changes can be made to the criteria and weights.

During a discussion about getting advantages from bulk buying, all the members of a focus group together denied to have bulk buy advantages, even if the option is available by saying "no bulk buy advantage [could be taken]" (ML1, ML2

& ML3). Further explanation was provided by a member of the same BEC, as follows:

> "We cannot change quantity by saying it will be cheaper. For instance, we want 3000 chairs for 3 schools. The approval will be for those 3 schools. Based on future needs, if we have storage, in the long run it is an advantage. But when a bulk of money goes out, the government will look to spread the expenses because, finances are set and checked in advance for monthly basis." ML2

As stated by the BEC member above, public sector institutions spend on pre-approved budgets and any change would require re-approval, which would again take considerable amounts of time.

Apparently, all BECs believe that changing criteria and requirements during evaluation process would be violating procurement related regulations. Therefore, even if the public sector institution benefits by changing the requirements during evaluation, the change cannot be practiced. A focus group has explained the issue of the change as follows:

> "So far that never happens [changes in requirements]. But, for instance, we check what would happen if we were to buy 100 items of the same. When bidding is done, even if we need to bear a loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation which should not be violated. If we take advantage of such discounts, it violates the regulations." DL3. "Cannot do that" DL1, DL2 & DL3

Changing the number of items to be purchased during the evaluation process would be considered as 'corruption' according to the BEC members. BEC members stressed it as follows:

> "Such increases [in number of items to be purchased] would be a corruption." DL2
> "It is corruption. That is how it is considered." DL1

In an ultimate situation, if the public sector institution needs to change the criteria or requirements, the whole procurement needs to be cancelled and re-announced with the correction. In this case, a new complete procurement procedure will be followed. The cancellation of the particular bid also needs to be publicly announced. A member of BEC mentioned the re-announcement as follows:

> "In that case, if we announce and buy 100 chairs, then we can buy only 100 chairs, even if we get cheaper by buying 150. If we want, we need to announce again for 150 chairs. We cannot change [pre-announced quantity]." IL3

5.5.1.16 Disqualifying bids

Bids are disqualified due to number of reasons, even after bids are submitted and accepted. One of the major reasons is incomplete bids, and missing required documents. For instance, two members of a BEC stated:

> "Bids will be checked for the presence of all required documents. If the documents are not complete [in a bid], the bid will be disqualified." DL1 & DL2

In addition, a member of a different BEC mentioned the same issue of incomplete bids rejection as follows:

> "If a bid is not submitted with requested information, then it will be disqualified." IL3

Furthermore, an illustration of rejection due to missing documents was provided by a member of another BEC in a different scenario, as follows:

> "If bids are not qualified, it can be disregarded. For instance, when teachers are recruited there is required information such as police report." ML2

Another situation where bids are rejected is when the bidder fails to attend the pre-bid information session. Attendance at the pre-bid meeting is necessary for some procurement. For those procurements which require bidders' attendance for the information session, and if a bidder has no record of attendance to the pre-bid meeting when the information session were held, the bidder's bid will be cancelled. The cancellation of bids due to failure of attendance at the pre-bid meeting was stated by BEC members as follows:

> "The jobs will not be awarded to those who did not attend the information session, even though they submit the bids on time. They will be disqualified. The bid announcement will state the same [that they will be disqualified]." DL1

> "A bid is not awarded to bidders who did not attend the pre-bid information session." DL3

BECs keep records of attendance of pre-bid meetings in order to verify the bids with attendance. A member of BEC stated it as follows:

> "Therefore, we have list of attendees to the pre-bid information session. We accept bids from them." DL2

Attendance at the pre-bid information session is important for some bids due the nature of the work and the past experiences of such work by public sector institutions. It was noted that, in some cases, after winning the bid, the supplier seemed to have inadequate information on procurement requirements. To avoid such situations, the pre-bid meeting attendance is made compulsory for some procurements. The situation was illustrated by a focus group as follows:

> "Without attending the information session, when someone takes the information sheet to a bidder, based on that, those who did not attend information session submit bids. After winning the bid, they may say that we were not clear about it …" DL2. "That is why we disqualify bids when [the bidder] has not attended the information session." DL3

In addition to the reasons for disqualifying bids discussed above, there is an extra ordinary case, when the bidder gets suspended from further bidding to the particular public sector institution for certain period of time. Any bids made under these conditions are rejected. Suspension occurs when a bidder rejects a bid after winning and signing a contract. A member of BEC explained the suspension as follows:

> "[… suppliers] can withdraw their bid after bidding. However, after agreement, if they reject, the bid committee may suspend them for 6 months." ML2

5.5.1.17 Showing calculations to bidders

Sometimes, after bid evaluation, calculations of the evaluation are shown to the bidders. Showing calculations helps to prevent misconceptions by bidders with regard to the bid evaluation. Usually, if a bidder is not happy about the bid evaluation the evaluation calculations are shown to the unhappy bidder, as explained by a BEC member as follows.

> "If someone is not happy, and wants to see [marks allocation], it can be shown to them." DL2

A similar explanation, as stated below, was provided, together with other BEC members, about showing calculations if the bidder wants to verify it.

> "If they [bidders] want to see, we show them the final written decision" DL2. "It is not provided to all bidders, but to bidders who want to see." DL1 & DL2

Showing the evaluated calculations to unhappy bidders satisfies their doubts about the evaluation. The calculation sheet would show where they get less marks and where other bidders have gained marks. This helps to minimise issues with regard to the evaluation process as mentioned by a BEC member below.

> "If they want to know why they did not win, we show them marks sheet. Then they know where their problem is." ML2

In some of such cases, it is not even necessary to show the evaluated calculation. When explained to the bidders, they would understand what their problems are. A BEC member explained this as follows:

> "To illustrate, if we get a short-sleeved shirt when we announced [the requirement] for a long-sleeved shirt, will not be fine. We have specific requirements [...]. [When they do not win] they may complain. In such cases we do not show the evaluation sheet but explain what has happened." ML2

However, it is very rare for bidders to come and ask for bid evaluation calculations. If ever any bidder requests it, we show the calculations to the bidder. The BEC member stated that it is a rare case to request for bid evaluation calculations, as follows:

> "If bidders want [calculations done for evaluation], [we] have to show them. We show them this sheet [evaluated sheet]. Hardly any bidder comes [to check the evaluation sheet]." ML2

BEC assumes that, when the bidders know the price and duration of the bids submitted as it is provided during the bid submission, they would probably know how the results will be, because bid evaluation calculations are always carried out in the same way.

> "All of them will see the prices and other information submitted [...]. But if anyone complains we will provide that information. They would know how calculations are done. Everybody does this calculation in the same way." IL3

The prior knowledge of evaluation calculations and bidders core performance values, like price and duration could be the reason why hardly any bidder requests for final evaluated calculations of the bids.

5.5.2 Awarding the bid

After selecting the bid based on the evaluation analysis, the successful bidder will be awarded the procurement. This award to the selected bidder also has some constraints and requirements that have to be taken into consideration. Some of the relevant constraints and requirements which have emerged are discussed in the following sub-sections.

5.5.2.1 Requires approval

Every public sector procurement bid proposal needs to be evaluated by the required number of BEC members, as mentioned earlier. However, this evaluation analysis does not grant awarding the bid to the winner. The BEC needs to approve the winner who is identified through the evaluation analysis.

> "Even after evaluation it cannot be awarded. [It is] awarded when decided by the board, the procurement committee." ML2

5.5.2.2 Confirmation and reason for selection

There is a responsibility on BEC on the confirmation of bids. Public sector procurement needs BEC to select the winning bid and state the reason for selection in writing. This sheet of information, showing selection, with reasons, needs be signed by all members for of the BEC who attended the BEC session to approve the bid. This requirement for winner confirmation is explained by a BEC member as follows:

> "[...] at the end of evaluation sheet there will be a written section saying that, based on the evaluation on all the aspects, the best bidder is this (name the bidder). Then all the attendees to the BEC sitting will sign on it." ML2

5.5.2.3 Informing bidders

One of the very important parts of public sector procurement is the announcement of the winner of the bid. When winning bidder is confirmed, the winner is informed about the selection. For instance, a member of BEC stated:

> "When bid committee finish [evaluation and confirmation], we inform the winning bidder that the bidder has won." ML2

In addition to informing the successful winner, unsuccessful bidders are also informed about the selection. In order to inform unsuccessful bidders, without writing separate letters, the awarding letter to the winner is copied to all bidders in the particular procurement, so that every bidder knows who has won. A member of BEC explained:

> "A letter of award is sent to the successful bidder. Instead of sending individual letter to unsuccessful bidders, the [awarding] letter is copied to them." ML2

5.5.3 Bidders' complaints

It is common that bidders complain about the outcome of the bid evaluation. Some bidders complain to the public sector institution that did the bid evaluation. These complaints are dealt within that institution. However, if the complaining bidder is not happy with the outcome of the complaint, the bidder can take the complaint to rightful other authorities. Bidders can and do complain directly to other authorities which handle such complains. Most of the time, the bidders' complaints are received and investigated by the Anti-Corruption Commission (ACC) or by the Courts. Some of the constraints and requirements with regard to the bidders' complaints are discussed in the following sub-sections.

5.5.3.1 Clarification to bidders

Clarification to the bidders regarding the procurement process can be provided if a bidder requests it. Even if the bidders request the procurement evaluation marks sheet, it will be shown to them. For instance, a member of BEC stated:

> "If bidders want [calculations done for evaluation], [we] have to show them. We show them this sheet [evaluated sheet]." ML2

If ever a bidder is unhappy about the procurement process and the outcome of the process, the bidder can request further clarification of the process and the clarifications are provided. A member of BEC mentioned the issue thus:

> "If someone is not happy, and wants to see [marks allocation], it can be shown to them." DL2

Providing clarification to the bidders helps to minimise acceleration of the complaints to higher authorities. This was indicated by a member of BEC as follows.

> "If they want to know why they did not win, we show them marks sheet. Then they know where their problem is." ML2

5.5.3.2 Complaints to authorities

If bidders are not happy about any of the procurement processes of public sector institutions, bidders can complain to relevant authorities. Most of the complaints are due to losing bids.

> "[...] They may think they are the lowest bidder and why they did not win. In that situation they complain." ML2

These complaints are usually submitted to ACC, as expressed by members of a BEC as follows:

> "[They] go to anti-corruption [ACC]" ML2 and ML3

When complaints are submitted to ACC, it will be investigated by ACC. Depending on the case, individual members of BEC or BEC as a whole are also called for further information by ACC during investigation. A member of BEC explained as follows:

> "[Bidders] complain to anti-corruption commission and they [ACC] investigate the case. We are also called for further inquiry." ML2

Complaints are even escaladed to court cases. The complaints can be related to any stage of procurement process. The complaining procedure is open and accessible to any bidder, by regulation. BEC feels that some of the complaints submitted by the bidders are submitted without properly understanding the situation. BEC also feels that it would have been better if ACC had accepted the complaints after analysing the information. However, according to *Anti-Corruption Commission Gaanoonu 2008* (literally, *Anti-Corruption Commission Act 2008*) ACC mandates acceptance of any complaint against the public sector even without proper evidence ("Anti-Corruption Commission Gaanoonu," 2008). Therefore, in current procedures, anyone can submit any public sector complaint to ACC. This issue was discussed by a group of BEC members, as follows:

> "We now even have a court case" (DL3). "It has happened recently too. But it is rare" (DL1). "They complain, not only about the bid evaluation stage, but sometimes after the bid submission too they complain to the Anti-Corruption Commission (ACC). The complaint procedure is accessible. Everything is open through regulations. Sometimes without proper analysis they complain. On the other hand, the authority [ACC], without collecting proper information, considers it to be a huge case. Anybody can complain about anything. Even if they assume there could be a problem, they go and complain." DL3

BEC also believes that there should be authorities to listen and investigate bidders' complaints. If any complaints are upheld, the procurement needs to be cancelled and re-announced for bids. A group of BECs explained:

> "Bidders complain. There should be an authority to listen and investigate their complaints too. If the authority says that there is a problem in the evaluation, we have to cancel it and announce again." (IL3). "Bidders can go to court too. They should be allowed to get their rights through all the avenues available." IL4

5.5.3.3 Misconceptions of bidders

There are misconceptions of bidders. For instance, a bidder may believe that the public sector bids are awarded to the lowest bid, as suggested by a member of BEC:

> "Some of the bidders think that they should win when the lowest price is submitted by them. This is their misconception." DL1

All the public sector bids are not specifically awarded to lowest bid, even though a higher priority is given to the price, in most cases. In addition, the duration of delivery is allocated some marks as they are the two compulsory criteria, by regulation. Most public sector procurement cases include more criteria for evaluation. Therefore, after evaluation, a bid may have total marks which succeed the lowest priced bid. This misconception was explained by a member of BEC as follows:

> "Such complaints are put forward for instance when their price is lower than the price of the winning bid. But price is not only the criteria, there are several other criteria. All those criteria are considered and the bid which gets the maximum marks is offered [the job]. Possibly, such complains are without proper consideration of the evaluation." DL1

5.5.4 Use of other MCDA methods

In terms of the MCDA method, BECs are currently using weighted sum method. No other methods have been tried in the evaluation of bids in the Maldivian Public Sector. BECs assume that the weighted sum provides accurate results for evaluating best bid. BEC members, not normally being statisticians, are not always aware that there are other more suitable methods for bid evaluation. Lack of knowledge of other MCDA methods keeps BECs focused only to the current evaluation method.

When discussed about the using other MCDA methods, a member of BEC stated that "[that method] would provide nearly the same result" (ML3) as their own approach. However, this was not the case. In the same discussion another BEC member stated a particular method could be used but would not provide accurate results as it would show only figures.

> "Can be done, but may not be so accurate. This will show figures only."
> ML2

In the focus group when explained and asked about the use of utility theory methods, there was total silence. Then interviewer commented just to break the silence by saying that "it will be based on the information sheet, right?". Then a member of the focus group said that "it will be based on the information provided" (IL4). But no further discussion took place on other methods.

5.5.5 Exceptions of evaluation method

BEC members have expectations and concerns about bid evaluation methods, mainly related to strengthening fundamental principles of public sector procurement.

More details of the wishes for the evaluation are discussed in the following sub-sections.

5.5.5.1 No discrimination in evaluation

According to BEC the evaluation method should not discriminate any bid or criteria within the bid in evaluation. All the criteria of every bid should be evaluated and deserved marks should be incorporated into evaluation. This was explained by BEC members as follows:

> "Every bid needs to be evaluated." DL2

> "For instance, two companies bid 4 days for duration and 4 days is the minimum duration. So both of the bidders will get 35 points, the maximum allocated points." ML3

BEC also believes that outranking could lose proportionality and proportionality should be maintained during the bid evolution. For instance, a member of BEC stated:

> "No outranking. Evaluation is done proportionate to all the criteria." DL1

Therefore, any evaluation method is expected to have no discrimination of bidders and criteria in evaluation.

5.5.5.2 Use of accurate method

Accuracy of the method is also important in public sector procurement evaluation. Chances of inaccuracy need to be avoided during bid evaluation. As such, any method used for evaluation should have no steps which could lead to inaccuracy. Indicating the need of accuracy, a member of BEC mentioned the statement about a method as follows:

"Can be done, but may not be so accurate. This will show figures only." ML2

Another member of a different BEC believed that any evaluation method should provide good results and stated it as follows:

"[a method which provides] good results is expected." DL1

Therefore, any evaluation method is expected to be accurate in bid evaluation.

5.5.5.3 Reasonable method of evaluation

Use of any bid evaluation method should be reasonable according to BEC, in terms of effort, results, time consumption, human resource needs, cost, and any other resources required.

Any evaluation method that requires unreasonable resources and produces unreasonable results is not in line with public sector interests. As such a BEC member stated:

"It should be reasonable." ML2

Therefore, any evaluation method is expected to be accurate in bid evaluation.

5.5.5.4 Compliancy of method with regulations

The BEC members in several incidences during the focus group discussions mentioned the need to comply with regulations, in the interest of bidders and

themselves. Some of the statements from the BEC members during the focus groups are as follows:

> "When bidding is done, even if we need to bear loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation, which should not be violated. If we take advantage of such discounts, it violates the regulations." DL3

> "Such [quantity discount] advantages are basically not taken because it contradicts laws and regulations. It violates public finance regulations." DL3

BEC members expressed the belief that any other method to be adopted would have to be in line with law and regulation and would have to be approved by the Ministry of Finance in the first instance and ultimately by the Parliament.

5.5.5.5 Minimise chance of manipulation

The bid evaluation should not provide any chance of manipulation by either side, suppliers or evaluators. Therefore, any method used for bid evaluation should minimise any chance of manipulation.

It is often easy for bidders to assume that the bid evaluation is manipulated by the evaluators. Therefore, the evaluation needs to be a transparent process where no change to initial requirements in terms of quantity, criteria, weights and any other form are accepted. As such the following statement was made by a member of BEC when discussing changes in quantity.

> "We cannot change quantity by saying it will be cheaper. For instance, we want 3000 chairs for 3 schools. The approval will be for those 3 schools." ML2

Manipulation can be regarded as corruption, according to members of a BEC, as stated bellow:

> "Such increases [in number of items to be purchased] would be a corruption" (DL2). "It is corruption. That is how it is considered." DL1

Manipulation violates public sector procurement regulations, according to BEC members:

> "So far that never happens [changes in requirements]. But, for instance, we check what would happen if we were to buy 100 items of the same. When bidding is done, even if we need to bear a loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation which should not be violated. If we take advantage of such discounts, it violates the regulations." DL3.

> "Cannot do that." DL1, DL2 & DL3

Since any manipulation violates public procurement law and regulations the BEC members say that they cannot do that.

Therefore, any evaluation method should minimise any chance of manipulation by evaluators and suppliers.

5.5.5.6 Minimise complaints

The public sector procurement process intends to minimise complaints from suppliers. Therefore, in turn, the bid evaluation should minimise complaints from bidders. Every possible measure is taken to minimise complaints from the bidders. As such, when bids are submitted, basic information of the bids are provided to all bidders. This information gives an indication of the winning bid, when bidders compare the proposals of the other bids. It also makes the process transparent and minimises complaints. For instance, a member of BEC stated:

> "On the day (when bids are submitted) qualified bids with their figures [cost and duration] are given to all the bidders. So they know who will probably win." ML3

In addition to providing information to bidders during bid submission, information could be provided after bid evaluation about the evaluation, to mitigate complaints from the bidder. For instance, a member of BEC stated:

> "If they want to know why they did not win, we show them marks sheet. Then they know where their problem is." ML2

Therefore, any bid evaluation method should minimise bidder complaints.

5.5.5.7 Support utility concept

Public sector procurement looks for the best possible bid. For instance, public procurement interest would be to look for lower cost, higher quality, faster delivery, and so on. This means it is optimising the outputs of the procurement with regard to the inputs to acquire the procurement. Therefore, the higher the utility gained the better for the public sector institution. This concept of utility is expected according to a BEC member as follows:

> "Should check both sides [inputs and outputs]." DL2

Therefore, any bid evaluation method is expected to support the utility concept in procurement.

5.5.5.8 Clear and good understanding of the method

Public sector procurement is a transparent process. Clear and good understanding of the bid evaluation method would make is easier to understand the evaluation process. A better understanding of the method of bid evaluation would even minimise complaints from the bidders.

Providing information of the evaluation method to the bidders is a good approach according to BEC. For instance, a member of BEC stated the following:

> "That is a good thing [to explain the method]. The bidders could be discussed and explained about how it is done and what should be done. So that both sides have a good understanding." DL2

Therefore, any bid evaluation method is expected to be clear and easy to understand.

5.6 Conclusion

This chapter has discussed the findings of the focus group interviews conducted in the Maldives with the public sector education institution BECs. The aim of the study was to find the constraints and requirements of public education sector procurement in relation to supplier selection.

The findings has identified several public sector constraints and requirements in public sector procurement, as presented in the Table 6.1, categorised into three major themes: the preparation process, the bidding process and the evaluation process.

From the findings the following criteria are identified, for the purpose of criteria-based evaluation as described in Research Methodology Section 2.4.3.3 and illustrated in Figure 2.2.

1. The maximum tender for the evaluation is MVR1,500,000.00.
2. The minimum tender for the evaluation is MVR25,000.00.
3. Different cost bands are evaluated differently.
4. A public announcement should be made for every procurement costing more than MVR25,000.00.
5. There are a minimum of two criteria for evaluation.

6. There can be more criteria for evaluation based on the procurement.
7. Allocation of criteria and weights are based on the needs of the organisation.
8. A pre-bid meeting is compulsory and needs to be announced.
9. Specification should be provided to potential bidders during the pre-bid meeting.
10. Marking criteria with weights are provided in the pre-bid meeting.
11. All required documents should be submitted with the bid and the requirements need to be articulated to bidders.
12. If any bidder requires, calculations procedures are explained.
13. All bids are submitted on specific dates and times. All the documents are checked and verified during the submission process.
14. It requires a minimum of three BEC members to evaluate bids.
15. The basis for evaluation solely depends on the information provided in the pre-bid meeting.
16. Suppliers' bids need to be verified for the correct information.
17. Suppliers' previous jobs are evaluated based on available information.
18. Submitted support documents are primary source of information and are assessed.
19. Assess the bid price compared to the expected work.
20. Suppliers' performances are evaluated based on the criteria provided, and the weights and marks are allocated according to the schemes provided in advance.
21. Marks are allocated based on the criteria and weights provided during pre-bid meeting in relation to performances of suppliers.
22. Technical expertise is used to get advice and explanations on procurement of technical good and services.
23. A thorough check is made if the proposed goods or services meet the specified standard.
24. Every criterion is assessed independently.
25. All the criteria need to be evaluated.
26. No ranking can be made in evaluation; rather marks are allocated in evaluation.
27. Pair-wise comparison cannot be done.

28. In the evaluation stage no changes to criteria, weights and requirements should be made.
29. Incomplete bids should be rejected.
30. Evaluation calculations are shown to bidders if requested.
31. BEC needs to approve the winner. Evaluation analysis does not award the bid to the winner.
32. BEC needs to state the reason for the selection of specific bids.
33. Bidders are informed of the winner but not the marks.
34. If any bidder wants more clarification, evaluation calculations are shown.
35. No discrimination in evaluation is allowed.
36. Evaluation method needs to be accurate.
37. Evaluation method should use reasonable amount of resources and provide reasonable results.
38. Evaluation method should comply with procurement rules and regulations.
39. Evaluation method should provide no chance of manipulation from either side.
40. Evaluation method needs to help minimise complaints.
41. Evaluation method needs to support the utility concept.
42. Evaluation method should be clear and easily understandable.

Together with these findings, the next chapter will evaluate previously identified MCDA methods against constraints and requirements of public sector procurement.

These findings also give guidance for an expected method for public sector bid evaluation in the research context. Using the guidance, MCDA methods which comply with public sector constraints and requirements of bid evaluation will be assessed based on their performances on applied procurement cases.

This chapter has given the basis for selecting a suitable MCDA method for public education sector procurement in the Maldivian context.

CHAPTER 6

MCDA METHODS AND DISCUSSION

6.1 Overview

As discussed in Chapter 4, public sector procurement decisions to choose suppliers are made based on the analysis of the multiple criteria of the procurement needs possessed by the supplier. This chapter offers literature review of MCDA methods and discussions of criteria-based evaluation, as explained in Research Methodology Section 2.4.3.1, Section 2.4.3.3 and Research Design Section 3.3.2.

In the chapter the characteristics of the MCDA methods are compared to the requirements of public sector procurement, gathered through the literature review discussed in Chapter 4 and field research findings, discussed in Chapter 5.

This chapter highlights the nature of MCDA and describes major MCDA methods and its characteristics. MCDA methods are grouped into logical categories and detail the MCDA methods that are in the context of the research. The discussions are based on the comparison of characteristics of methods with the public sector procurement requirements gathered through the literature review of the regulations of

the Maldivian public sector and findings of the field research. The chapter provides the results of the criteria-based evaluation (applicability of the MCDA methods to the research context).

6.2 Introduction to MCDA

Although MCDA and multi-criteria decision making (MCDM) are used interchangeably, “in a decision making context, MCDA would imply some sort of standard by which one particular choice or course of action could be judged to be more desirable than another. Consideration of different choices or courses of action becomes a MCDM” (Belton & Stewart, 2002). Multi-objective decision making (MODM) and multi-attribute decision making (MADM) also presents the same class of methods (Triantaphyllou, 2000).

MCDA is one of the most well-known branches of decision making (Triantaphyllou, 2000). MCDA is important in decision making when a wide number of factors are concerned for decision (Amponsah, 2011).

Even though MCDA has a wide variety of methods, they all have certain common features, which are the concept of alternatives and attributes (Triantaphyllou, 2000). In simple terms, the available choices and the evaluation criteria are fundamental to any MCDA method.

There are numerous MCDA methods used in different disciplines, including procurement. The next section will list the major MCDA methods discussed in the current MCDA literature.

6.3 MCDA methods

The MCDA methods listed in Table 6.1 are based on the work of Guitouni and Martel (1998) extended by some additional methods identified from the literature review. These methods are the reference methods for this study. The Table 6.1 also

shows the selection of the methods at research Phase II and Phase III as illustrated in research implementation model in Figure 2.2.

Guitouni and Martel (1998) believe that choosing an MCDA method in turn is choosing a compensation logic and there are no agreed definitions or principles to characterise the degree of compensation. According to the literature, MCDA methods have three groups, according to the degree of compensation (Luitzen de Boer, Labro, & Morlacchi, 2001; Guitouni & Martel, 1998; Luo et al., 2009), as follows:

1 "*Compensatory*: in this case, one admits that an absolute compensation between the different evaluations can exist. Hence, a good performance on one criterion can easily counterbalance a poor one on another. There exist many methods that can fall into this category like the weighted sum;
2 *Non-compensatory*: no compensation is accepted between the different dimensions. The DM [Decision Maker] may state that the dimensions are important enough to refuse any kind of compensation or trade-offs. The lexicographic method is considered as a non-compensatory method;
3 *Partially compensatory*: in this case, some kind of compensation is accepted between the different dimensions or criteria. Most of the MCDA methods fall within this category. The major problem is to evaluate the degree of compensation for each one." (Guitouni & Martel, 1998:506)

In literature MCDA methods are grouped in categories based on their characteristics. Table 6.1 lists major MCDA methods in five different categories found in the literature (Figueira, Greco, et al., 2005; Guitouni & Martel, 1998; Ho et al., 2010). The categories are:

- Elementary methods,
- Single synthesising criterion or utility theory,
- Outranking methods,
- Fuzzy methods,
- Mixed methods.

Table 6.1: MCDA methods based on Guitouni and Martel (1998:508-509)

No	Method	Author(s)	Results
	Elementary methods		
1	Weighted Sum	Churchman, C.W. and Ackoff, R.L. (1954) and many more	Rejected
2	Lexicographic method	Roy, B. and Hugonnard, J.C., (1982) and many more	Rejected
3	Conjunctive method	Hwang and Youn (1981)	Rejected
4	Disjunctive method	Chen and Hwang (1992)	Rejected
5	Maximin method	Hwang and Youn (1981)	Rejected
	Single synthesizing criterion or utility theory		
6	TOPSIS	Hwang and Youn (1981)	Selected
7	MAVT	Keeney and Raifa (1976)	Rejected
8	UTA	Jacquet-Lagreze and Siskos (1982)	Rejected
9	SMART	Edwards (1971)	Rejected
10	MAUT	Bunn (1984)	Rejected
11	AHP and ANP	Saaty (1980), Saaty (2005)	Rejected
12	DEA	Talluri et al. (1999)	Rejected
13	COPRAS	Zavadskas et al. (2007); Chatterjee et al. (2011)	Selected
	Outranking methods		
14	ELECTRE	De Boer et al. (1998); Dulmin and Mininno (2003)	All the methods in this group are rejected in phase II evaluation.
15	ELECTRE I	Roy (1968)	
16	ELECTRE IS	Roy and Bouyssou (1993)	
17	ELECTRE II	Roy and Bertier (1971)	
18	ELECTRE III	Roy (1978)	
19	ELECTRE IV	Roy and Hugonnard (1982)	
20	ELECTRE TRI	Yu (1992); Mousseau et al. (2000)	
21	PR OMETHEE	Dulmin and Mininno (2003)	
22	PROMETHEE TRI	Figueira et al. (2004)	
23	PROMETHEE/GAIA technique	Dulmin and Mininno (2003)	
24	NAIADE	Munda (1995)	
25	ELECCALC	Kiss et al. (1994)	
26	UTADIS	Doumpos et al. (2001)	
27	MELCHIOR	Leclerc (1984)	
28	ORESTE	Roubens (1980)	
29	REGIME	Hinloopen and Nijkamp (1982)	
30	PROMSORT	Araz and Ozkarahan (2007)	
31	EVAMIX	Voogd (1983)	
32	QUALIFLEX	Paelinck (1978)	
	Fuzzy methods		
33	Fuzzy relationship hierarchy	Lin and Chen (2004)	All the methods in this group are rejected in phase II evaluation.
34	Fuzzy set approach	Sarkar and Mohapatra (2006)	
35	Fuzzy suitability index (FSI)	Bevilacqua et al. (2006)	
36	Fuzzy weighted sum	Baas and Kwakernaak (1977)	
37	Fuzzy miximini	Bellman and Zadeh (1970)	
38	AI methods	Ng and Skitmore (1995); Vokurka et al. (1996); Kwong et al. (2002); Choy et al. (2002); Choy et al. (2003); Choy et al. (2005)	
39	CBR	Ng and Skitmore (1995); Choy et al. (2003)	
	Mixed methods		
40	Martel and Zaras method	Martel, J.M. and Zaras, K. (1990); Martel, J.M. and Zaras, K. (1995)	All the methods in this group are rejected.
41	Fuzzy conjunctive/ disjunctive method	Dubois, D., Prade, H. and Testemale, C. (1988)	

As the MCDA methods are grouped based on their characteristics, a single method may fall into more than one category if it has the characteristics of other

categories. However, based on the literature of the development and applicable context of the method, such methods are allocated to their originated category if not its applicable context category, as found in the literature, as the main focus of this research is to find a suitable method for the research context.

One such incidence occurred during this grouping with the EVAMIX method, which can be regarded as a single synthesis criterion (Guitouni & Martel, 1998) as it has very similar characteristic. However, it is one of the outranking methods in MCDA as it is originated from the basics of outranking methods (Martel & Matarazzo, 2005). In addition to the findings from the literature, the researcher followed, applied and analysed all the steps of the EVAMIX to understand the core principles of the method. Based on the analysis and also as illustrated by Chatterjee, Athawale, and Shankar (2011), it was clear that EVAMIX has a step of outranking, even though the concept of the single synthesis criterion is used. Therefore, for this research EVAMIX is categorised as an outranking method.

In the following sections, group level comparisons are done at first, and if the group meet the requirements, the individual methods of the group are discussed further for comparative analysis to identify its suitability. If the group does not meet the requirements the individual methods are not further considered for analysis, as discussed in Section 2.4.3.3.

6.3.1 Elementary methods

“Elementary methods are intended to reduce complex problems to a singular basis for selection of a preferred alternative” (Linkov et al., 2004: 19).

Elementary methods are simple and most of the times the analysis can be done without the help of computer software. These methods are more appropriate for single decision-maker problems with few alternatives and criteria (Linkov et al., 2004). Methods in this category, identified as elementary methods, are the weighted

sum method, the lexicographic method, the conjunctive method, the disjunctive method and the maximin method (Guitouni & Martel, 1998).

The weighted sum method uses linear weighting. Linear weighting lists the performance criteria, and the buyer assigns weights for each criteria based on importance. For every supplier the buyer assigns a score for each criterion which indicates the supplier's performance in that criterion. The scores can be based on quantitative data or qualitative values agreed by the buyer. (Monczka et al., 2010).

This category of methods is often used in supplier selection. However, all the methods in this category may not be applicable in public sector procurement, based on the structure of public sector procurement as discussed in Chapter 4. The individual methods in this are discussed in the following sub-sections.

6.3.1.1 Weighted sum

Weighted sum is the most common method for supplier evaluation (Mateus et al., 2010). It is a compensatory method (Guitouni & Martel, 1998).

This method calculates the ratio for each attribute for every supplier, by dividing the performance values of the attribute by the maximum value of the attribute, in case of input factors, subtracting these ratios from 1. Next, the allocated weight for each attribute is multiplied by the ratio calculated to get the weights for individual attributes. Finally, all the calculated weights for each individual attribute for every supplier is added, to get the total figure for the supplier (Falagario et al., 2012). This can be expressed mathematically as follows:

$$WS_a = \sum_{i=1}^{n} w_i \left(1 - \frac{x_{ia}}{x_{im}}\right) + \sum_{j=1}^{n} w_j \left(\frac{x_{ja}}{x_{jm}}\right) \qquad \text{(Equation: 6.3.1.1a)}$$

Where:

WS_a is weighted sum of an alternative a;

w is the weight of the criteria;

x is the performance value of the criteria;

i is the input criteria starting from i = 1 till n;

j is the output criteria starting from j = 1 till n;

x_{im} is the maximum performance value of i^{th} criteria for all alternatives;

x_{jm} is the maximum performance value of j^{th} criteria for all alternatives;

For example, an organisation announces for bids to purchase a multi-purpose printing machine with evaluation criteria; duration of delivery, price and experience of supplier along with their weights 10, 70, and 15 respectively. Three companies submitted bids and their bidding data as presented in Table 6.2.

Table 6.2: Weighted sum raw data

Bidder	Duration	Price	Experience
	10	75	15
A	21	67,667.00	13
B	30	66,067.00	14
C	28	33,161.00	12

Duration is counted in days, price in MVR, and experience in years. When weighted sum is applied, the criteria that are targeted to minimise (like price) will get highest score to the bidder with the lowest value. Similarly, for the criteria that are targeted to maximise (like experience) will get highest score to the bidder with the highest value. As such, Table 6.3 shows the results of applying weighted sum. The bidder with highest total score wins. Therefore, in this case bidder C wins.

Table 6.3: Weighted Sum results

Bidder	Duration	Price	Experience	Total
A	10	36.75462	13.92857	60.68319
B	7	37.64474	15	59.64474
C	7.5	75	12.85714	95.35714

There are other alternative equations used to calculate the weighted sum, such as the equation by Mateus, et al. (2010) ultimately doing similar calculation and giving the same result.

Due to the rationale that the weighting procedure follows, most people would at first glance, accept that the procedure is logical and commonsensical. However, it is the most common mistake in public procurement procedures (Mateus et al., 2010). Mateus et al. (2010) further explained that the definition of weights is completely arbitrary and inconsistent with the real preferences of the procurement authority.

Mateus et al. (2010) explain an issue with regard to compensation with an example of defining a 75% weight for one criterion (A) and 25% weight for the other criterion (B) where only two criteria existed. In this case, losing 10 partial points on criterion A (75% x -10 = -7.5 overall points) is equivalent to gaining 30 partial points on criterion B (25% x +30 = +7.5 overall points). Since the weights embody trade-offs, the assignment of weights will have to take into account the way those values were identified, that is, the performance levels set for each criterion (Mateus et al., 2010). Keeney (2002) also identified the same issue and further listed 12 common mistakes in making value trade-offs in Table 6.4, as follows:

Table 6.4: Twelve common mistakes in making value trade-offs

Mistake 1.	Not Understanding the Decision Context.
Mistake 2.	Not Having Measures for Consequences.
Mistake 3.	Using Inadequate Measures.
Mistake 4.	Not Knowing What the Measures Represent.
Mistake 5.	Making Trade-Offs Involving Means Objectives.
Mistake 6.	Using Willingness to Swap as a Value Trade-Off.
Mistake 7.	Trying to Calculate Correct Value Trade-Offs.
Mistake 8.	Assessing Value Trade-Offs Independent of the Range of Consequences.
Mistake 9.	Not Having Value Trade-Offs Depend on Where You Start.
Mistake 10.	Providing Conservative Value Trade-Offs.
Mistake 11.	Using Screening Criteria to Imply Value Judgments.
Mistake 12.	Failure to Use Consistency Checks in Assessing Value Trade-Offs

Source: Keeney (2002:937)

Boer et al. (2006) discussed five common mistakes using weighted sum in public sector procurement, namely (i) Same weights, undesirable outcome; (ii) Good procedure, wrong offer; (iii) The devil is in the detail; (iv) The runner up does not run up; and (v) With a little help from my friend. The examples shown by Boer et al. (2006) showed undesirable outcomes in all the 5 cases.

Therefore, despite being one of the most commonly used methods in procurement; weighted sum does not seem to be ideal for public sector procurement in the Maldives due to all the criticisms described above. This is especially so due to the vulnerability of the method to manipulation by both suppliers and buyers, as well as the very high risk of the tendered products or services approved not meeting public sector principles and standards behind regulations. Nonetheless, this is currently the method used in the Maldivian public sector. This represents, of course, a dissonant finding between theory and practice. It is expected that this study may contribute to a rectification discussion on current procurement practices.

6.3.1.2 Lexicographic method

The lexicographic approach uses a ranking of the objective functions based on its significance (Ehrgott & Wiecek, 2005), involving a sequential exclusion process to reach either a single alternative or all the problems being solved (Linkov et al., 2004).

In the lexicographic method attributes are ordered based on the importance of the attribute. The alternative with the best performance on the most important attribute is chosen. If there are more than one alternatives having best performance on the most important attribute, the performance of those alternatives on the next most important attribute are compared, and so on, until a unique alternative is found (Linkov et al., 2004).

Linkov et al. (2004) alerted that “multi-attribute decision-making problems with few alternatives, quantitative input data, and negligible uncertainty, the lexicographic method ends up becoming a selection method based on a single attribute.”

Based on the findings of the public sector procurement literature, the Maldivian regulation requires having minimum two criteria and contribution of all the criteria used are equally considered in evaluation. The same results were apparent with the finding of the focus groups with BECs. As lexicographic method gives priority of selection based on the most important attribute inline, the method contradicts public sector procurement of Maldivian context. Therefore, the lexicographic method is considered not applicable to evaluate suppliers in public sector procurement in the Maldives.

6.3.1.3 Conjunctive and disjunctive methods

The conjunctive and disjunctive methods are non-compensatory, screening methods. The attributes can be measured in commensurate units, requiring satisfactory rather than best performance in each criterion based on a predefined threshold.

The fundamental theory of the conjunctive method is that an alternative must meet a minimum cut off level for all attributes (Linkov et al., 2004). An alternative that fails to reach the least satisfactory levels for all criteria is rejected. The least satisfactory levels of each criterion are used to screen out unacceptable alternatives (Guitouni & Martel, 1998).

In the disjunctive method an alternative should exceed the minimum cut off level by at least one attribute (Linkov et al., 2004). An extreme score on any one criterion leads to an alternative selection. Alternatives are selected based on the performance of each attribute that is equal to or exceeds satisfactory levels on any attribute (Guitouni & Martel, 1998).

The disjunctive method requires performance criteria to be arranged in terms of importance. Alternatives that fail to meet the cut off level of most important criteria are eliminated. Remaining alternatives are then tested against the second most important criteria, and so on. The last alternative to be eliminated is preferred (Linkov et al., 2004).

Linkov et al. (2004) state that these screening rules are applicable to select a group of alternatives for analysis by other, more complex decision-making tools, or provide a basis for selection. Based on this fact, in public sector procurement, this method could be used to screen all the tenders to check if a satisfactory level of required information is submitted as requested in the tender announcement, to consider the tender to be accepted or rejected.

In public sector procurement a minute significance in any criteria should be counted, to be fair on each criteria informed in advance for selection as described in Section 4.4.2. Since these methods prioritise pre-set thresholds and do not regard every performance value of every attribute for selection, contradicting the requirements discussed in Section 4.4.2, Section 5.5.1.8, Section 5.5.1.11, and Section 5.5.1.12, it is rejected for public sector procurement decision analysis.

6.3.1.4 Maximin method

The maximin method is a non-compensatory method. This method tries to avoid the worst possible performance by maximizing the minimal performing criterion. It gives importance to the worst criteria of the alternatives. The alternatives are ranked based on their weakest performing criteria. The alternative, which has the highest score for its weakest attribute, is preferred (Linkov et al., 2004).

The overall performance of an alternative is selected on the basis of its poorest evaluation (Guitouni & Martel, 1998). The maximin method is applicable only when all attributes are comparable so that they can be measured on a common scale, which may present a serious limitation (Linkov et al., 2004).

As described in Section 4.4.3, public sector procurement regulations based on this research context require two compulsory attributes and several optional attributes for evaluation. The maximin method requires the highest performance of the weakest attribute and it may not be possible to have compulsory attributes as weakest attributes in every tender. It is also highly unlikely that only the two compulsory attributes are the weakest, having the same score for every alternative. In addition, all public sector procurement attributes are not comparable on a common scale. These inherent characteristics of the maximin method violate the requirements discussed in Section 4.4.3, Section 5.5.1.8, Section 5.5.1.11, Section 5.5.1.12, and Section 5.5.5.4. Therefore, the maximin method is rejected for public sector procurement for this research context.

6.3.2 Single synthesizing criterion, or utility theory

This is the most conventional approach (Roy, 2005). The assumption of these methods is that there exists a utility (or a value) function U to represent the decision maker's (DM) preferences. Based on this assumption, such a function is assessed and therefore the ranking of the choices is straightforward. The assessment of this function can be achieved in an additive, multiplicative, distributional mode, and many other methodologies were developed with the premise that there exists a partial utility functions u_j according to each attribute j (Guitouni & Martel, 1998).

This category of methods is also used in supplier selection. The individual methods in this category of methods are discussed in the following sections.

6.3.2.1 TOPSIS

TOPSIS (technique for order preference by similarity to an ideal solution) is an MCDA method to rank alternatives from a finite set of alternatives. The basic principle is to minimize the distance to the ideal solution while maximizing the distance to the negative-ideal solution for the chosen alternative (Jahanshahloo,

Lotfi, & Davoodi, 2009; Olson, 2004). Jahanshahloo et al. (2009:1138) provided the procedure of TOPSIS in a series of steps as follows:

"Step 1: Calculate the normalized decision matrix. The normalized value n_{ij} is calculated as $n_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2}$ for i=1,⋯,m and j=1,⋯,n.

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as $v_{ij} = w_i n_{ij}$ for $i = 1,\cdots,m$ and $j = 1,\cdots,n$ where w_i is the weight of the ith attribute or criterion, and $\sum_{i=1}^{n} w_i = 1$. These weights can be introduced by a decision maker.

Step 3: Determine the positive-ideal and negative-ideal solution

$$A^+ = \{(v_1^+, v_2^+, \dots, v_n^+)\} = \left\{\left(\max v_{ij} \mid i \in O\right), \left(\min v_{ij} \mid i \in I\right)\right\}$$

$$A^- = \{(v_1^-, v_2^-, \dots, v_n^-)\} = \left\{\left(\min v_{ij} \mid i \in O\right), \left(\max v_{ij} \mid i \in I\right)\right\}$$

where O is associated with benefit criteria, and I is associated with cost criteria.

Step 4: Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as $d_j^+ = \left[\sum_{i=1}^{n}\left(v_{ij} - v_i^+\right)\right]^{1/2} \forall j$.

Similarly, the separation from the negative-ideal solution is given as $d_j^- = \left[\sum_{i=1}^{n}\left(v_{ij} - v_i^-\right)\right]^{1/2} \forall j$.

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_j with respect to A^+ is defined as $R_j = \frac{d_j^-}{d_j^- + d_j^+}$ for $j = 1,\cdots,m$. Since $d_j^- \geq 0$ and $d_j^+ \geq 0$, then clearly $R_j \in [0,1]$.

Step 6: Rank the preference order. For ranking alternatives using this index, we can rank them in decreasing order."

To illustrate the application of this method, the same example used for weighted sum is repeatedly presented. For example, an organisation announces for bids to purchase a multi-purpose printing machine with evaluation criteria; duration of delivery, price and experience of supplier along with their weights 10, 70, and 15 respectively. Duration is counted in days, price in MVR, and experience in years. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise. Three companies submitted bids and their bidding data as presented in Table 6.5. The weighted normalised matrix is presented in Table 6.6.

Table 6.5: Raw data

Bidder	Duration	Price	Experience
	10	75	15
A	21	67,667.00	13
B	30	66,067.00	14
C	28	33,161.00	12

Table 6.6: Weighted normalised matrix

Bidder	Duration	Price	Experience
A	0.045555	0.506407	0.086432
B	0.065079	0.494433	0.093081
C	0.060741	0.248171	0.079784
A^+	0.045555	0.248171	0.093081
A^-	0.065079	0.506407	0.086432

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution (d_j^+), separation measures from the negative-ideal solution (d_j^-), relative closeness to the ideal solution (R_j), and the ranks which are presented in Table 6.7.

Table 6.7: TOPSIS results

Bidder	d_j^+	d_j^-	R_j	Rank
A	0.258322	0.019524	0.070268	2
B	0.247035	0.013696	0.05253	3
C	0.020184	0.258358	0.927536	1

Based on the TOPSIS results, bidder C is closest to the ideal solution getting the highest score, which ranked the bidder in first place.

The TOPSIS method is criticised due to the issue of the satisfactory level for both criteria of the shortest distance from the ideal solution and the farthest distance from the negative ideal solution, because TOPSIS does not consider the relative importance of those distances (Opricovic & Tzeng, 2004). In addition to this, with Euclidean distance, as used in TOPSIS, the closest alternative to the positive ideal solution is not necessarily the farthest alternative from the negative ideal solution (Aghajani & Hadi-Vencheh, 2011; Chamodrakas, Leftheriotis, & Martakos, 2011).

Bottani and Rizzi (2006) state that the major weakness in TOPSIS could be the need for monotonic criteria. However, Bottani and Rizzi (2006) believe that TOPSIS works well for a one tier decision tree, while AHP (Analytic Hierarchy Process) is preferable for widely spread hierarchies, and this is where AHP could become competitive against TOPSIS.

A further drawback stated by Tsaur (2011) is that a narrow gap between the performed measures is derived in the normalized scale for each criterion due to the operation of normalized decision matrix. Therefore, with a narrow gap in the method, it is not good for ranking and cannot reflect the true dominance of alternatives.

When drawbacks are compared to public sector procurement, as discussed in Section 4.4.2, having monotonic criteria could be considered, as the public sector requires pre-announced criteria with its weights for each bid or tender, which cannot be changed later in the procurement process as discussed in Section 5.5.1.14. The next drawback of having a narrow gap between the performance measures after normalisation is that it still provides relative comparative figures, though small, which can still be used for calculation. Finally, the public the sector is looking for the

best alternative based on the performance criteria, as described in Section 4.3.1 and Section 4.3.4. The best alternative should be the alternative closest to the ideal solution, even if the alternative is not the furthest from the negative ideal solution. Therefore, in the public sector procurement context, the best alternative by TOPSIS, by chance not being the furthest from the negative ideal solution is acceptable as the alternative will be closest to the ideal solution.

Considering the above mentioned drawbacks in TOPSIS have no direct conflict with public sector requirements, the method is considered appropriate and further evaluations are done in the next phase of the research as discussed in the following Chapter.

6.3.2.2 MAVT

MAVT (multi-attribute value theory) is a functional method for MCDA. MAVT is firmly grounded in von Neumann and Morgenstern's utility theory and assumes an existence of a value function, based on utility maximisation (Ananda & Herath, 2003).

Ananda and Herath (2003) explain the MAVT approach, stating that it "involves constructing value functions, which allow an analytical study of preferences and value judgements. Value assessment involves choosing the decision attributes, defining attribute value scales and checking for their qualitative properties such as monotonicity, linearity, concavity and single-peakedness" (Ananda & Herath, 2003:76).

Decomposed scaling and holistic scaling are the common assessment schemes. In decomposed scaling, separate assessments are done for the marginal value functions and weights. Merging these two parts through either an additive or multiplicative approach is used in the overall value model. Holistic scaling is based on overall judgements. Optimal fitting techniques, like regression analysis or linear optimisation, are used to estimate weights and value function. Decomposed scaling is simpler in estimation and accuracy than holistic scaling (Ananda & Herath, 2003).

MAVT is built up of a few basic axioms and starts from the basis that all things are comparable. DM preferences are represented as a set of estimated scores for the performance of the alternatives on the measurement criteria. Weights must be created based on the relative importance of criteria. This approach fits well with scientific methods and it is a transparent technique (Simpson, 1996).

MAVT places all the potential alternatives onto the same scale, making it possible to make comparisons globally. MAVT enforces comparability across criteria. MAVT has a strict mathematical basis, therefore the data input into the model must satisfy specific conditions, such as transitivity (Simpson, 1996).

One of the conditions of MAVT is illustrated as follows: "consider a decision problem with a number of alternative strategies. Examine two of these strategies, A and B. They are measured against two sets of criteria *I* and *J*, where *I* contains at least two criteria, and *J* contains at least one criterion" (Simpson, 1996:921).

Due to this condition of requiring minimum of three criteria for evaluation in this approach, it conflicts with public sector procurement regulations as mentioned in Section 4.4.3 which allows evaluation to be carried out with only two criteria. We cannot assume that every procurement would have three or more criteria, since the regulation allows minimum of two evaluation criteria.

In addition, the issue of a common scale of comparability in every criterion in MAVT (Simpson, 1996) is not in line with public sector regulations, as any procurement can have diverse criteria, as mentioned in Section 4.4.2. In fact, it may not even be possible to represent criteria on a scale, such as with Boolean or nominal criteria. Therefore, MVAT was rejected for public sector procurement for the research context.

6.3.2.3 UTA

The UTA (UTilités Additives) method aims to develop an additive utility function according to the decision maker's judgment strategy. The method requires providing a set of reference alternatives A'. The decision maker has to provide global evaluation for each reference alternative to form a total pre-order of the alternatives in A': $a_1 \succ a_2 \succ \cdots \succ a_m$. If the developed utility model reproduces the given pre-order of the reference alternatives as consistently as possible, then the utility model is believed to be consistent. As such, the utility model should be developed so that: $U(a_1) > U(a_2) > \cdots > U(a_m)$ (Spronk, Steuer, & Zopounidis, 2005).

Siskos et al. (2005:299) state that the modeling process must conclude with a consistent family of criteria (g_1,g_2,...,g_n). Each criterion is a non-decreasing real valued function defined on A, as follows:

$$g_i : A \rightarrow [g_{i^*}, g_i^*] \subset \mathfrak{R}/_a \rightarrow g(a) \in \mathfrak{R}, \qquad (6.3.2.3a)$$

where $[g_{i^*}, g_i^*]$ is the criterion evaluation scale, g_{i^*} and g_i^* are the worst and the best level of *i*-th criterion respectively, $g_i(a)$ is the evaluation or performance of action *a* on *i*-th criterion and $g(a)$ is the vector of performances of action *a* on the *n* criteria.

From the above definitions, the following preferential situations can be determined:

$$\begin{cases} g_i(a) > g_i(b) \Leftrightarrow a \succ b & \text{(a is preffered to b)} \\ g_i(a) = g_i(b) \Leftrightarrow a \sim b & \text{(a is indifferent to b)} \end{cases}$$

Siskos et al. (2005:302) state that the criteria aggregation model in UTA is assumed to be an additive value function of the following form:

$$u(g) = \sum_{i=1}^{n} p_i u_i(g_i) \qquad (6.3.2.3b)$$

subject to normalization constraints:

$$\sum_{i=1}^{n} p_i = 1$$

$$u_i(g_{i^*}) = 0, \qquad u_i(g_i^*) = 1, \qquad \forall i = 1,2,\dots,n;$$

where $u_i, i = 1,2,\dots,n$ are non-decreasing real value functions, named marginal value or utility functions, which are normalized between 0 and 1, and p_i is the weight of u_i. Both the marginal and the global value functions have the monotonicity property of the true criterion. For instance, in the case of the global value function the following properties hold:

$$\begin{cases} u[g(a)] > u[g(b)] \iff \text{a} \succ \text{b} & \text{(preference)} \\ u[g(a)] = u[g(b)] \iff \text{a} \sim \text{b} & \text{(indifference)} \end{cases}$$

Spronk et al. (2005:841) highlighted that there are two possible types of errors which may occur. The first is the under-estimation error when the developed model assigns a reference alternative to a lower (better) rank than the one specified in the given pre-order (the alternative is under-estimated by the decision maker). The second error is the over-estimation error when the developed model assigns a reference alternative to a higher (worse) rank than the one specified in the given pre-order (the alternative is over-estimated by the decision maker).

Beuthe and Scannella (2001) also stated that, if estimation errors exist or if the utility function is applied to a different set of projects, it will lead to different rankings.

There is no guarantee of the UTA method providing a utility function which is consistent with available information. This shortcoming is due to the inherent utility model of UTA (Angilella, Greco, Lamantia, & Matarazzo, 2004).

Based on the principles of public sector procurement as discussed in Section 4.3, it is not advisable to use a method with known chance of errors in estimation and also without any guarantee to find a utility function coherent with available information. In addition, BEC members require an error free, accurate method as discussed in Section 5.5.5.2, Section 5.5.5.4, and Section 5.5.5.5. Therefore, due to

the inherent shortcomings of the UTA method, as discussed above, the method is rejected for the study.

6.3.2.4 SMART

Edwards (1977) developed the SMART (simple multi-attribute rating technique) method and described the process in the following steps, elaborated in Edwards (1977:328):

Step 1: Identify the person or organization whose utilities are to be maximized.

Step 2: Identify the issue or issues (i.e., decisions) to which the utilities needed are relevant.

Step 3: Identify the entities to be evaluated.

Step 4: Identify the relevant dimensions of value for evaluation of the entities.

Step 5: Rank the dimensions in order of importance.

Step 6: Rate dimensions in importance, preserving ratios. To do this, start by assigning the least important dimension an importance of 10.

Step 7: Sum the importance weights, and divide each by the sum.

Step 8: Measure the location of each entity being evaluate on each dimension.

Step 9: Calculate utilities for entities using the equation below:

$$U_i = \sum_j w_j u_{ij} \qquad \text{6.3.2.4a}$$

where $\sum_j w_j = 1$. U_i is the aggregate utility for the ith entity. w_j is the normalized importance weight of the jth dimension of value, and u_{ij} is the rescaled position of the ith entity on the jth dimension. Thus w_j is the output of Step 7 and u_{ij} is the output of Step 8.

Step 10: Decide. If a single act is to be chosen, the rule is simple: maximize U_i. If a subset of i is to be chosen, then the subset for which $\sum_i U_i$ is maximum is best.

Edwards (1977) provided additional explanation on the above steps in terms of how to use the method and expectations of it.

There was a logical error in SMART (Jeffreys, 2004). Due to the shortcomings of the original SMART, Edwards and Barron (1994) developed SMARTS (simple multi-attribute rating technique with swings) and a further development, SMARTER (simple multi-attribute rating technique exploring ranks).

SMARTS use swing weights, which is done in two steps. The first step gives the rank order of the weights and the second gives the weights themselves (Edwards & Barron, 1994).

SMARTER uses rank weights, which are calculated using the ranking of attributes and the equations for the weights have a convenient computational form (Edwards & Barron, 1994). Edwards and Barron (1994:319) provide the following equations for calculating the weights:

If $w_1 \geq w_2 \geq \cdots \geq w_k$, then

$w_1 = (1 + 1/2 + 1/3 + \cdots + 1/K)/K$

$w_2 = (0 + 1/2 + 1/3 + \cdots + 1/K)/K$

$w_3 = (0 + 0 + 1/3 + \cdots + 1/K)/K$

$w_K = (0 + \cdots + 0 + 1/K)/K$

More generally, if K is the number of attributes, then the weight of the k^{th} attribute is:

$$w_k = (1/K)\sum_{i=k}^{K}(1/i) \qquad 6.3.2.4b$$

SMARTS and SMARTER is improved on assigning weights and the other procedure are same as SMART. However, there are still weaknesses in SMART methods.

Due to the shortcomings of the original SMART, the original developer of SMART, Ward Edwards, believes that SMART should be dead but it has evolved into SMARTS and SMARTER (Edwards & Barron, 1994).

Hutchinson and Kotonya (2006) stated that SMART has a further limitation in the way the technique have been applied. SMART explicitly consist of steps for sensitivity analysis, in which a provisional decision is examined to determine its strength in relation to changes in the measures (and weights) assigned during the decision making process. However, in public sector procurement as mentioned in Section 4.4.2, the weights are announced in advance, and even if the decision is not favourable, based on sensitivity analysis it is not possible to make changes to weights.

Based on the experimented results by Pöyhönen and Hämäläinen (2001) weights differ due to a restricted set of numbers for the decision-makers to choose from. This happens easily with methods like SMART and swing weights which start the weight elicitation with even numbers. “The consequences are that the spread of weights and the inconsistencies among the preference statements become dependent on the number of attributes present in the comparison” (Pöyhönen & Hämäläinen, 2001). Therefore in public sector procurement a known deficiency of the chances that the number of attributes would rule the spread of weights and inconsistencies should be avoided as it violates the basic public sector principles discussed in Section 4.3. The SMART methods also contradict the requirements identified in Section 5.5.1.14, Section 5.5.5.2, Section 5.5.5.4, and Section 5.5.5.5.

Due to the limitations in SMART and conflicts in public sector procurement, as described above, for this research SMART methods are not preferred.

6.3.2.5 MAUT

MAUT (multi-attribute utility theory) was explained by Ralph Keeney and Howard Raiffa in 1976 with the utility concept, to systematically analyse complex decision-making problems which have multiple attributes and multiple conflicting goals. The method aims to obtain the maximum overall utility, with trade-offs of the attainment of some objectives against other objectives. The method develops a utility function based on a decision-maker's preference structure, and the utility function is used to find an optimal solution (Sanayei, Mousavi, Abdi, & Mohaghar, 2008).

Huang (2011) states that MAUT is a quantitative method which has an orderly process to identify and analyse multiple variables to find a solution. By applying the developed MAU (multi-attribute utility) function, a decision-maker can find the utility of every alternative, to identify the alternative with the highest utility to be selected.

The expression of the MAU function given by Huang (2011:399) is as follows:

$$MAU(u_1, \dots, u_n) = \sum_{i=1}^{n} w_i \cdot u_i \qquad 3.3.2.5a$$

where n is the number of attribute, u_i is a single-attribute utility function over attribute i, w_i is the weight for attribute i and $\sum_{i=1}^{n} w_i = 1 (0 \leqq w_i \leqq 1 \text{ for all } i)$.

Many different utility elicitation methods have been developed in order to find a decision-maker's MAU function, which can be a holistic approach such as multiple regression analysis, or a decomposed approach, like SMART (Huang, 2011).

Min (1994:26) provided the following steps for the application of MAUT:

Step1: Identify the objectives or goals of the decision and define the problem scope.

Step 2: Define a finite set of relevant attributes affecting the decision outcome and structure them into a hierarchical form called a “value tree”.

Step 3: Elicit preference information concerning the attributes from the decision-maker(s), and determine the relative importance of the attributes.

Step 4: Develop the decision-maker’s utility function by establishing functional relationships between the attributes and the utility scores. If these relationships are uncertain, the expected utility score for each attribute will be determined by using the appropriate type of probability distributions.

Step 5: Compute the aggregate (overall) utility score for each decision alternative and rank alternatives in terms of aggregate utility scores.

Step 6: Perform sensitivity analyses.

As seen in above steps given by Min (1994), sensitivity analysis is a part of the MAUT procedure, similar to SMART. If inconsistency is found in MAUT, the preference information of the decision-maker has to be changed. (Moshkovich, Mechitov, & Olson, 2005). Therefore, similar weaknesses and contradictions to public sector procurement mentioned in Section 6.3.2.4 with SMART, exists in MAUT, in relation to sensitivity analysis.

MAUT needs the decision-maker’s involvement to develop the utility function. When it is done, it can be used to evaluate many alternatives. Decision-maker’s efforts are no longer needed, even if a new alternative is to be considered. Sensitivity analysis balances the likely inaccuracy in the measurements, so there is no justification for the questions faced by a decision-maker (Moshkovich et al., 2005).

To use MAUT, a special training should be undertaken by decision makers and MAUT does not consider likely human errors in evaluation. Sensitivity analysis examines the stability of the result (Moshkovich et al., 2005).

Public sector procurement evaluations are carried by very senior officials of the public sector as mentioned in Section 4.4.2 and Section 5.5.2.1, and they have limited time. Undergoing training and holding onto it during MAUT analysis involve practical difficulties. The BEC may change from time to time and would require the training to be conducted every time a new member joined. Since MAUT has mismatches with public sector procurement, as discussed above, and requires changing original DM preferences like SMART (in case of inconsistencies), MAUT is rejected in this research.

6.3.2.6 AHP and ANP

AHP (Analytic Hierarchy Process) and its new extension, the ANP (Analytic Network Process) are well known methodologies to build utility functions, presented by Thomas Saaty (Figueira, Greco, et al., 2005). In essence, the AHP procedure trims down complex decisions to a sequence of one-on-one comparisons, and then synthesizing is done (Chatterjee et al., 2011).

AHP uses pairwise comparisons together with expert judgment to assign values to qualitative criteria. The ANP is used to derive composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of elements that interact with respect to control criteria. The ANP considers the outcome of dependence and feedback within and between clusters of elements. AHP, with its dependence assumptions on clusters and elements is a special case of the ANP (Figueira, Greco, et al., 2005).

Forman and Gass (2001:469) states that the AHP employs three commonly agreed-to decision-making steps: (1) Given $i = 1, \ldots, m$ objectives, determine their respective weights w_i; (2) for each objective i, compare the $j = 1, \ldots, n$ alternatives and determine their weights w_{ij} with respect to objective i; and (3) determine the final (global) alternative weights (priorities) W_j with respect to all the objectives by $W_j = w_{1j}w_1 + w_{2j}w_2 + \cdots + w_{mj}w_m$. The alternatives are then ordered by the W_j, with the most preferred alternative having the largest W_j.

AHP also provides a methodology to standardise the numeric scale for the measurement of quantitative as well as qualitative performances. The least value for the scale is 1/9 and the highest value is 9 to compare alternatives and value 1 is used when alternatives are equal (Vaidya & Kumar, 2006). Saaty (2005:7) provided the fundamental scale of absolute numbers, as shown in Table 6.3.

Vaidya and Kumar (2006) gives the key and basic steps involved in AHP methodology as follows:

"Step 1: State the problem.

Step 2: Broaden the objectives of the problem or consider all actors, objectives and its outcome.

Step 3: Identify the criteria that influence the behavior.

Step 4: Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Step 5: Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $n(n-1)/2$ comparisons, where n is the number of elements with the considerations that diagonal elements are equal or '1' and the other elements will simply be the reciprocals of the earlier comparisons.

Step 6: Perform calculations to find the maximum Eigen value, consistency index CI, consistency ratio CR, and normalized values for each criteria/alternative.

Step 7: If the maximum Eigen value, CI, and CR are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in a desired range." (Vaidya & Kumar 2006:2)

Table 6.8: Fundamental scale of absolute numbers

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another, its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
Rationals	Ratio arising from the scale	
		If consistency were to be forced by obtaining n numerical values to span the matrix

Source: Saaty (2005:7)

The above procedure for AHP calculations is widely accepted. However, AHP procedure is complex and very time-consuming and there may be lack of transparency in the whole decision-making process (Chatterjee et al., 2011). Forman (1993) believes that consumption of great deal of time is the major weakness of AHP.

Chatterjee et al. (2011) state that major weaknesses in AHP are the use of the 9-point scale, giving a scale limitation and “phenomenon of rank reversal which occurs when indifferent criteria (for which all the alternatives perform in an equal manner) is added to the decision matrix causing a significant alteration of the aggregate priorities of the alternatives, with important undesirable consequence” (Chatterjee et al. 2011:859). The weakness of the addition of indifferent criteria causing alterations of the aggregate priorities are discussed with an example by Pérez, Jimeno, and Mokotoff (2006).

AHP approach accommodates 7±2 hierarchical decompositions and the number of alternatives accommodated by AHP is also limited to 7±2 (Shih, Shyur, & Lee, 2007).

The major concerns about AHP approach with regard to public sector procurement are the possibility of a lack of transparency, the complexity of its calculation (Chatterjee et al., 2011) and its time-consuming nature (Chatterjee et al., 2011; Forman, 1993). One of the principles of public sector procurement is transparency, as described in Section 4.3 and likely obstacles to transparency through the decision analysis approach should be avoided. Another concern in public sector procurement with AHP is the limit on the number of criteria and the number of alternatives (Shih et al., 2007), because public sector procurement cannot be limited to a certain number of suppliers, or attributes, by law ("Dhaulathuge Maaliyyathuge Gavaaidhu," 2009). In addition, according to BECs no pair-wise comparison can be used as discussed in Section 5.5.1.14. Therefore, AHP and ANP approaches are not suitable for the research context.

6.3.2.7 DEA

Charnes et al.(1978) introduced DEA (Data Envelopment Analysis) concept (Falagario et al., 2012; Li & Reeves, 1999; San Cristóbal, 2011) as a linear programming based technique to evaluate the efficiency of a group of decision making units (DMUs) that use multiple inputs to produce multiple outputs (Falagario et al., 2012; Wang, Chin, & Luo, 2011). Performances of the DMUs are calculated

by maximising the efficiency of every DMU having the constraint that no efficiencies can be greater than one (Wang et al., 2011). In supplier selection, suppliers are evaluated on the performance of benefit criteria (outputs) and cost criteria (inputs) (Wu, 2009).

The following DEA formulae and its explanations are taken from Falagario et al. (2012:525).

Falagario et al. (2012:525) explain the DEA approach with cross efficiency, initially explaining how the DEA defining the following formula for efficiency of supplier i:

$$E_i = \frac{\sum_{k=1}^{K} u_k \cdot y_{ki}}{\sum_{h=1}^{H} v_h \cdot x_{hi}} \qquad 3.3.2.7a$$

where y_{ki} is the k output performance value ($k = 1, 2, \cdots, K$) for the actor i ($i = 1, 2, \cdots, F$), x_{hi} is the h input performance value ($h = 1, 2, \cdots, H$) for the actor i, u_k is the weighting coefficient for the k output performance value, and v_h is the weight coefficient for the h input performance value. The supplier i is efficient if $E_i = 1$; otherwise, the supplier is considered as non-efficient.

Falagario et al. (2012:525) further describes that "in the classical DEA method, the efficiency of each actor is obtained by determining the set of coefficients u_k and v_h which maximizes this value and, at the same time, by taking into account that, for each actor i, $E_i \leq 1$ holds by definition". So, the supplier efficiency can be calculated by solving the following formulae for each supplier i (Falagario et al., 2012):

$$\max E_i \qquad 3.3.2.7b$$

$$\text{s.t. } \frac{\sum_{k=1}^{K} u_k \cdot y_{ki}}{\sum_{h=1}^{H} v_h \cdot x_{hi}} \leq 1 \text{ with } i = 1,2, \dots, F, \qquad 3.3.2.7c$$

$$u_k, v_h \geq 0 \text{ for } k = 1,2, \dots, K; h = 1,2, \dots, H. \qquad \text{3.3.2.7d}$$

Linearization can be done to solve the problem (3.3.2.7b - d) in two ways: minimizing the inputs and keeping fixed the output values (input-oriented method) or maximizing the outputs and keeping fixed the input values (output-oriented method) (Falagario et al., 2012).

Falagario et al. (2012:526) state that, according to the second method, the problem becomes as follows:

$$\max E_i = \sum_{k=1}^{K} u_k \cdot y_{ki} \qquad \text{3.3.2.7e}$$

$$\text{s.t. } \sum_{k=1}^{K} u_k \cdot y_{ki} - \sum_{h=1}^{H} v_h \cdot x_{hi} \leq 0 \text{ with } i = 1,2, \dots, F, \qquad \text{3.3.2.7f}$$

$$\sum_{h=1}^{H} v_h \cdot x_{hi} = 1. \qquad \text{3.3.2.7g}$$

and (3.3.2.7d).

The efficiency of the suppliers calculated by applying the formulae (3.3.2.7e - g) and (3.3.2.7d) for each *i*th supplier with $i = 1, 2, \cdots, F$. Hence, suppliers can be ranked based E_i value (Falagario et al., 2012).

Falagario et al. (2012) proposed a cross-efficiency approach for supplier evaluation and provided the following formula to calculate the *j*th DMU cross efficiency value:

$$CE_i = \frac{1}{F} \sum_{i=1}^{F} E_{ij} = \frac{1}{F} \sum_{i=1}^{F} \left(\frac{v_1^i y_{1j} + v_2^i y_{2j} + \cdots + v_K^i y_{Kj}}{u_1^i x_{1j} + u_2^i x_{2j} + \cdots + u_H^i x_{Hj}} \right) \qquad \text{3.3.2.7h}$$

However, the DEA method has some difficulties which make it inappropriate to apply in the public sector procurement. The approach also does not meet the requirements of the European Union Directive, as weights or priority ranking are not predefined in the DEA method (Falagario et al., 2012). The same requirement is

enforced in the research context as mentioned in Section 4.4.2, making the DEA not applicable in this research project.

Weights are not pre-defined in the DEA method by DM (Falagario et al., 2012). DEA method internally derives weights when applied. Optimal weights for the criteria are automatically calculated, based on performance scores of the supplier. There is no control or involvement of decision-makers for the importance of the criteria in DEA approaches (Ng, 2008). Since this is not in line with public sector procurement regulations, as described in Section 4.4.2 and requirements described in Section 5.4.1.4, DEA approaches are rejected for the research.

6.3.2.8 COPRAS

COPRAS (COmplex PRoportional ASsessment) was developed by Zavadskas and Kaklauskas in 1996 for determining the priority and utility degree of alternatives (Chatterjee et al., 2011; Edmundas Kazimieras Zavadskas & Antucheviciene, 2007)

COPRAS method is a structured approach for MCDA which evaluates the alternatives in terms of significance and degree of utility (Edmundas Kazimieras Zavadskas, Kaklauskas, Turskis, & Tamosaitiene, 2008). COPRAS was applied to solve various construction and engineering multi-objective and multi-attribute problems (Edmundas Kazimieras Zavadskas & Antucheviciene, 2007).

The method assumes “direct and proportional dependence of the significance and utility degree of the investigated versions in a system of criteria adequately describing the alternatives and of values and weights of the criteria” (Kaklauskas, Zavadskas, & Trinkunas, 2007:168).

The following formulae and procedural steps of COPRAS method are taken from Chatterjee, et al. (2011:853):

Step 1: Develop the initial decision matrix, *X*.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad 3.3.2.8a$$

where x_{ij} is the performance value of ith alternative on jth criterion, m is the number of alternatives compared and n is the number of criteria.

Step 2: Normalise the decision matrix using the following equation. The purpose of normalization is to obtain dimensionless values of different criteria so that all can be compared.

$$R = [r_{ij}]_{mxn} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad 3.3.2.8b$$

Step 3: Determine the weighted normalized decision matrix, *D*.

$$D = [y_{ij}]_{mxn} = r_{ij} x w_j \ \ (i = 1,2, \dots, m; j = 1,2, \dots, n) \quad 3.3.2.8c$$

where r_{ij} is the normalized performance value of ith alternative on jth criterion and w_j is the weight of jth criterion. The sum of dimensionless weighted normalized values of each criterion is always equal to the weight for that criterion.

$$\sum_{i=1}^{m} y_{ij} = w_j \quad 3.3.2.8d$$

Step 4: The sums of weighted normalized values are calculated for both the beneficial attributes and non-beneficial attributes. The lower is the value of a non-beneficial attribute, such as price, the better is the attainment of goal. On the other hand, the greater is the value of a beneficial attribute, such as quality, the better is the attainment of goal. These sums are calculated using the following equations:

$$S_{+i} = \sum_{j=1}^{n} y_{+ij} \quad 3.3.2.8e$$

$$S_{-i} = \sum_{j=1}^{n} y_{-ij} \quad 3.3.2.8f$$

where y_{+ij} and y_{-ij} are the weighted normalized values for the beneficial and non-beneficial attributes respectively.

Step 5: Determine the significances of the alternatives on the basis of defining the positive alternatives S_{+i} and negative alternatives S_{-i} characteristics.

Step 6: Determine the relative significances or priorities of the alternatives. The priorities of the candidate alternatives are calculated on the basis of Q_i. The greater the value of Q_i, the higher is the priority of the alternative. The alternative with the highest relative significance value (Q_{max}) is the best choice among the candidate alternatives.

Relative significance value (priority), Q_i of ith alternative can be obtained as below:

$$Q_i = S_{+i} + \frac{S_{-min}\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}(S_{-min}/S_{-i})} \quad (i = 1,2,\dots,m) \qquad 3.3.2.8g$$

where S_{-min} is the minimum value of S_{-i}.

Step 7: Calculate the quantitative utility (U_i) for ith alternative. The degree of an alternative's utility is directly associated with its relative significance value (Q_i). The degree of an alternative's utility, leading to a complete ranking of the candidate alternatives, is determined by comparing the priorities of all the alternatives with the most efficient one, and can be denoted as below:

$$U_i = \frac{Q_i}{Q_{max}} \times 100\% \qquad 3.3.2.8h$$

where Q_{max} is the maximum relative significance value. With the increase or decrease in the value of the relative significance for an alternative, it is observed that its degree of utility also increases or decreases.

The above steps provided by Chatterjee et al. (2011) give a clear mathematical procedure to apply COPRAS in MCDA to find alternatives in relation to its utility, based on the set criteria.

To illustrate the application of this method, the same example used for weighted sum and TOPSIS is repeatedly presented. For example, an organisation announces for bids to purchase a multi-purpose printing machine with evaluation criteria; duration of delivery, price and experience of supplier along with their weights 10, 70, and 15 respectively. Duration is counted in days, price in MVR, and experience in years. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise. Three companies submitted bids and their bidding data as presented in Table 6.9. The weighted normalised matrix for COPRAS is presented in Table 6.10.

Table 6.9: Raw data

Bidder	Duration	Price	Experience
	10	75	15
A	21	67,667.00	13
B	30	66,067.00	14
C	28	33,161.00	12

Table 6.10: Weighted normalised matrix

Bidder	Duration	Price	Experience
A	0.041176	0.304085	0.05
B	0.058824	0.296895	0.053846
C	0.054902	0.14902	0.046154

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes (S_{+i}) and non-beneficial attributes (S_{-i}), relative significances of the alternatives (Q_i), quantitative utility (U_i), and the ranks obtained. These results are shown in Table 6.11.

Table 6.11: COPRAS results

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A	0.05	0.345261	0.296991	63.96051	2
B	0.053846	0.355718	0.293576	63.22515	3
C	0.046154	0.203922	0.464335	100	1

Based on the COPRAS results, bidder C achieved the highest value utility score, which ranked the bidder in first place.

Since COPRAS evaluates the alternatives based on its significance and utility degree, and the method is applied in various MCDA problems (Edmundas Kazimieras Zavadskas & Antucheviciene, 2007), it is very appealing to apply in public sector procurement.

However, there are some critics of the method. Podvezko (2011) stated that COPRAS has an inherent inconsistency which may lead to incorrect evaluation of the alternatives. Stability of COPRAS is also less compared to other methods when data variation is considered, as it may have a huge degree of change in ranks of the alternatives due to changes in data, unlike other methods (Podvezko, 2011).

In the research context, the performance values of the suppliers will not be changed and the allocated weights will not be changed. Therefore, there will not be change in data in public sector procurement of the context. Considering the issue of data variation in COPRAS, the method is further evaluated in the following Chapter for its performance with the real life procurement data gathered from the public education institutions, as mentioned in Section 3.6.

6.3.3 Outranking methods

Outranking methods are originally developed to solve real-world problem regarding decisions dealing with the development of new activities in firms (Figueira, Mousseau, & Roy, 2005).

Outranking methods compare each criterion of two or more alternatives at a time to identify the degree of preference over the other. Based on the collected preference information for all relevant criteria of all the alternatives, the outranking method tries to show the substantiation of choice of one alternative over the other:

for example, by choosing the alternative that has a higher number of criteria with a greater degree of preference compared to other alternatives (Linkov et al., 2004).

Outranking methods are regarded as partially compensatory methods which also have the capability of dealing with situations in which imprecision is present (Luitzen de Boer, Wegen, & Telgen, 1998). Outranking models are suitable when criteria metrics are difficult to combine, variety of measurement scales are used, and units are unequal (Linkov et al., 2004).

Figueira et al. (2005) provided the contexts where the basic outranking methods are applicable. Figueira et al. (2005) state that basic outranking methods are applicable to the following situations:

1 "The decision-maker (DM) wants to include in the model at least three criteria. However, aggregation procedures are more adapted in situations when decision models include more than five criteria (up to twelve or thirteen).

And, at least one of the following situations must be verified.

2 Actions are evaluated (for at least one criterion) on an ordinal scale or on a weakly interval scale. These scales are not suitable for the comparison of differences. Hence, it is difficult and/or artificial to define a coding that makes sense in terms of preference differences of the ratios $\frac{g_j(a)-g_j(b)}{g_j(c)-g_j(d)}$ where $g_j(x)$ is the evaluation of x action on criterion g_j.
3 A strong heterogeneity related with the nature of evaluations exists among criteria (e.g., duration, noise, distance, security, cultural sites, monuments, ...). This makes it difficult to aggregate all the criteria in a unique and common scale.
4 Compensation of the loss on a given criterion by a gain on another one may not be acceptable for the DM. Therefore, such situations require the use of non-compensatory aggregation procedures.
5 For at least one criterion the following holds true: small differences of evaluations are not significant in terms of preferences, while the

> accumulation of several small differences may become significant. This requires the introduction of discrimination thresholds (indifference and preference) which leads to a preference structure with a comprehensive intransitive indifference binary relation." (Figueira et al., 2005:136)

The very first and compulsory context provided above by Figueira at al. (2005) limits the number of criteria to be used in the outranking methods. However, based on enforced procurement criteria discussed in Section 4.4.3 and Section 5.3.2, we cannot have a definite number of criteria in public sector procurement: they vary, based on the material or service under procurement consideration.

The second context provided as an optional situation above by Figueira et al. (2005) stating to have an ordinal scale for at least one criterion which cannot be confirmed for every public sector procurement, as the criteria are defined for every procurement, based on the material or service under procurement consideration as referred to in Section 4.4.3 and Section 5.3.2, and it may not necessarily have any criteria with ordinal scale.

The third context provided as an optional situation by Figueira et al. (2005) stating to have strong heterogeneity among criteria can also be applicable in certain public procurement situations but may not be established for every public sector procurement, as the criteria are defined for every procurement consideration, based on the procurement regulations referred in Section 4.4.3 and in practice stated in Section 5.3.2.

The fourth context provided as an optional situation by Figueira et al. (2005) regarding compensation of criteria could be accepted in the public sector procurement under study, as the procurement regulation does not specify anything about accepting or not accepting compensation of criteria in evaluation.

The fifth context provided as an optional situation by Figueira et al. (2005) relating to not considering the significance of small differences in evaluation cannot be accepted in public sector procurement as it violates the basic principles of public

sector procurement, as discussed in Section 4.3. However, the second criteria, stating that several small differences become significant is valid in public sector procurement too.

Therefore, public sector procurement contradictions identified above, based on the applicable situations for fundamental outranking methods provided by Figueira et al. (2005), and requirements identified in Section 5.5.1.12 outranking methods cannot be considered in public sector procurement in the context of this research.

In additional to that, Boer et al. (1998) state that outranking methods in purchasing decisions are not recommended in purchasing or operations research literature and outranking models should not be considered as a substitute for existing supplier selection models. However, it can be used as a supplement model. Since the research is focused not on a supplementary model but a primary model which fits in with public sector requirements, outranking methods are rejected. Therefore, no further description of individual outranking methods is made in this section.

6.3.4 Fuzzy methods

Fuzzy logic came into existence from the concept of a fuzzy set which is a set having no crisp, clear defined boundary (Parthiban, Dominic, & Dhanalakshmi, 2010). Kahraman, Cebeci, and Ulukan (2003) defined fuzzy set as “a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one.” Elements in a fuzzy set have only a partial membership. An element with a value of zero is not counted as a member of the fuzzy set and an element with a value of one is a full member. Fuzzy members hold values between 0 and 1 (Parthiban et al., 2010).

Fuzzy set theory was introduced by Zadeh (1965), to deal with vague parameters (Kahraman et al., 2003; Kumar, Vrat, & Shankar, 2006). The theory of

fuzzy set is one of the best tools in decision-making when a high degree of uncertainties are involved, due to imperfections and complications of the information process (Amid, Ghodsypour, & O'Brien, 2006; Kumar et al., 2006; Parthiban et al., 2010).

Some authors, such as Kumar et al. (2006) and Kahraman et al. (2003) suggested supplier selection models, using fuzzy theories combined with other models, and the fuzzy theories were employed due to the presence of vagueness and imprecision of information in the supplier selection problem which is intended for the private sector.

Based on the results of the review of literature done by Ho et al. (2010) on MCDA approaches for supplier selection appearing in the international journals from year 2000 to 2008, fuzzy theories were used mainly in hypothetical cases and only one suggestion was made for application in high-technology manufacturing. No literature showed any evidence of the application of fuzzy theories in the public sector.

As requirements discussed in Section 4.2.3.2, Section 4.3.3, Section 4.3.4 Section 5.5.1.7, Section 5.5.1.8, and Section 5.5.1.12, public sector procurement decisions are to be executed based on the prescribed information collected from the suppliers which are crisp data. Based on the public sector principles discussed in Section 4.3 the performances of the suppliers cannot be changed to fuzzy values, as it violates the principles of non-discrimination, equality and proportionality. Therefore, fuzzy methods are not best applicable in public sector procurement. Since fuzzy methods are not best applicable methods and have not been suggested by the literature (Ho et al., 2010), it is rejected for this research context. Therefore, no further description of individual fuzzy methods is made in this section.

6.3.5 Mixed methods

Mixed methods use a combination of more than one approach for MCDA. Even though Table 4.1 shows only two methods in the mixed methods group, there are numerous mixed methods in literature.

The first method listed under mixed methods is the Martel and Zaras method which uses pairwise comparison and an outranking method. For the pairwise comparison, the stochastic dominance is used. Partial preferences are based on these pairwise comparisons. The outranking relation is built based on a concordance index and discordance index (Guitouni & Martel, 1998). Since out ranking methods are not considered for public sector procurement as explained in Section 6.3.3, and it contradicts the requirements discussed in Section 5.5.1.13 and Section 5.5.1.14, Martel and Zaras method is not applicable to the research context.

The second method listed under mixed methods is fuzzy conjunctive/disjunctive method. This method is applied when data is fuzzy. A fuzzy value is computed using the possibility measure and the necessity measure. The preference will be the alternative with the highest degree of match (Guitouni & Martel, 1998). Since this method uses fuzzy logic, as explained in Section 6.3.4 and method of conjunctive/disjunctive approach as explained in Section 6.3.1.3, fuzzy conjunctive/disjunctive method is not applicable for the research context.

In addition to the mixed methods listed in Table 4.1, based on the review of literature by Ho et al. (2010) on MCDA approaches for supplier selection appearing in the international journals from year 2000 to 2008, there are 20 more mixed methods listed in literature in 32 publications. 15 methods out of the 20 methods are intended for manufacturing firms, one of which was also suggested for pharmaceutical industry and the rest are hypothetical cases. None of these methods are suggested for public sector procurement in literature.

Most of the mixed methods are context specific and no literature suggested applying mixed methods in the public sector (Ho et al., 2010). Mixed methods are also more complex than other single methods and the complexity may cause

difficulty for public sector suppliers to understand and submit best offers. In addition, BEC members require a clear, easy method and to minimise complaints from suppliers as explained in Section 5.5.5.8, Section 5.5.5.6 and Section 5.5.3.1. Since mixed methods are more complex for meeting the requirements discussed above, they are rejected.

6.4 Applicable MCDA methods in public sector procurement

Guitouni and Martel (1998) state that almost all MCDA methods are based on DM preferences, to make suggestions, and problems exist in assessing and modelling the DM preferences as it may not be modelled only by logical rules and relations. The assumptions made through DM preferences influence the MCDA process and the result (Guitouni & Martel, 1998).

Similarly, in selecting the MCDA model, public sector procurement regulations influence the choice of the method through its rigid procedures and expected outcome. Through comparison of public sector procurement regulations with the characteristics of MCDA methods studied, it is evident that only a few methods among them are applicable in the research context. The possible MCDA methods that could be applied in the research context based on the comparisons are as follows:

1. TOPSIS. It has some weaknesses. However, no direct conflict with public sector procurement is evident, as discussed in Section 6.3.2.1.
2. COPRAS. It is also an appealing technique with some weaknesses. However, no direct conflict with public sector procurement is evident as discussed in section 6.3.2.8.

Weighted sum is the current practice for procurement decision-making in the research context. However, it has conflicting issues, as discussed in Section 6.3.1.1.

To identify the method to be applied in an e-procurement decision support system for the research context, the applicable methods identified above are analysed with real life procurement data to assess its performances. This analysis is done in Chapter 7.

6.5 Conclusion

This chapter has discussed the major MCDA methods and their characteristics, and compared the characteristics with public sector procurement regulations of the research context to identify the applicability of the methods.

MCDA methods are logically grouped based on similar characteristics. Initially, the group characteristics are compared with the public sector procurement under concern. If the group characteristics are in a considerable nature, the individual methods in the group are discussed, with their characteristics, and compared to public sector procurement regulation in research context to verify its applicability in the research.

Based on the qualitative comparison of the MCDA methods with the public sector procurement under concern, it identified two MCDA methods to be considered for the next phase of data analysis. The identified methods are TOPSIS and COPRAS. Along with two methods, the weighted sum method, which is the method currently in practice will be applied to the collected procurement data for quantitative analysis.

CHAPTER 7

PERFORMANCE ANALYSIS

7.1 Overview

As mentioned in Chapter 6 and Chapter 2 on research methodology and illustrated in Figure 2.2, a performance analysis was conducted on the filtered MCDA methods as one of the major components of the research project. This chapter presents and discusses the performance analysis, based on real life procurement data from public sector institutions.

At first the chapter presents the performances of the suppliers for the selected procurements from the institution with the evaluation results in Section 7.4. The second part presents the application of the same data to the filtered two methods, TOPSIS and COPRAS, with their results. Application of TOPSIS is presented in Section 7.5 and application of COPRAS is presented in Section 7.6. Finally the results are analysed in order to assess the performance of the two methods. The comparative result analysis is presented in Section 7.7. Performance analyses of these results are presented in Section 7.8 using three different methods of evaluation. Finally MCDA application on the methods is presented in Section 7.9.

7.2 Introduction

Performance analysis is one of the major components of this research project, as discussed in the research methodology chapter. The performance analyses are executed according to the research design discussed in Section 3.5.

Real life procurement data collected from public sector institutions were applied to TOPSIS and COPRAS. Variance analysis, congruence/incongruence analysis and stability analysis were applied to the results.

7.3 Data collection and analysis

Real life procurement data sets were collected from public sector education institutions. The data collection and analysis procedures are discussed in Section 3.6.1. The following sections show the sample data and its application on TOPSIS and COPRAS.

7.4 Sample sets of real life procurement data

This data represents the allocated supplier performances for the assigned criteria and weights for the criteria. The samples also show the results obtained by the institutions using their current evaluation method, which is weighted sum.

The names of the bidders are represented as ‘A’ followed by a sequence number to show the alternatives for the particular procurement. The names of the bidders and the institutions are not shown, for information protection purposes as stated in information sheet provided to the education institutions. However, the performance values are unchanged.

The institutions followed weighted sum evaluation method for bid evaluation as described in Section 6.3.1.1 to find the best alternative. Therefore, along with the

data, the results of weighted sum for the data are shown to represent the selection made by the institutions.

7.4.1 Sample 1

Sample 1 is a procurement of work related to building interior restructuring. Three companies submitted the bids. The criteria, weights and supplier performances are shown in Table 7.1. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outgoing and the rest are beneficial criteria targeted to maximise positive outcome.

Table 7.1: Sample 1 data

Bidder	Duration	Price	Experience (20)		Financial Strength
			No. Of Years	Similar Task	
	30	40	10	10	10
A1	90	678,919.00	10	10	10
A2	60	549,972.44	0	0	0
A3	44	730,000.00	10	10	10

Duration is counted in days; price counted in MVR; the number of years of experience counted in years; similar tasks and financial strength is the financial strength of the supplier and it represent marks allocated to them. Table 7.2 shows the results of applying weighted sum.

Table 7.2: Weighted Sum results of Sample 1

Bidder	Price	Duration	Experience	Financial strength	Total
A1	27.10	14.67	20.00	10.00	71.77
A2	40.00	22.00	0.00	0.00	62.00
A3	25.20	30.00	20.00	10.00	85.20

According to the weighted sum results bidder A3 achieved the highest score and won the procurement.

7.4.2 Sample 2

Sample 2 is a procurement of materials and the set up of computer laboratories. Three companies submitted the bids. However A3 was rejected for not meeting the specification. The criteria, weights and supplier performances are shown in Table 7.3. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and experience is a beneficial criterion targeted to maximise outcomes.

Table 7.3: Sample 2 data

Bidder	Duration	Price	Experience
	10	75	15
A1	21	676,677.83	13
A2	30	660,671.55	14
A3	28	331,614.00	0

Duration is counted in days, price in MVR, and experience in years. Table 7.4 shows the results of applying weighted sum.

Table 7.4: Weighted Sum results of Sample 2

Bidder	Duration	Price	Experience	Total
A1	10.00	73.23	13.00	96.23
A2	7.00	75.00	14.00	96.00

According to the weighted sum results, bidder A1 achieved the highest scores and won the procurement.

7.4.3 Sample 3

Sample 3 is a procurement of printing books. Four companies submitted the bids. The criteria, weights and supplier performances are shown in Table 7.5. The weights are shown below the listed criteria. Duration and price are cost criteria

targeted to minimise outlay, and experience is a beneficial criterion targeted to maximise outcomes.

Table 7.5: Sample 3 data

Bidder	Duration	Price	Experience
	35	50	15
A1	4	195,301.00	15
A2	25	175,626.00	15
A3	25	249,230.00	15
A4	4	170,397.00	15

Duration is counted in days, price in MVR, and experience in years. Table 7.6 shows the results of applying weighted sum.

Table 7.6: Weighted Sum results of Sample 3

Bidder	Price	Duration	Experience	Total
A1	43.62	35.00	15.00	93.62
A2	48.51	5.60	15.00	69.11
A3	34.18	5.60	15.00	54.78
A4	50.00	35.00	15.00	100.00

According to the weighted sum results, bidder A4 achieved the highest score and won the procurement.

7.4.4 Sample 4

Sample 4 is a procurement of renovating a science laboratory. Seven companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.7. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and experience is beneficial criteria targeted to maximise outcome.

Table 7.7: Sample 4 data

Bidder	Duration	Price	Experience
	10	75	15
A1	5	16,500.00	0
A2	15	38,700.00	0
A3	28	46,730.00	0
A4	26	49,900.00	0
A5	28	115,532.00	0
A6	60	121,405.00	0
A7	24	137,867.80	0

Duration is counted in days, price in MVR, and experience in years. Table 7.8 shows the results of applying weighted sum.

Table 7.8: Weighted Sum results of Sample 4

Bidder	Price	Duration	Experience	Total
A1	75.00	10.00	0.00	85.00
A2	31.98	3.33	0.00	35.31
A3	26.48	1.79	0.00	28.27
A4	24.80	1.92	0.00	26.72
A5	10.71	1.79	0.00	12.50
A6	10.19	0.83	0.00	11.03
A7	8.98	2.08	0.00	11.06

According to the weighted sum results, bidder A1 achieved the highest score and won the procurement.

7.4.5 Sample 5

Sample 5 is a procurement of renovating a staff room. Four companies submitted bids. The criteria, weights and supplier performances are shown in Table

7.9. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and experience is a beneficial criteria targeted to maximise outcomes.

Table 7.9: Sample 5 data

Bidder	Duration	Price	Experience
	10	80	10
A1	9	88,600.00	3.6
A2	25	101,632.00	7.6
A3	15	116,297.78	4.8
A4	13	139,000.00	4.4

Duration is counted in days, price in MVR, and experience in years. Table 7.10 shows the results of applying weighted sum.

Table 7.10: Weighted Sum results of Sample 5

Bidder	Price	Duration	Experience	Total
A1	80.00	10.00	2.74	92.74
A2	69.74	3.60	5.78	79.12
A3	60.95	6.00	3.65	70.59
A4	50.99	6.92	3.34	61.26

According to the weighted sum results, bidder A1 achieved the highest score and won the procurement.

7.4.6 Sample 6

Sample 6 is a procurement of renovating desks. Fifteen companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.11. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and experience is a beneficial criteria targeted to maximise outcomes.

Table 7.11: Sample 6 data

Bidder	Duration	Price	Experience
	10	80	10
A1	10	8,165.00	0.64
A2	12	9,260.00	8.18
A3	9	13,000.00	0.00
A4	7	18,000.00	0.00
A5	8	19,000.00	0.00
A6	8	19,500.00	0.00
A7	12	19,400.00	0.00
A8	10	22,979.00	0.00
A9	20	24,250.00	0.00
A10	15	27,750.00	0.00
A11	10	29,900.00	0.00
A12	6	37,500.00	0.00
A13	10	33,950.00	0.00
A14	7	39,000.00	0.00
A15	20	55,500.00	0.00

Duration is counted in days, price in MVR, and experience in years. Table 7.12 shows the results of applying weighted sum.

Table 7.12: Weighted Sum results of Sample 6

Bidders	Price	Duration	Experience	Total
A1	80.00	6.00	0.64	86.64
A2	70.54	5.00	8.18	83.72
A3	50.25	6.67	0.00	56.91
A4	36.29	8.57	0.00	44.86
A5	34.38	7.50	0.00	41.88
A6	33.50	7.50	0.00	41.00
A7	33.67	5.00	0.00	38.67
A8	28.43	6.00	0.00	34.43
A9	26.94	3.00	0.00	29.94
A10	23.54	4.00	0.00	27.54
A11	21.85	6.00	0.00	27.85
A12	17.42	10.00	0.00	27.42
A13	19.24	6.00	0.00	25.24
A14	16.75	8.57	0.00	25.32
A15	11.77	3.00	0.00	14.77

According to the weighted sum results, bidder A1 achieved the highest score. However the evaluation committee selected A2 under their discretion, since the price was less than MVR25,000.

7.4.7 Sample 7

Sample 7 is a procurement of building repair works. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.13. The weights are given below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.13: Sample 7 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	75	240,750.00	14	0	3
A2	85	284,820.00	12	0	17
A3	58	197,961.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.14 shows the results of applying weighted sum.

Table 7.14: Weighted Sum Results of Sample 7

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	32.89	15.47	14.00	3.53	0.00	65.89
A2	27.80	13.65	12.00	20.00	0.00	73.45
A3	40.00	20.00	3.00	3.53	0.00	66.53

According to the weighted sum results, bidder A2 achieved the highest score and won the procurement.

7.4.8 Sample 8

Sample 8 is a procurement of repair works of a science laboratory. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.15. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.15: Sample 8 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	20	92,232.00	14	0	3
A2	12	34,200.00	12	0	17
A3	15	40,720.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.16 shows the results of applying weighted sum.

Table 7.16: Weighted Sum results of Sample 8

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	14.83	12.00	15.00	3.53	0.00	45.36
A2	40.00	20.00	12.86	20.00	0.00	92.86
A3	33.60	16.00	3.21	3.53	0.00	56.34

According to the weighted sum results, bidder A2 achieved the highest score. Therefore, A2 was the best candidate to be awarded the bid.

7.4.9 Sample 9

Sample 9 is a procurement of repair works of a science laboratory. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.17. The weights are shown below the listed criteria. Duration and price are cost criteria targeted to minimise outlay and the rest of the criteria are beneficial criteria targeted to maximise outcomes.

Table 7.17: Sample 9 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	15	59,140.00	14	0	3
A2	18	62,220.00	12	0	17
A3	20	23,341.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.18 shows the results of applying weighted sum.

Table 7.18: Weighted Sum results of Sample 9

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	15.79	20.00	15.00	3.53	0.00	54.32
A2	15.01	16.67	12.86	20.00	0.00	64.53
A3	40.00	15.00	3.21	3.53	0.00	61.74

According to the weighted sum results, bidder A2 achieved the highest score. Therefore, A2 was the best candidate to be awarded the procurement.

7.4.10 Sample 10

Sample 10 is a procurement of repair works of interior painting. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.19. The weights are shown below the listed criteria. Duration and

price are cost criteria targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.19: Sample 10 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	15	32,656.00	14	0	3
A2	20	71,500.00	12	0	17
A3	10	24,000.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.20 shows the results of applying weighted sum.

Table 7.20: Weighted Sum results of Sample 10

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	29.40	13.33	15.00	3.53	0.00	61.26
A2	13.43	10.00	12.86	20.00	0.00	56.28
A3	40.00	20.00	3.21	3.53	0.00	66.74

According to the weighted sum results, bidder A3 achieved the highest score. Therefore, A3 was the best candidate to award the procurement.

7.4.11 Sample 11

Sample 11 is a procurement of repair works of interior painting. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.21. The weights are shown below the listed criteria. Duration and

price are cost criteria targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.21: Sample 11 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	15	30,945.00	14	0	3
A2	19	65,450.00	12	0	17
A3	7	102,000.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.22 shows the results of applying weighted sum.

Table 7.22: Weighted Sum results of Sample 11

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	40.00	9.33	15.00	3.53	0.00	67.86
A2	18.91	7.37	12.86	20.00	0.00	59.14
A3	12.14	20.00	3.21	3.53	0.00	38.88

According to the weighted sum results, bidder A1 achieved the highest score. Therefore, A1 was the best candidate to be award the procurement.

7.4.12 Sample 12

Sample 12 is a procurement of repair works of interior painting. Three companies submitted bids. The criteria, weights and supplier performances are shown in Table 7.23. The weights are shown below the listed criteria. Duration and

price are cost criteria targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.23: Sample 12 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
	20	40	15	5	20
A1	10	25,777.00	14	0	3
A2	16	62,450.00	12	0	17
A3	6	7,900.00	3	0	3

Duration is counted in days, price in MVR, and experience in years; financial capability and technical capability show their allocated marks. Table 7.24 shows the results of applying weighted sum.

Table 7.24: Weighted Sum results of Sample 12

Bidders	Price	Duration	Experience	Technical capability	Financial capability	Total
A1	12.26	12.00	15.00	3.53	0.00	42.79
A2	5.06	7.50	12.86	20.00	0.00	45.42
A3	40.00	20.00	3.21	3.53	0.00	66.74

According to the weighted sum results, bidder A3 achieved the highest score. Therefore, A3 was the best candidate to be awarded the procurement.

7.4.13 Sample 13

Sample 13 is a procurement of security services. Five companies submitted the bids. The criteria, weights and supplier performances are shown in Table 7.25.

The weights are shown below the listed criteria. Price is a cost criterion targeted to minimise outlay and the rest are beneficial criteria targeted to maximise outcomes.

Table 7.25: Sample 13 data

Bidder	Price	Experience	
		Financial capability	Technical capability
	50	**10**	**25**
A1	12,000.00	10	25
A2	9,180.00	10	10
A3	12,620.00	0	18
A4	8,500.00	5	5
A5	10,500.00	3	5

Price is in MVR; financial capability and technical capability show their allocated marks. Table 7.26 shows the results of applying weighted sum.

Table 7.26: Weighted Sum results of Sample 13

Bidders	Price	Experience		Total
		Financial capability	Technical capability	
A1	35.42	10.00	25.00	70.42
A2	46.30	10.00	10.00	66.30
A3	33.68	0.00	18.00	51.68
A4	50.00	5.00	5.00	60.00
A5	40.48	3.00	5.00	48.48

According to the weighted sum results, bidder A1 achieved the highest score and won the procurement.

7.5 Application of TOPSIS

TOPSIS was applied to the sets of data samples above using the TOPSIS formulae provide in Section 6.3.2.1. The following sections show the significant parts of the results obtained with TOPSIS, which include a weighted normalised matrix, positive-ideal solution (A^+), negative-ideal solution (A^-), separation measures from the ideal solution (d_j^+), separation measures from the negative-ideal solution (d_j^-), relative closeness to the ideal solution (R_j), and the ranks obtained.

7.5.1 Sample 1: TOPSIS application

Table 7.27 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 1 data presented in Table 7.1 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest are beneficial criteria targeted to maximise.

Table 7.27: TOPSIS weighted normalised matrix for Sample 1 data

Bidder	Duration	Price	No. Of Years	Similar Tasks	Financial Strength
A1	0.231217	0.23852	0.070711	0.070711	0.070711
A2	0.154145	0.193218	0	0	0
A3	0.11304	0.256466	0.070711	0.070711	0.070711
A^+	0.11304	0.193218	0.070711	0.070711	0.070711
A^-	0.231217	0.256466	0	0	0

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.28.

Table 7.28: TOPSIS results for Sample 1 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.126563	0.123782	0.494446	2
A2	0.129188	0.099702	0.435588	3
A3	0.063248	0.170194	0.729064	1

Based on the TOPSIS results bidder A3 was closest to the ideal solution, getting the highest score, which ranked the bidder in first place.

7.5.2 Sample 2: TOPSIS application

Table 7.29 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 2 data presented in Table 7.3 by TOPSIS. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise.

Table 7.29: TOPSIS weighted normalised matrix for Sample 2 data

Bidder	Duration	Price	Experience
A1	0.057346	0.536639	0.102068
A2	0.081923	0.523945	0.109919
A^+	0.057346	0.523945	0.109919
A^-	0.081923	0.536639	0.102068

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.30.

Table 7.30: TOPSIS results for Sample 2 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.014926	0.024577	0.62216	1
A2	0.024577	0.014926	0.37784	2

Based on the TOPSIS results, bidder A1 was closest to the ideal solution getting the highest score, which ranked the bidder in first place.

7.5.3 Sample 3: TOPSIS application

Table 7.31 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 3 data presented in Table 7.5 by TOPSIS. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise.

Table 7.31: TOPSIS weighted matrix for Sample 3 data

Bidder	Duration	Price	Experience
A1	0.039101	0.244021	0.075
A2	0.244379	0.219438	0.075
A3	0.244379	0.311404	0.075
A4	0.039101	0.212905	0.075
A^+	0.039101	0.212905	0.075
A^-	0.244379	0.311404	0.075

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.32.

Table 7.32: TOPSIS results for Sample 3 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.031117	0.216055	0.874109	2
A2	0.205382	0.091965	0.309286	3
A3	0.227687	0	0	4
A4	0	0.227687	1	1

Based on the TOPSIS results, bidder A4 is closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.4 Sample 4: TOPSIS application

Table 7.33 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 4 data presented in Table 7.7 by TOPSIS. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise.

Table 7.33: TOPSIS weighted normalised matrix for Sample 4 data

Bidder	Duration	Price	Experience
A1	0.006122	0.053483	0
A2	0.018367	0.125441	0
A3	0.034284	0.15147	0
A4	0.031835	0.161745	0
A5	0.034284	0.374483	0
A6	0.073466	0.39352	0
A7	0.029387	0.446882	0
A^+	0.006122	0.053483	0
A^-	0.073466	0.446882	0

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.34.

Table 7.34: TOPSIS results for Sample 4 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0	0.399122	1	1
A2	0.072993	0.326129	0.817116	2
A3	0.101954	0.298	0.745086	3
A4	0.111274	0.28816	0.721421	4
A5	0.322234	0.082321	0.203487	5
A6	0.346642	0.053362	0.133404	6
A7	0.394087	0.04408	0.100601	7

Based on the TOPSIS results, bidder A1 is closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.5 Sample 5: TOPSIS application

Table 7.35 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 5 data presented in Table 7.9 by TOPSIS. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise.

Table 7.35: TOPSIS weighted normalised matrix for Sample 5 data

Bidder	Duration	Price	Experience
A1	0.027136	0.313784	0.033848
A2	0.075378	0.359938	0.071457
A3	0.045227	0.411878	0.045131
A4	0.039196	0.49228	0.04137
A^+	0.027136	0.313784	0.071457
A^-	0.075378	0.49228	0.033848

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.36.

Table 7.36: TOPSIS results for Sample 5 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.037609	0.1849	0.830978	1
A2	0.066764	0.137582	0.673279	2
A3	0.103164	0.086607	0.456378	3
A4	0.181415	0.036955	0.169231	4

Based on the TOPSIS results, bidder A1 was closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.6 Sample 6: TOPSIS application

Table 7.37 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 6 data presented in Table 7.11 by TOPSIS. Duration and price are cost criteria targeted to minimise and the experience is a beneficial criteria targeted to maximise.

Table 7.37: TOPSIS weighted normalised matrix for Sample 6 data

Bidder	Duration	Price	Experience
A1	0.022054	0.06038	0.0078
A2	0.026465	0.068477	0.099695
A3	0.019849	0.096134	0
A4	0.015438	0.133109	0
A5	0.017643	0.140504	0
A6	0.017643	0.144202	0
A7	0.026465	0.143462	0
A8	0.022054	0.169929	0
A9	0.044108	0.179328	0
A10	0.033081	0.20521	0
A11	0.022054	0.221109	0
A12	0.013232	0.277311	0
A13	0.022054	0.251059	0
A14	0.015438	0.288403	0
A15	0.044108	0.41042	0
A^+	0.013232	0.06038	0.099695
A^-	0.044108	0.41042	0

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.38.

Table 7.38: TOPSIS results for Sample 6 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.092318	0.350821	0.791673	2
A2	0.015513	0.356617	0.958312	1
A3	0.106119	0.315221	0.748138	3
A4	0.123424	0.278789	0.693137	4
A5	0.127979	0.27121	0.679403	5
A6	0.130325	0.267531	0.672431	6
A7	0.130449	0.26754	0.67223	7
A8	0.148384	0.241501	0.619415	8
A9	0.158244	0.231093	0.593555	9
A10	0.176943	0.205506	0.537342	10
A11	0.189343	0.190591	0.501642	11
A12	0.238743	0.136643	0.364007	13
A13	0.21535	0.16088	0.427611	12
A14	0.248875	0.12534	0.334941	14
A15	0.365268	0	0	15

Based on the TOPSIS results, bidder A2 was closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.7 Sample 7: TOPSIS application

Table 7.39 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 7 data presented in Table 7.13 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.39: TOPSIS weighted normalised matrix for Sample 7 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.1178	0.228079	0.11241	0	0.034244
A2	0.133507	0.26983	0.096352	0	0.194048
A3	0.091099	0.187542	0.024088	0	0.034244
A^+	0.091099	0.187542	0.11241	0	0.194048
A^-	0.133507	0.26983	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.40.

Table 7.40: TOPSIS results for Sample 7 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.167014	0.098948	0.372038	2
A2	0.093955	0.175384	0.651164	1
A3	0.182588	0.092573	0.336431	3

Based on the TOPSIS results, bidder A2 was closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.8 Sample 8: TOPSIS application

Table 7.41 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 8 data presented in Table 7.15 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.41: TOPSIS weighted normalised matrix for Sample 8 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.144244	0.34653	0.11241	0	0.034244
A2	0.086546	0.128495	0.096352	0	0.194048
A3	0.108183	0.152991	0.024088	0	0.034244
A^+	0.086546	0.128495	0.11241	0	0.194048
A^-	0.144244	0.34653	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.42.

Table 7.42: TOPSIS results for Sample 8 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.276416	0.088322	0.242153	3
A2	0.016059	0.285706	0.946784	1
A3	0.18549	0.196869	0.51488	2

Based on the TOPSIS results, bidder A2 was closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.9 Sample 9: TOPSIS application

Table 7.43 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 9 data presented in Table 7.17 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.43: TOPSIS weighted normalised matrix for Sample 9 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.097384	0.265921	0.11241	0	0.034244
A2	0.116861	0.27977	0.096352	0	0.194048
A3	0.129845	0.104952	0.024088	0	0.034244
A^+	0.097384	0.104952	0.11241	0	0.194048
A^-	0.129845	0.27977	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.44.

Table 7.44: TOPSIS results for Sample 9 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.226822	0.095113	0.29544	3
A2	0.176631	0.175864	0.498912	1
A3	0.185451	0.174818	0.485243	2

Based on the TOPSIS results, bidder A2 was closest to the ideal solution getting the highest score, which ranked this bidder in first place.

7.5.10 Sample 10: TOPSIS application

Table 7.45 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 10 data presented in Table 7.19 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.45: TOPSIS weighted normalised matrix for Sample 10 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.111417	0.158936	0.11241	0	0.034244
A2	0.148556	0.347988	0.096352	0	0.194048
A3	0.074278	0.116807	0.024088	0	0.034244
A^+	0.074278	0.116807	0.11241	0	0.194048
A^-	0.148556	0.347988	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.46.

Table 7.46: TOPSIS results for Sample 10 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.169386	0.211946	0.555804	2
A2	0.243351	0.175384	0.418842	3
A3	0.182588	0.24282	0.570794	1

Based on the TOPSIS results, bidder A3 was closest to the ideal solution getting the highest score, which ranked the bidder in first place.

7.5.11 Sample 11: TOPSIS application

Table 7.47 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 11 data presented in Table 7.21 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.47: TOPSIS weighted normalised matrix for Sample 11 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.119051	0.09896	0.11241	0	0.034244
A2	0.150798	0.209304	0.096352	0	0.194048
A3	0.055557	0.326188	0.024088	0	0.034244
A^+	0.055557	0.09896	0.11241	0	0.194048
A^-	0.150798	0.326188	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.48.

Table 7.48: TOPSIS results for Sample 11 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.171956	0.245849	0.588429	2
A2	0.146645	0.210764	0.5897	1
A3	0.291498	0.095241	0.246267	3

Based on the TOPSIS results, bidder A2 was closest to the ideal solution getting the highest score, which ranked the bidder in first place.

7.5.12 Sample 12: TOPSIS application

Table 7.49 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 12 data presented in Table 7.23 by TOPSIS. Duration and price are cost criteria targeted to minimise and the rest of the criteria are beneficial criteria targeted to maximise.

Table 7.49: TOPSIS weighted normalised matrix for Sample 12 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.101015	0.151582	0.11241	0	0.034244
A2	0.161624	0.367239	0.096352	0	0.194048
A3	0.060609	0.046456	0.024088	0	0.034244
A^+	0.060609	0.046456	0.11241	0	0.194048
A^-	0.161624	0.367239	0.024088	0	0.034244

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.50.

Table 7.50: TOPSIS results for Sample 12 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.195504	0.240795	0.551904	2
A2	0.336695	0.175384	0.342494	3
A3	0.182588	0.336312	0.648125	1

Based on the TOPSIS results, bidder A3 was closest to the ideal solution getting the highest score, which ranked the bidder in first place.

7.5.13 Sample 13: TOPSIS application

Table 7.51 shows the weighted normalised matrix, positive-ideal solution, and negative-ideal solution for Sample 13 data presented in Table 7.25 by TOPSIS. Price is cost criteria targeted to minimise and the other two criteria are beneficial criteria targeted to maximise.

Table 7.51: TOPSIS weighted normalised matrix for Sample 13 data

Bidder	Price	Financial capability	Technical capability
A1	0.295652	0.076908	0.2218
A2	0.226174	0.076908	0.08872
A3	0.310927	0	0.159696
A4	0.20942	0.038454	0.04436
A5	0.258696	0.023072	0.04436
A^+	0.20942	0.076908	0.2218
A^-	0.310927	0	0.04436

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.52.

Table 7.52: TOPSIS results for Sample 13 data

Bidder	d_j^+	d_j^-	R_j	Rank
A1	0.086232	0.193993	0.692276	1
A2	0.134131	0.122743	0.477834	2
A3	0.141688	0.115336	0.448737	3
A4	0.181559	0.108547	0.374163	4
A5	0.191863	0.057101	0.229354	5

Based on the TOPSIS results, bidder A1 was closest to the ideal solution getting the highest score, which ranked the bidder in first place.

7.6 Application of COPRAS

COPRAS was applied to the sets of data samples using the COPRAS formulae provide in Section 6.3.2.8. The following sections show the significant parts of the results obtained with COPRAS which include sums of weighted normalised values calculated for the beneficial attributes (S_{+i}) and non-beneficial

attributes(S_{-i}), relative significances or priorities of the alternatives (Q_i), quantitative utility (U_i), and the ranks obtained.

7.6.1 Sample 1: COPRAS application

The following Table 7.53 shows the weighted normalised matrix for Sample 1 data presented in Table 7.1 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest are beneficial attributes targeted to maximise.

Table 7.53: COPRAS weighted normalised matrix for Sample 1 data

Bidder	Duration	Price	No. Of Years	Similar Task	Financial Strength
A1	0.139175	0.138633	0.05	0.05	0.05
A2	0.092784	0.112303	0	0	0
A3	0.068041	0.149064	0.05	0.05	0.05

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.54.

Table 7.54: COPRAS results for Sample 1 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.15	0.277809	0.342615	86.41619	2
A2	0	0.205086	0.260915	65.80935	3
A3	0.15	0.217105	0.396471	100	1

Based on the COPRAS results, bidder A3 achieved the highest value utility score, which ranked the bidder in first place.

7.6.2 Sample 2: COPRAS application

The following Table 7.55 shows the weighted normalised matrix for Sample 2 data presented in Table 7.3 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and experience is a beneficial attribute targeted to maximise.

Table 7.55: COPRAS weighted normalised matrix for Sample 2 data

Bidder	Duration	Price	Experience
A1	0.041176	0.379488	0.072222
A2	0.058824	0.370512	0.077778

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.56.

Table 7.56: COPRAS results for Sample 2 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.072222	0.420665	0.501558	100	1
A2	0.077778	0.429335	0.498442	99.37893	2

Based on the COPRAS results, bidder A1 achieved the highest value utility score, which ranked the bidder in first place.

7.6.3 Sample 3: COPRAS application

The following Table 7.57 shows the weighted normalised matrix for Sample 3 data presented in Table 7.5 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and experience is a beneficial attribute targeted to maximise.

Table 7.57: COPRAS weighted normalised matrix for Sample 3 data

Bidder	Duration	Price	Experience
A1	0.024138	0.123522	0.0375
A2	0.150862	0.111078	0.0375
A3	0.150862	0.15763	0.0375
A4	0.024138	0.107771	0.0375

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.58.

Table 7.58: COPRAS results for Sample 3 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.0375	0.14766	0.306336	90.51486	2
A2	0.0375	0.26194	0.189047	55.85879	3
A3	0.0375	0.308492	0.166178	49.10162	4
A4	0.0375	0.131909	0.338438	100	1

Based on the COPRAS results, bidder A4 achieved the highest value utility score, which ranked the bidder in first place.

7.6.4 Sample 4: COPRAS application

The following Table 7.59 shows the weighted normalised matrix for Sample 4 data presented in Table 7.7 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and experience is a beneficial attribute targeted to maximise.

Table 7.59: COPRAS weighted normalised matrix for Sample 4 data

Bidder	Duration	Price	Experience
A1	0.002688	0.023498	0
A2	0.008065	0.055114	0
A3	0.015054	0.06655	0
A4	0.013978	0.071064	0
A5	0.015054	0.164533	0
A6	0.032258	0.172897	0
A7	0.012903	0.196343	0

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.60.

Table 7.60: COPRAS results for Sample 4 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0	0.026186	0.348089	100	1
A2	0	0.063179	0.144277	41.44825	2
A3	0	0.081604	0.111701	32.08977	3
A4	0	0.085043	0.107184	30.79202	4
A5	0	0.179587	0.050756	14.58146	5
A6	0	0.205155	0.044431	12.76419	6
A7	0	0.209246	0.043562	12.51467	7

Based on the COPRAS results, bidder A1 achieved the highest value utility score, which ranked the bidder in first place.

7.6.5 Sample 5: COPRAS application

The following Table 7.61 shows the weighted normalised matrix for Sample 5 data presented in Table 7.9 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and experience is a beneficial attribute targeted to maximise.

Table 7.61: COPRAS weighted normalised matrix for Sample 5 data

Bidder	Duration	Price	Experience
A1	0.014516	0.159091	0.017647
A2	0.040323	0.182492	0.037255
A3	0.024194	0.208826	0.023529
A4	0.020968	0.24959	0.021569

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.62.

Table 7.62: COPRAS results for Sample 5 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.017647	0.173608	0.30193	100	1
A2	0.037255	0.222815	0.258756	85.70068	2
A3	0.023529	0.23302	0.23533	77.9419	3
A4	0.021569	0.270558	0.203983	67.55967	4

Based on the COPRAS results, bidder A1 achieved the highest value utility score, which ranked the bidder in first place.

7.6.6 Sample 6: COPRAS application

The following Table 7.63 shows the weighted normalised matrix for Sample 6 data presented in Table 7.11 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and experience is a beneficial attribute targeted to maximise.

Table 7.63: COPRAS weighted normalised matrix for Sample 6 data

Bidder	Duration	Price	Experience
A1	0.006098	0.017319	0.007256
A2	0.007317	0.019642	0.092744
A3	0.005488	0.027575	0
A4	0.004268	0.038181	0
A5	0.004878	0.040302	0
A6	0.004878	0.041362	0
A7	0.007317	0.04115	0
A8	0.006098	0.048742	0
A9	0.012195	0.051438	0
A10	0.009146	0.058862	0
A11	0.006098	0.063422	0
A12	0.003659	0.079543	0
A13	0.006098	0.072013	0
A14	0.004268	0.082725	0
A15	0.012195	0.117724	0

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.64.

Table 7.64: COPRAS results for Sample 6 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.007256	0.023417	0.133251	65.90576	2
A2	0.092744	0.026959	0.202184	100	1
A3	0	0.033063	0.089236	44.13599	3
A4	0	0.042449	0.069504	34.37673	4
A5	0	0.04518	0.065303	32.29882	5
A6	0	0.04624	0.063805	31.55801	6
A7	0	0.048467	0.060873	30.10803	7
A8	0	0.054839	0.0538	26.60962	8
A9	0	0.063633	0.046366	22.9324	9
A10	0	0.068008	0.043383	21.45706	10
A11	0	0.06952	0.042439	20.99049	11
A12	0	0.083202	0.035461	17.5388	13
A13	0	0.078111	0.037772	18.68194	12
A14	0	0.086993	0.033915	16.7744	14
A15	0	0.129919	0.022709	11.23206	15

Based on the COPRAS results, bidder A2 achieved the highest value utility score, which ranked the bidder in first place.

7.6.7 Sample 7: COPRAS application

The following Table 7.65 shows the weighted normalised matrix for Sample 7 data presented in Table 7.13 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.65: COPRAS weighted normalised matrix for Sample 7 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.068807	0.133097	0.072414	0	0.026087
A2	0.077982	0.157461	0.062069	0	0.147826
A3	0.053211	0.109442	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.66.

Table 7.66: COPRAS results for Sample 7 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.201905	0.292119	77.70511	2
A2	0.209895	0.235443	0.375933	100	1
A3	0.041604	0.162653	0.281948	74.99938	3

Based on the COPRAS results, bidder A2 achieved the highest value utility score, which ranked the bidder in first place.

7.6.8 Sample 8: COPRAS application

The following Table 7.67 shows the weighted normalised matrix for Sample 8 data presented in Table 7.15 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.67: COPRAS weighted normalised matrix for Sample 8 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.085106	0.220714	0.072414	0	0.026087
A2	0.051064	0.081842	0.062069	0	0.147826
A3	0.06383	0.097444	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.68.

Table 7.68: COPRAS results for Sample 8 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.30582	0.213945	42.44667	3
A2	0.209895	0.132906	0.504032	100	1
A3	0.041604	0.161274	0.284002	56.34599	2

Based on the COPRAS results, bidder A2 achieved the highest value utility score, which ranked the bidder in first place.

7.6.9 Sample 9: COPRAS application

The following Table 7.69 shows the weighted normalised matrix for Sample 9 data presented in Table 7.17 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.69: COPRAS weighted normalised matrix for Sample 9 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.056604	0.163482	0.072414	0	0.026087
A2	0.067925	0.171996	0.062069	0	0.147826
A3	0.075472	0.064522	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.70.

Table 7.70: COPRAS results for Sample 9 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.220086	0.270448	73.56589	3
A2	0.209895	0.239921	0.367627	100	1
A3	0.041604	0.139994	0.311925	84.84812	2

Based on the COPRAS results, bidder A2 achieved the highest value utility score, which ranked the bidder in first place.

7.6.10 Sample 10: COPRAS application

The following Table 7.71 shows the weighted normalised matrix for Sample 10 data presented in Table 7.19 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.71: COPRAS weighted normalised matrix for Sample 10 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.066667	0.101926	0.072414	0	0.026087
A2	0.088889	0.223166	0.062069	0	0.147826
A3	0.044444	0.074909	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.72.

Table 7.72: COPRAS results for Sample 10 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.168592	0.301697	91.80469	3
A2	0.209895	0.312054	0.319675	97.27541	2
A3	0.041604	0.119353	0.328629	100	1

Based on the COPRAS results, bidder A3 achieved the highest value utility score, which ranked the bidder in first place.

7.6.11 Sample 11: COPRAS application

The following Table 7.73 shows the weighted normalised matrix for Sample 11 data presented in Table 7.21 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.73: COPRAS weighted normalised matrix for Sample 11 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.073171	0.062391	0.072414	0	0.026087
A2	0.092683	0.131959	0.062069	0	0.147826
A3	0.034146	0.20565	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.74.

Table 7.74: COPRAS results for Sample 11 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.135561	0.375155	99.55188	2
A2	0.209895	0.224642	0.376843	100	1
A3	0.041604	0.239797	0.198002	52.54217	3

Based on the COPRAS results, bidder A2 achieved the highest value utility score, which ranked the bidder in first place.

7.6.12 Sample 12: COPRAS application

The following Table 7.75 shows the weighted normalised matrix for Sample 12 data presented in Table 7.23 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.75: COPRAS weighted normalised matrix for Sample 12 data

Bidder	Duration	Price	Experience	Financial capability	Technical capability
A1	0.0625	0.107262	0.072414	0	0.026087
A2	0.1	0.259865	0.062069	0	0.147826
A3	0.0375	0.032873	0.015517	0	0.026087

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.76.

Table 7.76: COPRAS results for Sample 12 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.098501	0.169762	0.252979	61.06857	3
A2	0.209895	0.359865	0.282768	68.25977	2
A3	0.041604	0.070373	0.414253	100	1

Based on the COPRAS results, bidder A3 achieved the highest value utility score, which ranked the bidder in first place.

7.6.13 Sample 13: COPRAS application

The following Table 7.77 shows the weighted normalised matrix for Sample 13 data presented in Table 7.25 by COPRAS. Duration and price are non-beneficial attributes targeted to minimise and the rest of attributes are beneficial attribute targeted to maximise.

Table 7.77: COPRAS weighted normalised matrix for Sample 13 data

Bidder	Price	Financial capability	Technical capability
A1	0.113636	0.035714	0.099206
A2	0.086932	0.035714	0.039683
A3	0.119508	0	0.071429
A4	0.080492	0.017857	0.019841
A5	0.099432	0.010714	0.019841

Using the weighted normalised matrix by COPRAS calculated sums of weighted normalised values for the beneficial attributes and non-beneficial attributes, relative significances of the alternatives, quantitative utility, and the ranks obtained. These results are shown in Table 7.78.

Table 7.78: COPRAS results for Sample 13 data

Bidder	S_{+i}	S_{-i}	Q_i	U_i	Rank
A1	0.134921	0.113636	0.220939	100	1
A2	0.075397	0.086932	0.18784	85.01864	2
A3	0.071429	0.119508	0.153221	69.34996	4
A4	0.037698	0.080492	0.159137	72.0273	3
A5	0.030556	0.099432	0.128863	58.32492	5

Based on the COPRAS results, bidder A1 achieved the highest value utility score, which ranked the bidder in first place.

7.7 Comparative results

The final results and the rankings by the two filtered methods, TOPSIS and COPRAS for these sample procurements are studied along with the results of weighted sum (WS), which is the method used by the public sector institutions of the Maldives. The rankings produced alternative winners through the application of different methods for some of the samples, while some of the results show that the rankings for the alternatives were the same for all three methods. However, even in the latter cases, the preference gap between the alternatives for different methods varies. Such performance analyses are calculated and discussed in the next section.

The combined results from the three methods are shown and discussed below for every sample.

The results of the three methods for the sample 1 data are shown in Table 7.79.

Table 7.79: Results of the three methods for Sample 1

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	71.77	0.494446	86.41619	2	2	2
A2	62	0.435588	65.80935	3	3	3
A3	85.2	0.729064	100	1	1	1

The three methods provide the same rankings for alternative bidders. A3 being most preferred, A1 the second preference and A2 ranked third.

The results of the three methods for Sample 2 data are shown in Table 7.80.

Table 7.80: Results of the three methods for Sample 2

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	96.23	0.62216	100	1	1	1
A2	96	0.37784	99.37893	2	2	2

The three methods provide the same rakings for alternative bidders, A1 being most preferred alternative and A2 the second.

The results of the three methods for the Sample 3 data are shown in Table 7.81.

Table 7.81: Results of the three methods for Sample 3

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	93.6242	0.874109	90.51486	2	2	2
A2	69.11133	0.309286	55.85879	3	3	3
A3	54.78469	0	49.10162	4	4	4
A4	100	1	100	1	1	1

The three methods provide the same rankings for alternative bidders, A4 being most preferred, A1 having the second preference, A2 the third preference, and A3 being ranked fourth.

The results of the three methods for Sample 4 data are shown in Table 7.82.

Table 7.82: Results of the three methods for Sample 4

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	85	1	100	1	1	1
A2	35.31008	0.817116	41.44825	2	2	2
A3	28.26763	0.745086	32.08977	3	3	3
A4	26.72268	0.721421	30.79202	4	4	4
A5	12.49703	0.203487	14.58146	5	5	5
A6	11.02649	0.133404	12.76419	6	6	6
A7	11.05932	0.100601	12.51467	7	7	7

The three methods provide the same rankings for alternative bidders, A1 being the most preferred alternative, A2 being the second preference, and A7 being ranked last.

The results of the three methods for Sample 5 data are shown in Table 7.83.

Table 7.83: Results of the three methods for Sample 5

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	100	0.830978	100	1	1	1
A2	78.07866	0.673279	85.70068	2	2	2
A3	74.44699	0.456378	77.9419	3	3	3
A4	66.0977	0.169231	67.55967	4	4	4

The three methods provide the same rankings for alternative bidders, A1 being the most preferred alternative, A2 the second preference, and A4 ranked last.

The results of the three methods for Sample 6 data are shown in Table 7.84.

Table 7.84: Results of the three methods for Sample 6

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	86.64	0.791673	65.90576	**1**	**2**	**2**
A2	83.71996	0.958312	100	**2**	**1**	**1**
A3	56.91282	0.748138	44.13599	3	3	3
A4	44.86032	0.693137	34.37673	4	4	4
A5	41.87895	0.679403	32.29882	5	5	5
A6	40.99744	0.672431	31.55801	6	6	6
A7	38.6701	0.67223	30.10803	7	7	7
A8	34.42595	0.619415	26.60962	8	8	8
A9	29.93608	0.593555	22.9324	9	9	9
A10	27.53874	0.537342	21.45706	10	10	10
A11	27.84615	0.501642	20.99049	11	11	11
A12	27.41867	0.364007	17.5388	**12**	**13**	**13**
A13	25.24006	0.427611	18.68194	**13**	**12**	**12**
A14	25.32015	0.334941	16.7744	14	14	14
A15	14.76937	0	11.23206	15	15	15

The three methods provide different rankings for 1, 2, 12 and 13 but for the others the same rankings are realised. A1 is the most preferred alternative using WA but the second preference by TOPSIS and COPRAS. A2 is the second most preferred alternative by WA but the most preferred using TOPSIS and COPRAS. Similarly, A12 is the 12th preference by WA but 13th by TOPSIS and COPRAS, while A13 is the 13th preference by WA but 12th preference by TOPSIS and COPRAS.

The results of the three methods for Sample 7 data are shown in Table 7.85.

Table 7.85: Results of the three methods for Sample 7

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	65.88679	0.372038	77.70511	**3**	**2**	**2**
A2	73.44862	0.651164	100	1	1	1
A3	66.52941	0.336431	74.99938	**2**	**3**	**3**

The three methods provide different rankings for A1, and A3 but first ranking was given to A2 by all methods. A1 is the third most preferred alternative using WA but the second most preferred by TOPSIS and COPRAS, while A3 is the second most preferred alternative using WA but the third by TOPSIS and COPRAS.

The results of the three methods for the Sample 8 data are shown in Table 7.86.

Table 7.86: Results of the three methods for Sample 8

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	45.36157	0.242153	42.44667	3	3	3
A2	92.85714	0.946784	100	1	1	1
A3	56.33898	0.51488	56.34599	2	2	2

The three methods provide the same rankings for alternative bidders, A2 being the most preferred alternative, A3 the second preference, and A1 ranked last.

The results of the three methods for Sample 9 data are shown in Table 7.87.

Table 7.87: Results of the three methods for Sample 9

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	54.31636	0.29544	73.56589	3	3	3
A2	64.52927	0.498912	100	1	1	1
A3	61.7437	0.485243	84.84812	2	2	2

The three methods provide the same rankings for alternative bidders, A2 being the most preferred alternative, A3 the second, and A1 being ranked last.

The results of the three methods for Sample 10 data are shown in Table 7.88.

Table 7.88: Results of the three methods for Sample 10

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	61.2601	0.555804	91.80469	**2**	**2**	**3**
A2	56.28372	0.418842	97.27541	**3**	**3**	**2**
A3	66.7437	0.570794	100	1	1	1

The three methods provide different rankings for A1 and A2 but first ranking was given to A3 by the methods. A1 is the second most preferred alternative by WA and TOPSIS but the third most preferred by COPRAS. A2 is the third most preferred alternative using WA and TOPSIS but second by COPRAS.

The results of the three methods for Sample 11 data are shown in Table 7.89.

Table 7.89: Results of the three methods for Sample 11

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	67.86275	0.588429	99.55188	**1**	**2**	**2**
A2	59.13771	0.5897	100	**2**	**1**	**1**
A3	38.87899	0.246267	52.54217	3	3	3

The three methods provide different rankings for A1, and A2 but the third ranking was given to A3 by all methods. A1 is the most preferred alternative by WA but second most preferred by COPRAS and TOPSIS. A2 is the second most preferred alternative by WA but the most preferred one by COPRAS and TOPSIS.

The results of the three methods for Sample 12 data are shown in Table 7.90.

Table 7.90: Results of the three methods for Sample 12

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	42.7884	0.551904	61.06857	**3**	**2**	**3**
A2	45.41719	0.342494	68.25977	**2**	**3**	**2**
A3	66.7437	0.648125	100	1	1	1

The three methods provide different rankings for A1 and A2 but first ranking was given to A3 by all the methods. A1 is third most preferred alternative by WA and COPRAS but second most preferred by TOPSIS. A2 is second most preferred alternative by WA and COPRAS but third most preferred by TOPSIS.

The results of the three methods for Sample 13 data are shown in Table 7.91.

Table 7.91: Results of the three methods for Sample 13

Alternative	Results			Ranking		
	WS	TOPSIS	COPRAS	WA	TOPSIS	COPRAS
A1	70.41667	0.692276	100	1	1	1
A2	66.2963	0.477834	85.01864	2	2	2
A3	51.6767	0.448737	69.34996	**4**	**3**	**4**
A4	60	0.374163	72.0273	**3**	**4**	**3**
A5	48.47619	0.229354	58.32492	5	5	5

The three methods provide different rankings for A3 and A4 but first ranking was given to A1 by all methods. A3 is the fourth most preferred alternative using WA and COPRAS but third by TOPSIS. A4 is the third most preferred alternative by WA and COPRAS but fourth by TOPSIS.

Considering the changes in the results of the different methods the next section discusses the performance of the three methods with real procurement data.

7.8 Performance analysis

Performance analysis is used to understand how the two filtered methods behave with the real life procurement data from the Maldivian context. Three different performance analyses were conducted and discussed.

The first analysis is congruence/incongruence of ranking analysis by calculating correlation coefficients proposed for similar studies in literature (Antucheviciene et al., 2012; Raju & Pillai, 1999).

The second analysis is variance analysis which measures the spread of data (Field, 2005).

Finally, the third analysis is stability analysis or robustness of results of the methods judged based on the effect of changes in parameter values (Podvezko, 2011; Raju & Pillai, 1999).

The following sections show the results and discussions of the analyses.

7.8.1 Congruence/incongruence analysis

Congruence/incongruence of ranking analysis was conducted as explained in research methodology chapter, Section 2.3.4.1. The procedure and formula for the analysis are provided in the research design chapter, Section 3.6.3.

The analysis identified the correlation between the resulting ranks by the filtered methods for the alternative bidders in every sample. In addition to the results of the two filtered methods, WS results are shown to compare with the current system used by public sector institutions in the Maldives.

There was perfect correlation between the ranks produced by the three methods for samples 1, 2, 3, 4, 5, 8 and 9. For the rest of the samples there were slight changes in the correlation coefficients for some methods, as follows.

Analysis of Sample 6 results correlation coefficients as shown in Table 7.92.

Table 7.92: Rank correlation coefficient values for Sample 6

Method	WS	TOPSIS	COPRAS
WS	1.00	0.9929	0.9929
TOPSIS		1.00	1.00
COPRAS			1.00

WS and TOPSIS show a higher correlation for Sample 6 results, but not perfect correlation. Similarly, WS and COPRAS are not in perfect correlation, but show high correlation, like WS and TOPSIS. Since the correlations are very high, the methods would have minimum contention.

Analysis of Sample 7 results correlation coefficients as shown in Table 7.93.

Table 7.93: Rank correlation coefficient values for Sample 7

Method	WS	TOPSIS	COPRAS
WS	1.00	0.50	0.50
TOPSIS		1.00	1.00
COPRAS			1.00

WS and TOPSIS show partial correlation for Sample 7 results. Similarly, WS and COPRAS also show partial correlation. There were only two instances of changes in rank results with the methods. In addition, the sample size had three alternatives, which could be the cause of the semi-congruence/incongruence result.

Analysis of Sample 10 results correlation coefficients as shown in Table 7.94.

Table 7.94: Rank correlation coefficient values for Sample 10

Method	WS	TOPSIS	COPRAS
WS	1.00	1.00	0.50
TOPSIS		1.00	0.50
COPRAS			1.00

WS and COPRAS show partial correlation for Sample 10 results. Similarly, TOPSIS and COPRAS also show partial correlation. As with Sample 7, there are only two instances of changes in rank results with the methods. In addition the sample size was three alternatives. This could be the reasons for semi-congruence/incongruence result. However for this sample, only COPRAS is not in agreement, while the other methods are in perfect rank correlation. This could be due to the stability issue of COPRAS data variation stated by Podvezko, (2011). The stability tests will be carried out in the following sections.

Analysis of Sample 11 results correlation coefficients as shown in Table 7.95.

Table 7.95: Rank correlation coefficient values for Sample 11

Method	WS	TOPSIS	COPRAS
WS	1.00	0.50	0.50
TOPSIS		1.00	1.00
COPRAS			1.00

WS and TOPSIS show partial correlation for Sample 11 results. Similarly, WS and COPRAS also show partial correlation. As with Sample 7 and 10, there are only two instances of changes in rank results with these methods. In addition, the sample size has three alternatives. This could be the reasons for the semi-congruence/incongruence result. For this sample, only WS is not in agreement but the other methods are in perfect rank correlation.

Analysis of Sample 12 results correlation coefficients as shown in Table 7.96.

Table 7.96: Rank correlation coefficient values for Sample 12

Method	WS	TOPSIS	COPRAS
WS	1.00	0.50	1.00
TOPSIS		1.00	0.50
COPRAS			1.00

WS and TOPSIS show partial correlation for Sample 12 results. Similarly, TOPSIS and COPRAS also show partial correlation. As with Sample 7, 10 and 11, there are only two instances of changes in rank results with these methods. In addition, the sample size has three alternatives. This could be the reasons for semi-congruence/incongruence result. For this sample, only TOPSIS is not in agreement but the other methods are in perfect rank correlation.

Analysis of Sample 13 results correlation coefficients as shown in Table 7.97.

Table 7.97: Rank correlation coefficient values for Sample 13

Method	WS	TOPSIS	COPRAS
WS	1.00	0.90	1.00
TOPSIS		1.00	0.90
COPRAS			1.00

WS and TOPSIS show a higher correlation for Sample 13 results. Similarly, TOPSIS and COPRAS also show higher correlation. For this sample, only TOPSIS is not in agreement, resulting in partial congruence/incongruence, but the other methods are in perfect rank correlation.

Based on the congruence/incongruence analysis, 7 out of 13 samples show all the methods are in perfect condition. In two cases, TOPSIS is not in line with the rest of methods in rank correlation. Similarly, in two cases, WS is not in line with the rest of methods. COPRAS has only one case not fully congruent with other methods.

This congruence/incongruence analyses are inconclusive for identifying the best method for the public sector procurement evaluation as the results are varying in different cases for different methods.

7.8.2 Variance analysis

The variance analysis was conducted as explained in research methodology chapter, Section 2.3.4.1. The procedure and formula for the analysis are provided in the research design chapter, Section 3.6.4.

The variance analysis compares the results of TOPSIS and COPRAS to check which method spreads the data points more, with real procurement data. In addition to the results of the two filtered methods, WS results are also shown, to compare the current system used by public sector institutions in the Maldives.

To calculate variance all the results are converted to a same scale. WS results for sample 13 and all TOPSIS results were not in same scale with other results. Therefore, the results are projected to the scale of others which is between 0 and 100. The results in same scale and variances for all the samples are shown in Table 7.98 to Table 7.111 below.

Table 7.98: Results with variance for Sample 1

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	71.7700	49.4446	86.4162
A2	62.0000	43.5588	65.8093
A3	85.2000	72.9064	100.0000
Mean	72.9900	55.3032	84.0752
Variance	135.6763	241.0627	**296.3605**

Table 7.99: Results with variance for Sample 2

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	96.2300	62.2160	100.0000
A2	96.0000	37.7840	99.3789
Mean	96.1150	50.0000	99.6895
Variance	0.0265	**298.4615**	0.1929

Table 7.100: Results with variance for Sample 3

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	93.6242	87.4109	90.5149
A2	69.1113	30.9286	55.8588
A3	54.7847	0.0000	49.1016
A4	100.0000	100.0000	100.0000
Mean	79.3801	54.5849	73.8688
Variance	446.1522	**2226.4038**	632.5682

Table 7.101: Results with variance for Sample 4

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	85.0000	100.0000	100.0000
A2	35.3101	81.7116	41.4483
A3	28.2676	74.5086	32.0898
A4	26.7227	72.1421	30.7920
A5	12.4970	20.3487	14.5815
A6	11.0265	13.3404	12.7642
A7	11.0593	10.0601	12.5147
Mean	29.9833	53.1588	34.8843
Variance	682.0057	**1,390.8421**	951.6001

Table 7.102: Results with variance for Sample 5

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	100.0000	83.0978	100.0000
A2	78.0787	67.3279	85.7007
A3	74.4470	45.6378	77.9419
A4	66.0977	16.9231	67.5597
Mean	79.6558	53.2466	82.8006
Variance	209.1092	**822.2235**	186.7076

Table 7.103: Results with variance for Sample 6

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	86.6400	79.1673	65.9058
A2	83.7200	95.8312	100.0000
A3	56.9128	74.8138	44.1360
A4	44.8603	69.3137	34.3767
A5	41.8789	67.9403	32.2988
A6	40.9974	67.2431	31.5580
A7	38.6701	67.2230	30.1080
A8	34.4260	61.9415	26.6096
A9	29.9361	59.3555	22.9324
A10	27.5387	53.7342	21.4571
A11	27.8462	50.1642	20.9905
A12	27.4187	36.4007	17.5388
A13	25.2401	42.7611	18.6819
A14	25.3201	33.4941	16.7744
A15	14.7694	0.0000	11.2321
Mean	40.4117	57.2923	32.9733
Variance	433.1230	**522.2868**	522.1035

Table 7.104: Results with variance for Sample 7

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	65.8868	37.2038	77.7051
A2	73.4486	65.1164	100.0000
A3	66.5294	33.6431	74.9994
Mean	68.6216	45.3211	84.2348
Variance	17.5783	**297.0606**	188.2357

Table 7.105: Results with variance for Sample 8

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	45.3616	24.2153	42.4467
A2	92.8571	94.6784	100.0000
A3	56.3390	51.4880	56.3460
Mean	64.8526	56.7939	66.2642
Variance	618.3181	**1262.3773**	901.8750

Table 7.106: Results with variance for Sample 9

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	54.3164	29.5440	73.5659
A2	64.5293	49.8912	100.0000
A3	61.7437	48.5243	84.8481
Mean	60.1964	42.6532	86.1380
Variance	27.8714	129.3543	**175.9384**

Table 7.107: Results with variance for Sample 10

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	61.2601	55.5804	91.8047
A2	56.2837	41.8842	97.2754
A3	66.7437	57.0794	100.0000
Mean	61.4292	51.5147	96.3600
Variance	27.3742	**70.1208**	17.4192

Table 7.108: Results with variance for Sample 11

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	67.8627	58.8429	99.5519
A2	59.1377	58.9700	100.0000
A3	38.8790	24.6267	52.5422
Mean	55.2931	47.4799	84.0314
Variance	221.1000	391.7051	**743.7266**

Table 7.109: Results with variance for Sample 12

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	42.7884	55.1904	61.0686
A2	45.4172	34.2494	68.2598
A3	66.7437	64.8125	100.0000
Mean	51.6498	51.4174	76.4428
Variance	172.5978	244.2027	**429.1353**

Table 7.110: Results with variance for Sample 13

Alternative	Results		
	WS	TOPSIS	COPRAS
A1	82.8431	69.2276	100.0000
A2	77.9956	47.7834	85.0186
A3	60.7961	44.8737	69.3500
A4	70.5882	37.4163	72.0273
A5	57.0308	22.9354	58.3249
Mean	69.8508	44.4473	76.9442
Variance	120.5056	**284.3933**	256.3231

These variance results show that in most of the cases (9 out of 13) TOPSIS have higher variance contributing 69.23% of the cases. Only 4 out of 13 cases show higher variance in COPRAS contributing 30.77% while no result shows higher variance for WS as shown in Figure 7.1.

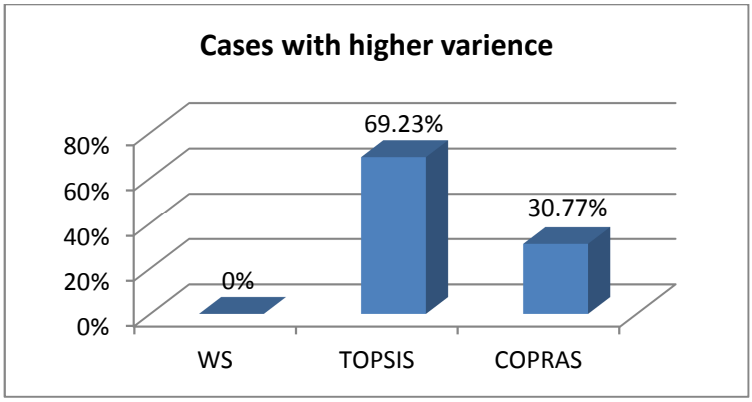

Figure 7.1: Percentage of cases with higher variance

The total variance of all the cases for TOPSIS results 8180.4946, while that of COPRAS is 5302.1860 and WS 3111.4382. The combined samples, however, for different procurements, show that TOPSIS has higher variance.

There are some inherent drawbacks of this analysis. First of all, the majority of sample sizes are small. Therefore the variances are confined only to the limited number of alternatives in each sample. However, these sample data sets are real life procurement data from Maldivian institutions. Therefore, number of alternatives are expected to be small for public sector procurements in the research context. As such, accommodation of the small number of alternatives in this analysis is acceptable.

The second inherent drawback is that COPRAS uses highest value in the range (100) for the first ranking alternative, unlike the other two methods. The use of extreme values in COPRAS could increase the variances for the method. However for this study only 4 cases have higher variances for COPRAS.

The higher the variance of the results, the farther the alternatives are from each other. Therefore the method which provides the higher variance would make alternatives more distinct from each other for better selection by the BECs. For this research project, TOPSIS provides highest variances compared to the other two methods. TOPSIS has 69.23% chance of having higher variances for public education sector procurement evaluation in Maldives. Therefore, based on this analysis, TOPSIS is preferred.

7.8.3 Stability analysis

Stability analysis or robustness analysis was conducted, as explained in research methodology chapter, Section 2.3.4.1. The procedures for the analysis are provided in the research design chapter, Section 3.6.5.

The analysis was based on the sensitivity of the methods to changes in data. The sensitivity is measured on the changes to the results of the methods and levels of change in the data. The stability analysis was applied to TOPSIS and COPRAS with the real life procurement data from the public sector institutions following the approach used by Podvezko (2011).

Podvezko (2011) changed two data parameters for a single set of data to show changes in the results by the MCDA methods used. For this study, the first set of analysis was undertaken by changing two data parameters in alternate direction. The second set of analysis was carried out by changing only one data parameter. Finally, an analysis of a case by changing two data parameters, both in favourable direction, was conducted. The following sections discuss the analyses.

7.8.3.1 Changes in two parameters in alternate direction

In this analysis two data parameters are changed. The data parameters are for two alternatives in same criteria. The values are changed in opposite direction to increase the result of lower ranking alternative and to decrease the result of higher ranking alternative. Some of the analysed samples are as follows.

Test 1: Test 1 was conducted on real life data Sample 5. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.111. For the analysis, original data values for A1 and A2 with regard to criterion ‘duration’ were changed. The value for A1 was increased by 11 and A2 decreased by 10. The results with the two changes in parameters are shown in Table 7.112.

Table 7.111: Initial data and results for Sample 5

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	9	88,600.00	0.36	0.8310	1	100.0000	1
A2	25	101,632.00	0.76	0.6733	2	85.7007	2
A3	15	116,297.78	0.48	0.4564	3	77.9419	3
A4	13	139,000.00	0.44	0.1692	4	67.5597	4

Table 7.112: Changed data and results for Sample 5 with two changes

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	**20**	88,600.00	0.36	0.8039	1	**99.9775**	**2**
A2	**15**	101,632.00	0.76	0.7483	2	**100.0000**	**1**
A3	15	116,297.78	0.48	0.4483	3	85.2655	3
A4	13	139,000.00	0.44	0.1135	4	73.8759	4

As seen in the results involving change in the data, COPRAS results are changed and the ranking altered. A1, which was ranked first, falls to second and A2 gains first rank.

The analysis also checked how much change is required in the same data parameters to alter the ranks in TOPSIS. The analysis showed that TOPSIS requires the A1 value to increase by 16 and A2 to decrease by 15. Therefore, the threshold for TOPSIS is stronger by a value of 4 for A1 and by a value of 6 for A2 compared to COPRAS as shown in the following Figure 7.2.

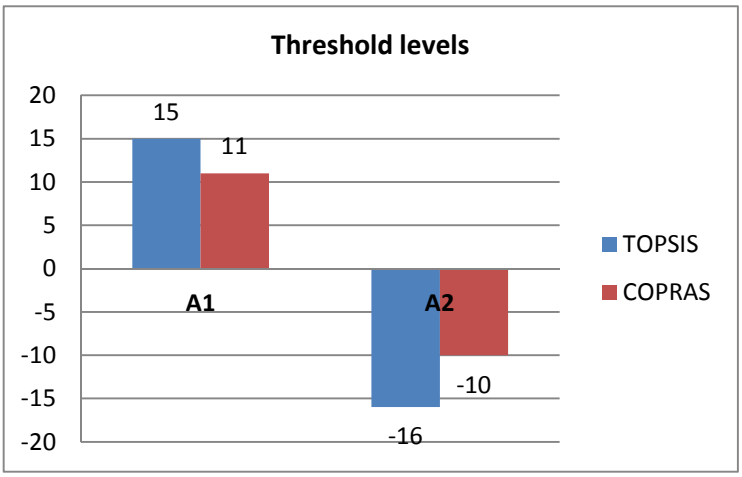

Figure 7.2: Threshold levels for TOPSIS and COPRAS in Test 1

Test 2: Test 2 was conducted on real life data Sample 4. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.113. Test 2 was targeted at the middle ranged ranks rather than top ranks, in order to check a different level. For the analysis original data values for A3 and A4 with regard to criterion 'duration' were changed. The value for A3 was increased by 3 and A4 decreased by 4. The results, with two changes in parameters are shown in Table 7.114.

Table 7.113: Initial data and results for Sample 4

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	5	16,500.00	0	1	1	100.0000	1
A2	15	38,700.00	0	0.817116	2	41.44825	2
A3	28	46,730.00	0	0.745086	3	32.08977	3
A4	26	49,900.00	0	0.721421	4	30.79202	4
A5	28	115,532.00	0	0.203487	5	14.58146	5
A6	60	121,405.00	0	0.133404	6	12.76419	6
A7	24	137,867.80	0	0.100601	7	12.51467	7

Table 7.114: Changed data and results for Sample 4 with two changes

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	5	16,500.00	0	1	1	100.0000	1
A2	15	38,700.00	0	0.817116	2	41.4427	2
A3	**31**	46,730.00	0	0.742775	3	**31.4512**	**4**
A4	**22**	49,900.00	0	0.723801	4	**31.5840**	**3**
A5	28	115,532.00	0	0.203526	5	14.5829	5
A6	60	121,405.00	0	0.133399	6	12.7604	6
A7	24	137,867.80	0	0.100702	7	12.5174	7

As seen from the results, with the very slight change in the data, COPRAS results are changed and the rankings altered. A3, which was ranked third, falls to fourth rank and A4 gains third rank.

The values of change required in the same data parameters to alter the ranks in TOPSIS were also checked. The analysis shows that TOPSIS requires the A3 value to increase by 20 and A4 to decrease by 21. Therefore, the threshold for TOPSIS is stronger by a value of 17 for A3 and A4 each, compared to COPRAS, as shown in the following Figure 7.3.

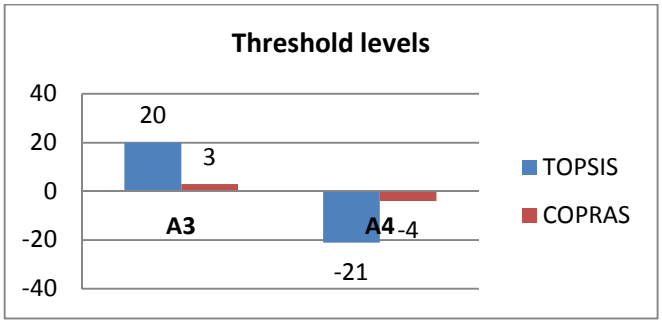

Figure 7.3: Threshold levels for TOPSIS and COPRAS in Test 2

Test 3: Test 3 was conducted on real life data Sample 6. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.115. For the analysis, original data values for A5 and A6 with regard to criterion 'duration' were changed. The value for A5 was increased by 1 and A6 decreased by 1. The results, with these two changes in parameters are shown in Table 7.116.

Table 7.115: Initial data and results for Sample 6

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	10	8,165.00	0.064	0.7917	2	65.9058	2
A2	12	9,260.00	0.818	0.9583	1	100.0000	1
A3	9	13,000.00	0	0.7481	3	44.1360	3
A4	7	18,000.00	0	0.6931	4	34.3767	4
A5	8	19,000.00	0	0.6794	5	32.2988	5
A6	8	19,500.00	0	0.6724	6	31.5580	6
A7	12	19,400.00	0	0.6722	7	30.1080	7
A8	10	22,979.00	0	0.6194	8	26.6096	8
A9	20	24,250.00	0	0.5936	9	22.9324	9
A10	15	27,750.00	0	0.5373	10	21.4571	10
A11	10	29,900.00	0	0.5016	11	20.9905	11
A12	6	37,500.00	0	0.3640	13	17.5388	13
A13	10	33,950.00	0	0.4276	12	18.6819	12
A14	7	39,000.00	0	0.3349	14	16.7744	14
A15	20	55,500.00	0	0.0000	15	11.2321	15

Table 7.116: Changed data and results for Sample 6 with two changes

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	10	8,165.00	0.064	0.7917	2	65.9063	2
A2	12	9,260.00	0.818	0.9583	1	100.0000	1
A3	9	13,000.00	0	0.7481	3	44.1364	3
A4	7	18,000.00	0	0.6931	4	34.3770	4
A5	**9**	19,000.00	0	0.6791	5	**31.8690**	**6**
A6	**7**	19,500.00	0	0.6727	6	**31.9800**	**5**
A7	12	19,400.00	0	0.6722	7	30.1083	7
A8	10	22,979.00	0	0.6194	8	26.6099	8
A9	20	24,250.00	0	0.5936	9	22.9326	9
A10	15	27,750.00	0	0.5373	10	21.4573	10
A11	10	29,900.00	0	0.5016	11	20.9907	11
A12	6	37,500.00	0	0.3640	13	17.5390	13
A13	10	33,950.00	0	0.4276	12	18.6821	12
A14	7	39,000.00	0	0.3349	14	16.7745	14
A15	20	55,500.00	0	0.0000	15	11.2322	15

As seen from the results with the very slight change in the data, COPRAS results are changed and the rankings altered. A5, which was ranked fifth, falls to sixth rank and A6 gains fifth rank.

The value of change required in the same data parameters to alter the ranks in TOPSIS was also checked. The analysis showed that TOPSIS requires the A5 value to increase by 7 and A6 to decrease by 6. Therefore, the threshold for TOPSIS is stronger by a value of 6 for A5 and 5 for A6, compared to COPRAS, as shown in the following Figure 7.4.

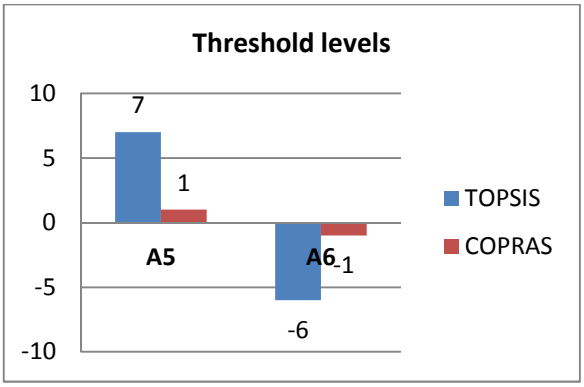

Figure 7.4: Threshold levels for TOPSIS and COPRAS in Test 3

Test 4: Test 4 was conducted on real life data Sample 7. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.117. For the analysis, original data values for A1 and A3 with regard to criterion 'duration' were changed. The value for A1 was increased by 5 and A3 decreased by 5. The results, with the two changes in parameters, are shown in Table 7.118.

Table 7.117: Initial data and results for Sample 7

Alternative	Duration	Price	Experience	Financial capability	Technical capability	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	75	240,750.00	0.9333	0	0.15	0.3720	2	77.7051	2
A2	85	284,820.00	0.8	0	0.85	0.6512	1	100.000	1
A3	58	197,961.00	0.2	0	0.15	0.3364	3	74.9994	3

Table 7.118: Changed data and results for Sample 7 with two changes

Alternative	Duration	Price	Experience	Financial capability	Technical capability	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	**80**	240,750.00	0.9333	0	0.15	0.3655	2	**76.4874**	**3**
A2	85	284,820.00	0.8	0	0.85	0.6425	1	100.000	1
A3	**53**	197,961.00	0.2	0	0.15	0.3452	3	**76.7132**	**2**

As seen from the results with the change in the data, COPRAS results are changed and the rankings altered. A1, which was ranked second, falls to third rank and A3 gains second rank.

The value of change required in the same data parameters to alter the ranks in TOPSIS was also checked. The analysis shows that TOPSIS requires A1 value to increase by 11 and A3 to decrease by 11. Therefore, the threshold for TOPSIS is stronger by a value of 6 for both A1 and A3, compared to COPRAS, as shown in the following Figure 7.5.

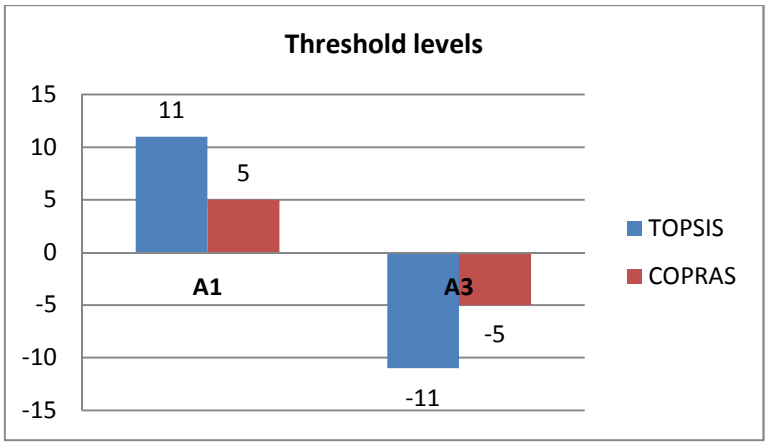

Figure 7.5: Threshold levels for TOPSIS and COPRAS in Test 4

Test 5: Another case was considered by changing the two parameters of the same alternative. Two criteria values for the alternative are changed in order to realise the threshold level of change for its ranking.

This test was conducted on real life data Sample 13. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.119. In contrast to the previous tests, in Test 5, the data parameters are for two criteria of a single alternative and the change in data is in the same direction. For the analysis original data values for A2 with regard to criteria 'financial capability' and 'technical capability' were changed. The value for 'financial capability' was increased by 5 and 'technical capability' increased by 4. The results, with the two changes in parameters, are shown in Table 7.120.

Table 7.119: Initial data and results for Sample 13

Alternative	Price	Financial capability	Technical capability	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	12,000.00	10	25	0.6923	1	100.0000	1
A2	9,180.00	10	10	0.4778	2	85.0186	2
A3	12,620.00	0	18	0.4487	3	69.3500	4
A4	8,500.00	5	5	0.3742	4	72.0273	3
A5	10,500.00	3	5	0.2294	5	58.3249	5

Table 7.120: Changed data and results for Sample 13 with two changes

Alternative	Price	Financial capability	Technical capability	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	12,000.00	10	25	0.6648	1	**99.7474**	**2**
A2	9,180.00	**15**	**14**	0.6079	2	**100.0000**	**1**
A3	12,620.00	0	18	0.4243	3	70.8859	4
A4	8,500.00	5	5	0.3695	4	73.8790	3
A5	10,500.00	3	5	0.2239	5	59.9872	5

As seen from the results with the change in the data, COPRAS results are changed and the rankings altered. A1, which was ranked first, falls to the second rank and A2 gains first rank.

The value of change required in the same data parameters to alter the ranks in TOPSIS was also checked. The analysis showed that TOPSIS requires A2 values in both the criteria to increase by 6. Therefore, the threshold for TOPSIS is stronger by a value of 1 for criteria ‘financial capability’ and by 2 for the criteria ‘technical capability’, compared to COPRAS, as shown in the following Figure 7.6.

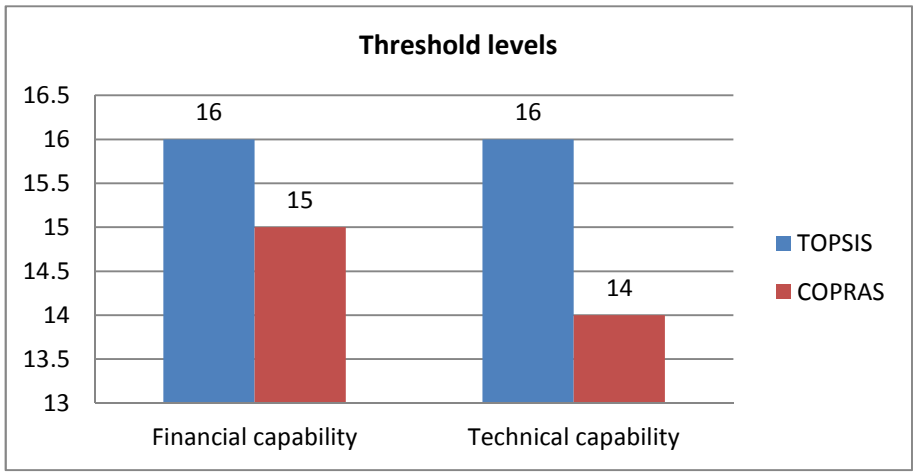

Figure 7.6: Threshold levels for TOPSIS and COPRAS in Test 5

All the tests done with changes in two parameters showed that TOPSIS is stronger in stability than COPRAS when raw data is manipulated. The next set of tests on stability is with one data parameters, as shown in the following section.

7.8.3.2 Changes in one parameter

In this set of analysis one data parameter is changed. The value for a criterion for an alternative is changed. Some of the analysed samples are as follows.

Test 6: This test was conducted on real life data Sample 2. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.121. For the analysis original data values for A1 with regard to criteria 'duration' was changed. The value for the criteria was increased by 2. The results with the change in parameter are shown in Table 7.122.

Table 7.121: Initial data and results for Sample 2

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	21	676,677.83	0.8667	0.62216	1	100.0000	1
A2	30	660,671.55	0.9333	0.37784	2	99.3789	2

Table 7.122: Changed data and results for Sample 2 with one change

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	**23**	676,677.83	0.8667	0.55370	1	**99.73545**	**2**
A2	30	660,671.55	0.9333	0.44630	2	**100.0000**	**1**

As seen from the results with the change in the data, COPRAS results are changed and the rankings altered. A1, which was at the first rank, falls to the second rank and A2 gains first rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS was also checked. The analysis showed that TOPSIS requires A1 values to increase by 4. Therefore, the threshold for TOPSIS is stronger by a value of 2 for the criteria, compared to COPRAS, as shown in the following Figure 7.7.

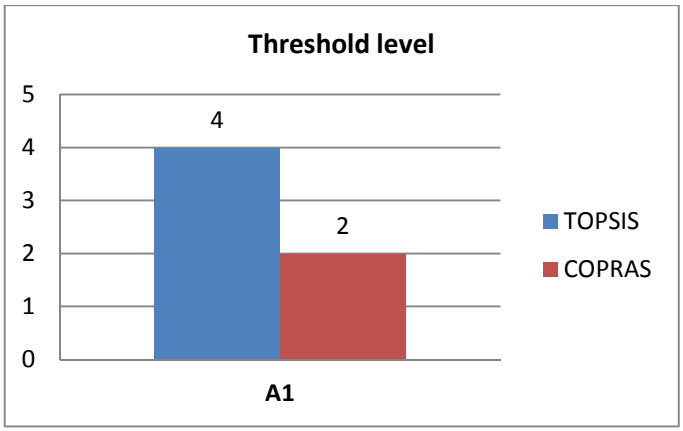

Figure 7.7: Threshold levels for TOPSIS and COPRAS in Test 6

Test 7: This test was conducted on real life data Sample 1. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.123. For the analysis original data values for A1 with regard to criteria 'financial strength' was changed. The value for the criteria was increased by 3. The results, with the change in parameter, are shown in Table 7.124.

Table 7.123: Initial data and results for Sample 1

Alternative	Duration	Price	Years of experience	Similar Task	Financial Strength	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	90	678,919.00	1	1	1	0.4944	2	86.4162	2
A2	60	549,972.44	0	0	0	0.4356	3	65.8093	3
A3	44	730,000.00	1	1	1	0.7291	1	100.000	1

Table 7.124: Changed data and results for Sample 1 with one change

Alternative	Duration	Price	Years of experience	Similar Task	Financial Strength	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	90	678,919.00	1	1	**4**	0.4904	1	**100.0000**	**1**
A2	60	549,972.44	0	0	0	0.4736	2	70.0226	3
A3	44	730,000.00	1	1	1	0.7124	3	**98.3511**	**2**

As seen from the results, with the change in the data, COPRAS results are changed and the rankings altered. A3, which was ranked first, falls to the second rank and A1 gains first rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS was also checked. The analysis showed that in TOPSIS, even applying the maximum allowable value to the parameter set by the institution made no changes to the top rank by TOPSIS. Therefore, the threshold for TOPSIS is stronger for this criterion, compared to COPRAS.

Test 8: This test was conducted on real life data Sample 4. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.113. For the analysis original data values for A3 with regard to criteria 'duration' was changed. The value for the criteria was increased by 7. The results, with the change in parameter, are shown in Table 7.125.

Table 7.125: Changed data and results for Sample 4 with one change

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	5	16,500.00	0	1.0000	1	100.000	1
A2	15	38,700.00	0	0.8171	2	41.4860	2
A3	**35**	46,730.00	0	0.7401	3	**30.8072**	**4**
A4	26	49,900.00	0	0.7216	4	**30.8614**	**3**
A5	28	115,532.00	0	0.2024	5	14.5715	5
A6	60	121,405.00	0	0.1335	6	12.7896	6
A7	24	137,867.80	0	0.0978	7	12.4960	7

As seen from the results, with the change in the data, COPRAS results are changed and the rankings altered. A3, which was ranked third, falls to the fourth rank and A4 gains third rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS also was checked. The analysis showed that TOPSIS requires A3 values to increase by 34. Therefore, the threshold for TOPSIS is stronger by a value of 27 for the criteria, compared to COPRAS, as shown in the following Figure 7.8.

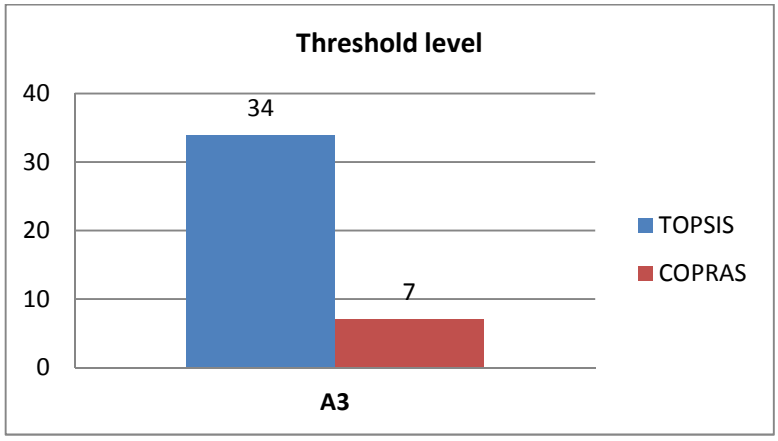

Figure 7.8: Threshold levels for TOPSIS and COPRAS in Test 8

Test 9: This test was conducted on real life data Sample 6. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.115. For the analysis original data values for A5 with regard to criteria 'duration' was changed. The value for the criteria was increased by 2. The results, with the change in parameter, are shown in Table 7.126.

Table 7.126: Changed data and results for Sample 6 with one change

Alternative	Duration	Price	Experience	TOPSIS		COPRAS	
				Result	Rank	Result	Rank
A1	10	8,165.00	0.064	0.7917	2	65.9850	2
A2	12	9,260.00	0.818	0.9586	1	100.0000	1
A3	9	13,000.00	0	0.7481	3	44.1463	3
A4	7	18,000.00	0	0.6931	4	34.3576	4
A5	**10**	19,000.00	0	0.6787	5	**31.4441**	**6**
A6	8	19,500.00	0	0.6724	6	**31.5423**	**5**
A7	12	19,400.00	0	0.6722	7	30.1096	7
A8	10	22,979.00	0	0.6194	8	26.5982	8
A9	20	24,250.00	0	0.5936	9	22.9448	9
A10	15	27,750.00	0	0.5374	10	21.4539	10
A11	10	29,900.00	0	0.5016	11	20.9755	11
A12	6	37,500.00	0	0.3639	13	17.5171	13
A13	10	33,950.00	0	0.4276	12	18.6665	12
A14	7	39,000.00	0	0.3348	14	16.7546	14
A15	20	55,500.00	0	0.0000	15	11.2249	15

As seen from the results, with the change in the data, COPRAS results are changed and the rankings altered. A5, which was ranked fifth, falls to the sixth rank and A6 gains fifth rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS was also checked. The analysis showed that TOPSIS requires A3 values to increase by 17. Therefore, the threshold for TOPSIS is stronger by a value of 15 for the criteria, compared to COPRAS, as shown in the following Figure 7.9.

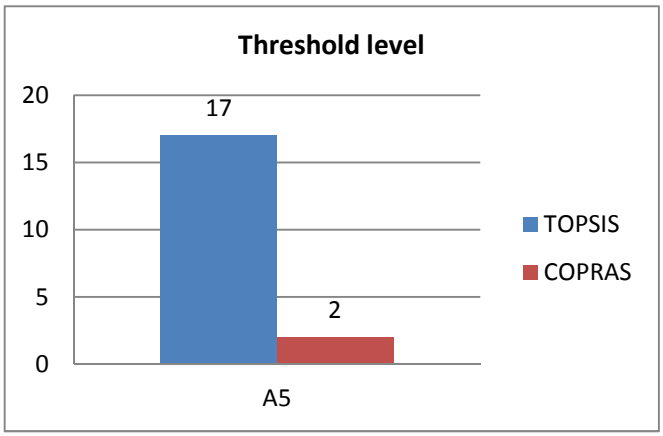

Figure 7.9: Threshold levels for TOPSIS and COPRAS in Test 9

Test 10: This test was conducted on real life data Sample 7. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.117. For the analysis original data values for A5 with regard to criteria 'duration' was changed. The value for the criteria was increased by 12. The results, with the change in parameter, are shown in Table 7.127.

Table 7.127: Changed data and results for Sample 6 with one change

Alternative	Duration	Price	Experience	Financial capability	Technical capability	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	**87**	240,750.00	0.9333	0	0.15	0.3644	2	**75.4109**	**3**
A2	85	284,820.00	0.8	0	0.85	0.6537	1	100.000	1
A3	58	197,961.00	0.2	0	0.15	0.3371	3	**75.4847**	**2**

As seen from the results with the change in the data, COPRAS results are changed and the rankings altered. A1, which was ranked second, falls to the third rank and A3 gains second rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS was also checked. The analysis showed that TOPSIS requires A1 values to increase by 27. Therefore, the threshold for TOPSIS is stronger by a value of 15 for the criteria, compared to COPRAS, as shown in the following Figure 7.10.

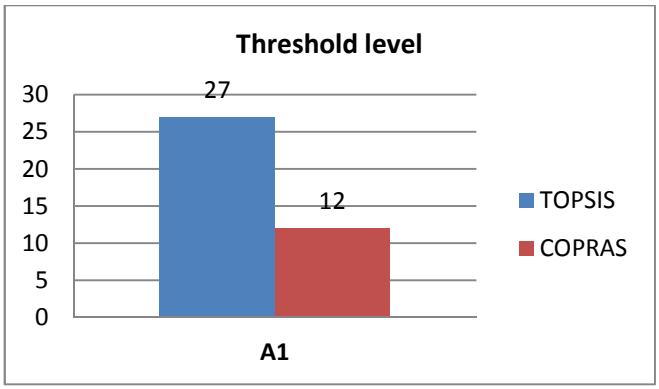

Figure 7.10: Threshold levels for TOPSIS and COPRAS in Test 10

7.8.3.3 Changes in two parameters in favourable direction

In this analysis, two data parameters are changed. The data parameters are for two alternatives in the same criteria. The values are changed in favourable direction to increase the result for both alternatives. Test 11 tested and analysed the data using real life data Sample 11. The original data for the sample and its results with TOPSIS and COPRAS are shown in Table 7.128. For the analysis original data values for A1 and A2 were decreased by 1 each, with regard to the criteria ‘duration’. The results, with the change in parameters, are shown in Table 7.129.

Table 7.128: Initial data and results for Sample 11

Alternative	Duration	Price	Experience	Financial capability	Technical capability	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	15	30,945.00	0.9333	0	0.15	0.5884	2	99.5519	2
A2	19	65,450.00	0.8	0	0.85	0.5897	1	100.000	1
A3	7	102,000.00	0.2	0	0.15	0.2463	3	52.5422	3

Table 7.129: Changed data and results for Sample 11 with two changes

Alternative	Duration	Price	Experience	Financial capability	Technical capability	TOPSIS		COPRAS	
						Result	Rank	Result	Rank
A1	**14**	30,945.00	0.9333	0	0.15	0.5911	2	**100.000**	**1**
A2	**18**	65,450.00	0.8	0	0.85	0.5929	1	**99.8677**	**2**
A3	7	102,000.00	0.2	0	0.15	0.2404	3	52.0742	3

As seen from the results, with the slight changes in data, COPRAS results are changed and the rankings altered. Even though it was a favourable change to both the methods, there was no change of ranking in TOPSIS. In COPRAS, A2, which was ranked first, falls to the second rank and A1 gains first rank.

The value of change required in the same data parameter to alter the ranks in TOPSIS was also checked. TOPSIS rankings did not change when the value of A1 and A2 was equally decreased until it reached the value of A3 (7), representing 12 negative performance measures each. Therefore, the threshold for TOPSIS is stronger by a value of 11 for each of the criteria, compared to COPRAS as shown in the following Figure 7.10.

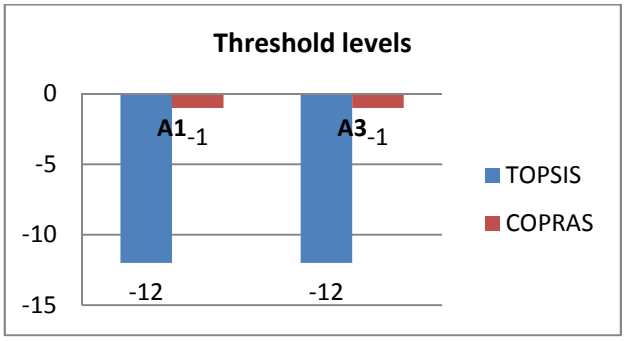

Figure 7.11: Threshold levels for TOPSIS and COPRAS in Test 11

There are some inherent limitations of this analysis similar to variance analysis as the majority of sample sizes are small. Therefore, the results of stability are confined only to the limited number of alternatives in each sample. However, as mentioned before, the limitation is accommodated as the samples are from a real life context, which is expected in public sector procurement.

The second limitation is that testing every combination of a parameter with every possible data value is practically not possible for this project. The study looked for least possible changes in parameters as described in Section 3.6.5. Therefore, there could be some data values for some parameters that could show favourable results for COPRAS but not TOPSIS. However 100% of cases studied showed that stability of TOPSIS is higher than COPRAS.

The method which provides higher stability would help BECs for some extent to accommodate unidentified improper supplier performances in the evaluation of public sector procurement. Based on the stability analysis carried out above, TOPSIS showed a strong threshold level for every test done compared to the COPRAS. Therefore, based on this analysis, TOPSIS is preferred.

7.9 Application of MCDA on performance

As discussed in research methodology, Section 2.3.4.2, this step of the research is to identify the highest ranking method under MCDA.

So far several analyses have been executed on MCDA methods, as discussed in research methodology and research design chapters. At first, legal and operational requirements and constraints in the Maldivian context are checked against the characteristics of groups of MCDA methods through criteria-based evaluation. A second analysis involved the extension of the first by doing similar analysis at method level for the methods in filtered groups from the first analysis. The filtered

individual methods went through three different performance analyses, as discussed above. Based on these analyses, TOPSIS is the most suitable MCDA method for the evaluation of public education sector procurement in the Maldives.

In addition to the analysis described above, as discussed in Section 2.3.4.1 and Section 3.7, WS method and TOPSIS method are applied to TOPSIS and COPRAS to select from the two. WS method is used as it is the current procurement evaluation method by the public sector education institutions. That is to check the preference results based on the current system. TOPSIS is used as it was one of the methods filtered out by the evaluation process of this project as one of the applicable candidates. However, the other applicable candidate, COPRAS, requires at least one cost criteria to apply it and there was no cost criterion in this analysis. Therefore, this analysis could not use COPRAS to check for performance results.

The criteria for the analysis are drawn from the previous analyses. Equal preference weight is allocated for every criterion, as explained in Section 3.7. The following four criteria are each set with a 25% weight:

1. **Adherence to requirements:** The methods which pass through criteria-based evaluation are given the highest score. Since both methods are cleared through this, the highest performance score is given to both methods.
2. **Average correlation coefficients:** The average correlation coefficient score for the 13 samples are allocated as the performance score for the methods.
3. **Average variance:** The average variances for the 13 samples are allocated as the performance score for the methods.
4. **Average threshold:** The average threshold values for the 11 cases tested under stability analysis are allocated as the performance score for the methods.

The calculated data matrix for the two alternatives, TOPSIS and COPPRAS, the four criteria are shown in Table 7.130 below.

Table 7.130: Data matrix for TOPSIS and COPPRAS

Alternative	Adherence to requirements	Average correlation coefficient	Average variance	Average threshold
	0.25	0.25	0.25	0.25
TOPSIS	100	0.89588	629.26881	23.18182
COPRAS	100	0.89973	407.86046	8.72727

Based on the data, the results of the WS method are presented in Table 7.131 below.

Table 7.131: WS results for TOPSIS and COPPRAS

Alternative	Adherence to requirements	Average correlation coefficients	Average variance	Average threshold	Total	Rank
TOPSIS	0.25000	0.24893	0.25000	0.25000	0.74893	1
COPRAS	0.25000	0.25000	0.16204	0.09412	0.50616	2

As seen from the WS results, TOPSIS gets a higher value and the first rank. Therefore, TOPSIS is preferred to COPRAS, according to the analysis.

The resulting weighted normalised matrix by application of TOPSIS is shown in Table 7.132.

Table 7.132: TOPSIS weighted normalised matrix for TOPSIS and COPPRAS

Alternative	Adherence to requirements	Average correlation coefficients	Average variance	Average threshold
TOPSIS	0.1767767	0.176398	0.209788	0.233969
COPRAS	0.1767767	0.177155	0.135974	0.088082

Calculations using the weighted normalised matrix by TOPSIS results separation measures from the ideal solution, separation measures from the negative-

ideal solution, relative closeness to the ideal solution, and the ranks which are presented in Table 7.133.

Table 7.133: TOPSIS results for TOPSIS and COPPRAS

Alternative	d_j^+	d_j^-	R_j	Rank
TOPSIS	0.001010	0.217996	0.995389	1
COPRAS	0.217996	0.001010	0.004611	2

Based on the TOPSIS results, TOPSIS is closest to the ideal solution, getting the highest score, which ranked TOPSIS in first position. Therefore, TOPSIS is more preferred than COPRAS according to the analysis.

As all the conclusive analysis done in this research project has shown that the TOPSIS is more preferable, the conclusion of the research is that TOPSIS is 'good enough' and the best applicable decision model to use in Maldivian public education sector procurement.

7.10 Conclusion

This chapter has discussed the performance analysis of the research project. The chapter discussed 13 sample data sets, and the application of the data sets in TOPSIS and COPRAS. The results of the TOPSIS and COPRAS are analysed for their performance levels.

Congruence/incongruence analysis of the results of TOPSIS and COPRAS were carried out on the samples. The analysis was inconclusive as it showed varied results for two methods in different samples.

Variance analysis was also executed on the results of TOPSIS and COPRAS. The results showed that TOPSIS has a higher variance than COPRAS, indicating the further spread of alternatives for easier selection in TOPSIS. The analysis was in favour of TOPSIS.

Stability or robustness analysis also was undertaken on the results of TOPSIS and COPRAS, and showed that TOPSIS has a higher threshold value in every tested case than COPRAS. Therefore, stability was higher in TOPSIS.

Finally, based on the results of the analyses done in the project, the two methods, TOPSIS and COPRAS were evaluated using WS and TOPSIS. The criteria are adherence to requirements, average correlation coefficients, average variance, and average threshold for the methods. By allocating equal weights for the criteria both the WS method and TOPSIS method preferred TOPSIS over COPRAS.

Therefore, based on this analysis the chapter concluded that TOPSIS is best applicable decision model to use in Maldivian public education sector procurement.

CHAPTER 8

CONCLUSIONS

8.1 Overview

This chapter discusses the overall findings of the research project, its achievements and how the research question has been answered. It also discusses the contributions and suggestion to public sector procurement based on this research, and the limitations of the research and its mitigation strategy. Finally, future work related to the research is discussed.

8.2 Summary of research and findings

The research aimed to identify a suitable MCDA method to evaluate suppliers for public sector procurement in the Maldivian context. The research focused on the public education sector, where procurement decisions are made within the public institution by BEC. BEC evaluates and decides the procurements that cost between MVR25,000.00 and MVR1,500,000.00.

Public sector procurement evaluations are made based on multiple criteria that are set for each procurement and announced to public. This creates a context in which MCDA techniques should be applied to the evaluation. Manual processing of MCDA methods for procurement evaluation are time-consuming and can lead to errors. In addition, manual processing leaves all accountability with a particular individual. Therefore, to save time and mitigate procurement evaluation errors, the research is intended for e-procurement DSS, where evaluation processing is computerised.

The identified decision evaluation model for the e-procurement DSS is the identified artefact for this research. To select this decision evaluation model the research adopted the DSR methodology, which provides the artefact, a theory of use of it in the context, and how to evaluate the artefact. As these three components are of prime importance for the research project, DSR is chosen. DSR for this project includes several research activities in a series to analyse the best applicable MCDA methods to the research context.

In the first phase of development, as explained in Section 2.3 and illustrated in Figure 2.2, the first major research activity was a literature review of public sector procurement, mainly focusing on the Maldivian context. This literature review provided the requirements and constraints of public sector procurement.

The second activity, a field research involving focus group discussions with public procurement decision-makers from selected education institutions, was conducted. The results of the focus groups provided the operational requirements and constraints in public sector procurement.

The third activity in the first phase of development was a systematic literature review of MCDA methods. This literature review provided the requirements and constraints of MCDA methods.

In the second phase of development, criteria-based evaluation was done on the requirements and constraints of public sector procurement gathered against the requirements and constraints of MCDA methods. This evaluation filtered the MCDA

methods that adhere to the public sector procurement requirements and constraints. The result of this stage was that TOPSIS and COPRAS are the two applicable methods for public sector procurement evaluation in the Maldivian education sector.

The third phase of the research was performance analysis, as explained in Section 2.3.4.1 and illustrated in Figure 2.2, For this performance analysis, selected real procurement data sets collected from selected public sector institutions were applied to two filtered MCDA methods, TOPSIS and COPRAS. Congruence/incongruence analysis was executed on the results. The analysis showed no preference for any of the methods. Next, variance analysis was done on the results of the application of the real life procurement data on the two methods. The analysis resulted that TOPSIS has a higher variance compared to COPRAS. Therefore, based on the variance analysis, alternatives in TOPSIS would have longer distance gaps, and so was preferred in the variance analysis. The final performance analysis was stability analysis. The analysis changed data parameters to check the changes of results by the two methods. The result showed that, in all the cases tested, TOPSIS performed better, having a higher threshold value. Based on this stability analysis, TOPSIS was preferred.

The fourth phase of the research was to apply MCDA on selection of the two methods. The criteria for evaluation were the results of criteria-based evaluation, congruence/incongruence analysis, variance analysis, and stability analysis. All the criteria are output or favourable criteria and are given equal preference weights. For the purpose, the two filtered methods and WS were planned to be used. However, due to the inherent requirements of COPRAS to have input criteria, the analysis could not use COPRAS, as there were no input criteria for the analysis. WS is the current evaluation method used by public sector education institutions. WS applications on TOPSIS and COPRAS based on the performance criteria showed that TOPSIS is preferable. A similar result was shown when TOPSIS was applied, resulting in a higher rank for TOPSIS over COPRAS.

Therefore based on the series of the research analysis, TOPSIS is the best applicable model for public sector procurement evaluation in an e-procurement decision support system for public education sector of the Maldives.

8.3 Responding to research question

The primary aim of the research was to analyse and evaluate MCDA methods to apply as the decision model for an e-procurement DSS in the Maldives public education sector to suggest the most preferred supplier based on supplier performances of pre-set criteria. In view of the primary aim of the research, the purpose of the study is addressed through the following research question:

What is the most suitable MCDA method that can be used in public sector procurement in the Maldives education sector?

To answer this research question, the following research objectives were set, as presented in the introductory chapter:

i. To identify procurement characteristics, constraints and limitations of public sector procurement in general and more specific to the education sector in relation to local laws and regulations.
ii. To identify operational constraints, limitations and expected characteristics of public sector procurement from the education sector procurement decision makers' perspective.
iii. To identify and analyse the characteristics of potential MCDA methods in context of public procurement decision-making.
iv. To filter applicable MCDA methods by undertaking a comparative analysis of identified methods with the public sector procurement characteristics, constraints and limitations in relation to law and regulation and decision-makers' view.
v. To carry out a comparative analyse of the applicable MCDA methods, based on the results of application of real procurement data sets as a proof of the model with the best performance.

The first objective was achieved through the literature review, which identified requirements and constraints for public sector procurement in general and specifically to the Maldivian public sector, as discussed in Chapter 4.

The second objective was achieved through focus group discussions with public education sector procurement decision-makers. The analysis of focus groups has generated the operational requirements of the Maldivian public sector, as discussed in Chapter 5.

The third objective was achieved through the systematic literature review of MCDA methods as discussed in Chapter 6 together with criteria-based evaluation.

The fifth objective was achieved through the criteria-based evaluation done to filter MCDA methods according to the requirements of public sector, discussed in Chapter 6.

The sixth objective was achieved through the performance analyses done to evaluate applicable methods, based on their performance when real life procurement data were used. Congruence/incongruence analysis, variance analysis, and stability analysis was conducted for performance analyses. In addition, MCDA was applied to identify the best performing method, as discussed in Chapter 7.

By achieving the six research objectives, the research question is answered by selecting a suitable MCDA method for public sector procurement in the Maldives education sector. The selected method is TOPSIS.

Therefore, the primary research objective to analyse and evaluate MCDA methods to select and apply as the decision model for an e-procurement DSS in the Maldives public education sector has been achieved.

8.4 Contributions to knowledge

One of the major contributions to knowledge is the framework to identify and evaluate the decision model, which is the implemented design science research model for this study. The research design is presented in Section 2.3 and illustrated in Figure 2.2. The research design used a series of activities and evaluations to identify the most suitable decision model for the research context. This research needed to identify a decision model that fitted public sector regulations and operational requirements. Therefore, the research design helped to meet the requirements.

The research design involved various checks and evaluations at different phases of the research to validate the artefact for the research context. At first the research identified the regulatory requirements of public sector procurement followed by operational requirements from decision-makers. These requirements are used to evaluate the MCDA methods, in order to check if it met the public sector requirements. Next, the methods that adhered to the public sector requirements were evaluated for their performance in procurement evaluation. In addition, MCDA was applied, to identify the most applicable method. This research approach has yielded good results and research findings. This research design is easily transferable to other contexts and studies that aim at understanding the use of artefacts in complex human activity systems that share legal, operational and performance requirements. This type of research is becoming common in Social Science in general and Management Studies and Information Systems in particular.

Second major contribution is the identification of the most suitable decision model for the Maldivian public sector procurement for the education sector for supplier evaluation, according to the regulatory and operational needs of the Maldives. The identified decision model is selected, based on a thorough evaluation of more than 80 published MCDA methods, as discussed in Section 2.3. The research suggested that the most suitable decision model for the context is TOPSIS. Based on this result, public sector procurement officials would initiate discussions to adopt TOPSIS for public procurement evaluation. Using TOPSIS for public procurement

evaluation in Maldives will improve the evaluation procedure and provide the best results in line with the public procurement principles.

Third major contribution to the knowledge is the identification of the public sector procurement requirements for the Maldivian context as presented in Chapter 4 and Chapter 5. The requirements are gathered from the literature and through field research. The literature review covered academic and grey literature and gathered requirements, based on public sector procurement fundamentals, laws and regulations specific to Maldivian context. Operational requirements for public sector procurement were identified through focus group discussions. A series of focus groups discussions were conducted with procurement decision-makers from the Maldivian public sector and analysed to identify the operational requirements, constraints and wishes. The emerged findings are new contributions in the context of research. The identified requirements can be used to evaluate any model for its appropriateness to the public procurements in Maldives.

Fourth major contribution is the outcome of the criteria-based evaluation. These finding are presented in Chapter 6. For this evaluation, firstly, a systematic literature review was conducted, in order to identify the characteristics of the MCDA methods in the context of public sector procurement. This study gathered the characteristics of the MCDA methods in relation to the research context from the literature. This study helped to contextualise the characteristics to evaluate MCDA methods for suitability in relation to public sector procurement evaluation. The criteria-based evaluation compared the identified characteristics of MCDA methods against the public sector procurement requirements of the research context. This analysis helped to identify the MCDA methods that are applicable to public sector procurement evaluation in the Maldivian context. This criteria-based evaluation provided two methods that are suitable to be used, based on the legal and operational requirements of the Maldives public sector procurement. The two methods are TOPSIS and COPRAS.

Fifth major contribution is the finding of the relative strength of performance of TOPSIS and COPRAS, as presented in Chapter 7. A series of performance evaluations were executed on TOPSIS and COPRAS with real life data. These

evaluations measured the strengths of performance of the two methods in same scenarios. Based on the evaluation, TOPSIS has a higher performance than COPRAS. These analyses, data and results can be used by other researchers for situations where similar performance analysis is required.

Sixth contribution is the application of the identified decision model in practice, as shown in Section 7.5 and Section 7.6. In addition to applying the selected decision model with real procurement data, both TOPSIS and COPRAS were used to illustrate how to apply the method in procurement evaluations. Actual procurement data sets are used in TOPSIS and COPRAS and the required calculations were undertaken and illustrated to show the application of the methods in practice. These sample applications, with segmented and staged results, will allow users to understand the application of the methods in procurement and its results in procurement context.

8.5 Suggestion for public sector procurement

This research project is focused on public sector procurement. Based on the study, it was evident that the current procurement evaluation method by Maldivian public sector, WS, has unfavourable issues with regard to procurement evaluation. Some of the major problems occurred in WS due to its inherent compensation procedure. Similarly, it could be the case that the definition of weights in WS is completely arbitrary and inconsistent with the real preferences of the procurement authority. Numerous issues of application of WS were identified in the literature (Luitzen de Boer et al., 2006; Keeney, 2002; Mateus et al., 2010).

This research has analysed and evaluated published MCDA methods with regard to procurement evaluation. Based on the analysis, other appropriate methods for evaluating public sector procurement in the Maldivian context have been identified. The research suggests that the best applicable method in terms of performances is TOPSIS. Therefore, the suggestion for Maldivian public education

sector procurement is to become cognisant with the possibilities TOPSIS brings and adopt it as the procurement evaluation method.

For the public sectors in Maldives and other countries currently using WS method are still vulnerable to the inherent weaknesses of WS discussed in the research which could potentially bring unfavourable results in procurement. Therefore identifying a potential decision model which adheres to the legal and operational requirements proving best performance is important. As such, the research implementation framework used in this research is a useful model to adapt to identify the decision model for the specific context. Because it has a series of tests conducted to evaluate legal, operational and performance measures of potential decision models for a specific context. In addition, based on this research, implementation of this approach in public education sector in Maldives has given positive results.

8.6 Limitations of study and mitigation strategy

There are known limitations to the research. However, every effort was made to minimise these limitations.

This research is a three years sponsored PhD project. The timeframe was strictly set by the sponsor. In addition, this was the first experience of the researchers working on such a project involving managing field trips, conducting focus groups and working on rigorous analytical processes. With better experience, the research is likely to have been conducted better as the learning curve will be high and less time would be required to do the analysis.

The researcher was able to obtain access to the research site, focus groups and some of the documents. However, he was refused access to large numbers of similar documents. Real life procurement data was one of the key documents required for the research project. However, the government institutions provided only a limited number of real life procurement data sets.

As discussed in Section 7.8.2 and in Section 7.8.3, there are some inherent drawbacks to performance analysis. Firstly, the majority of real life procurement data sample sizes were small, so the variance and stability tests are confined only to a limited number of alternatives in each sample. However, it is unrealistic to expect a high number of alternatives to be available in every procurement because the current sample data sets are from real life procurement data from the Maldivian institutions, which have small number of alternatives. Therefore, the number of alternatives is expected to be small for public sector procurements in the research context. As such, accommodation of the small number of alternatives in this analysis is considered acceptable.

The second limitation with stability analysis is that testing every permutation of two data parameters with every possible value is practically not possible for this project. Therefore, the focus was on applying the least possible values which could show differentiated performances. However, all the tests conducted showed that the stability of TOPSIS is higher than COPRAS. The effect of these limitations is also mitigated, as the research used several methods of evaluation on the same artefact, thus offsetting them against each another.

8.7 Future work

It would be possible to research the applicability of the decision model in procurement in public sectors areas other than education. In addition, future research could focus on the applicability of the decision model in public sector, where decision analysis is required. This would help the public sector to make more appropriate decisions.

The research approach used series of evaluation and analysis based on legal, practical and performance aspects of the methods, in order to identify the decision model. It would also be interesting to research how this approach could be used in

other areas of decision analysis, such as recruitment decisions in human resource management.

It would also be interesting to research similarities and differences in the results of the approach used in this research provide in a similar context in other countries. This would help researchers to understand the applicability of MCDA methods in similar contexts in different societies.

The research provided the decision model to use in public sector e-procurement in the Maldivian education sector. Therefore, an expected direct extension of the research is the implementation of the decision model in the research context. The implementation would require development of a DSS, requiring further research projects, such as research in the context of design and development of the DSS, adoption of DSS, change management, bidder education, and so on.

Decision analysis is part of the everyday life of an individual and of organisations. Therefore, wherever multiple criteria of interest exist, based on the magnitude of the case, MCDA research can be implemented.

8.8 Conclusion

This chapter has discussed the research project as a whole. It has highlighted the research question and how it was addressed and answered. The chapter also discussed the contribution of the research and provided suggestions to the public sector, based on the research findings. Limitations of the research and future related work have also been discussed in the chapter.

The research project developed a decision model for public sector procurement evaluation for the Maldivian education sector using DSR which involved several research activities. Literature reviews, focus group discussions, criteria-based evaluation, congruence/incongruence analysis, variance analysis, stability analysis and MCDA are the major research activities employed in the study.

However, there were some inherent limitations to these research activities which have been mitigated and accommodated as far as is possible.

The research suggested that TOPSIS is the most suitable decision model for public sector procurement evaluation for the research context.

REFRERENCES

Aghajani, M., & Hadi-Vencheh, A. (2011). *A multiple attribute decision making model in the presence of grey numbers*. Paper presented at the 3rd International Conference on Advanced Management Science, Singapore.

Amid, A., Ghodsypour, S. H., & O'Brien, C. (2006). Fuzzy multiobjective linear model for supplier selection in a supply chain. *International Journal of Production Economics, 104*(2), 394-407.

Amponsah, C. T. (2011). Application of multi-criteria decision making process to determine critical success factors for procurement of capital projects under public-private partnerships. *International Journal of the Analytic Hierarchy Process, 3*(2), 107-129.

Ananda, J., & Herath, G. (2003). Incorporating stakeholder values into regional forest planning: a value function approach. *Ecological Economics, 45*(1), 75-90.

Angilella, S., Greco, S., Lamantia, F., & Matarazzo, B. (2004). Assessing non-additive utility for multicriteria decision aid. *European Journal of Operational Research, 158*(3), 734–744.

Anti-Corruption Commission Gaanoonu, 13/2008 Stat. (2008).

Antucheviciene, J., Zavadskas, E. K., & Zakarevicius, A. (2012). Ranking redevelopment decisions of derelict buildings and analysis of ranking results. *Journal of Economic Computation and Economic Cybernetics Studies and Research, 46*(2), 37-62.

Arrowsmith, S., & Anderson, R. D. (Eds.). (2011). *The WTO regime on government procurement: challenge and reform*. Cambridge: Cambridge University Press.

Baily, P., Farmer, D., Jessop, D., & Jones, D. (1994). *Purchasing Principles and Management* (7th ed.). London: Pitman Publishing.

Barbour, R. S., & Kitzinger, J. (Eds.). (1999). *Developing focus group research: Politics, theory and practice*. London: SAGE.

Belton, V., & Stewart, T. J. (2002). *Multiple Criteria Decision Analysis: An Integrated Approach*. Dordrecht Kluwer Academic Publishers.

Beuthe, M., & Scannella, G. (2001). Comparative analysis of UTA multicriteria methods. *European Journal of Operational Research, 130*(2), 246-262.

Boer, L. d., Harink, J., & Heijboer, G. (2002). A conceptual model for assessing the impact of electronic procurement. *European Journal of Purchasing & Supply Management, 8*(1), 25-33.

Boer, L. d., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. *European Journal of Purchasing & Supply Management, 7*(2), 75-89.

Boer, L. d., Linthorst, M. M., Schotanus, F., & Telgen, J. (2006). *An analysis of some mistakes, miracles and myths in supplier selection.* Paper presented at the 15th IPSERA Conference, SanDiego.

Boer, L. d., Wegen, L. v. d., & Telgen, J. (1998). Outranking methods in support of supplier selection. *European Journal of Purchasing & Supply Management, 4*, 109-118.

Bottani, E., & Rizzi, A. (2006). A fuzzy TOPSIS methodology to support outsourcing of logistics services. *Supply Chain Management: An International Journal, 11*(4), 294-308.

Brereton, P., Kitchenham, B. A., Budgen, D., Turner, M., & Khalil, M. (2007). Lessons from applying the systematic literature review process within the software engineering domain. *Journal of systems and software, 80*(4), 571-583.

Brown, R. B., Wright, R. D. J., Cloke, C. G., Morris, T. B., & Trumper, I. F. S. (1984). *Government purchasing : a multi-department review of government contract and procurement procedures*. London: HMSO.

Carlson, E. D. (2000). A Case Study in Translation Methodology Using the Health-Promotion Lifestyle Profile II. *Public Health Nursing, 17*(1), 61-70.

Chamodrakas, I., Leftheriotis, I., & Martakos, D. (2011). In-depth analysis and simulation study of an innovative fuzzy approach for ranking alternatives in multiple attribute decision making problems based on TOPSIS. *Applied Soft Computing, 11*(1), 900-907.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429–444.

Chatterjee, P., Athawale, V. M., & Shankar, C. (2011). Materials selection using complex proportional assessment and evaluation of mixed data methods. *Materials and Design, 32*(2), 851–860.

Chen, S., Osman, M., & Peng, G. C. (2012). Information systems evaluation: methodologies and practical case studies. In P. Isaias & J. M. B. Nunes (Eds.), *Information systems research and exploring social artifacts: Approaches and methodologies*. Hershey, USA: IGI Global.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3 ed.): SAGE Publications, Incorporated.

Croom, S., & Brandon-Jones, A. (2007). Impact of e-procurement: experiences from implementation in the UK public sector. *Journal of Purchasing & Supply Management, 13*(4), 294–303.

Dhaulathuge Maaliyyathu Gaanoonu, 03/2006 Stat. (2006).

Dhaulathuge Maaliyyathuge Gavaaidhu (2009).

Dobler, D. W., & Burt, D. N. (1996). *Purchasing and supply management : text and cases* (6th ed.). New York; London: McGraw-Hill.

Edwards, W. (1977). How to use multiattribute utility measurement for social decision making. *IEEE Transactions on Systems Man and Cybernetics, SMC-7*(5), 326–340.

Edwards, W., & Barron, F. H. (1994). SMARTS and SMARTER: Improved simple methods for multiattribute utility measurement. *Organizational Behavior and Human Decision Processes, 60*(3), 306–325.

Ehrgott, M., & Wiecek, M. M. (2005). Multiobjective programming. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 667-722). Boston: Springer.

England, W. B. (1967). *The purchasing system*. Homewood, Illinois: Irwin.

Esposito, N. (2001). From meaning to meaning: the influence of translation techniques on non-English focus group research. *Qualitative Health Research, 11*(4), 568-579.

Falagario, M., Sciancalepore, F., Costantino, N., & Pietroforte, R. (2012). Using a DEA-cross efficiency approach in public procurement tenders. *European Journal of Operational Research, 218*(2), 523-529.

Field, A. (2005). *Discovering statistics using SPSS : (and sex and drugs and rock 'n' roll)* (2nd ed.). London: SAGE Publications.

Figueira, J., Greco, S., & Ehrgott, M. (Eds.). (2005). *Multiple criteria decision analysis : state of the art surveys*. Boston: Springer.

Figueira, J., Mousseau, V., & Roy, B. (2005). ELECTRE methods. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 133-162). Boston: Springer.

Flick, U. (2009). *An introduction to qualitative research* (4th ed.). London: SAGE.

Forman, E. H. (1993). Facts and fictions about the analytic hierarchy process. *Mathematical and Computer Modelling, 17*(4/5), 19-26.

Forman, E. H., & Gass, S. I. (2001). The analytic hierarchy process: An exposition. *Operations Research, 49*(4), 469-486.

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston: Pitman.

GOSIP. (1994). *GOSIP 4: UK Government OSI profile : procurement handbook*. London: HMSO.

Guitouni, A., & Martel, J.-M. (1998). Tentative guidelines to help choosing an appropriate MCDA method. *European Journal of Operational Research, 109*(2), 501-521.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection : A literature review. *European Journal of Operational Research, 202*(1), 16–24.

Huang, S.-l. (2011). Designing utility-based recommender systems for e-commerce: Evaluation of preference-elicitation methods. *Electronic Commerce Research and Applications, 10*(4), 398–407.

Hutchinson, J., & Kotonya, G. (2006). *A review of negotiation techniques in component based software engineering.* Paper presented at the 32nd EUROMICRO Conference on Software Engineering and Advanced Applications Cavtat, Croatia.

Jahanshahloo, G. R., Lotfi, F. H., & Davoodi, A. R. (2009). Extension of TOPSIS for decision-making problems with interval data: Interval efficiency. *Mathematical and Computer Modelling, 49*(5-6), 1137-1142.

Jeffreys, I. (2004). The use of compensatory and non-compensatory multi-criteria analysis for small-scale forestry. *Small-scale Forest Economics, Management and Policy, 3*(1), 99-117.

Kahraman, C., Cebeci, U., & Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. *Logistics Information Management, 16*(6), 382-394.

Kaklauskas, A., Zavadskas, E. K., & Trinkunas, V. (2007). A multiple criteria decision support on-line system for construction. *Engineering Applications of Artificial Intelligence, 20*(2), 163–175.

Keeney, R. L. (2002). Common mistakes in making value trade-offs. *Operations research, 50*(6), 935-945.

King, N., & Horrocks, C. (2010). *Interviews in qualitative research*. London: SAGE.

Krueger, R. A. (1998). *Analyzing and reporting focus group results*. London: Sage.

Kumar, M., Vrat, P., & Shankar, R. (2006). A fuzzy programming approach for vendor selection problem in a supply chain. *International Journal of Production Economics, 101*(2), 273-285.

Laws, S. (2003). *Research for development: a practical guide*. London: SAGE.

Leenders, M. R., & Fearon, H. E. (1997). *Purchasing and supply management* (7th ed.). Chicago: Irwin.

Leenders, M. R., Johnson, P. F., Flynn, A. E., & Fearon, H. E. (2006). *Purchasing and supply management : with 50 supply chain cases* (13th ed.). New York: McGraw-Hill.

Li, X.-B., & Reeves, G. R. (1999). A multiple criteria approach to data envelopment analysis. *European Journal of Operational Research, 115*(3), 507-517

Linkov, I., Varghese, A., Jamil, S., Seager, T. P., Kiker, G., & Bridges, T. (2004). Multi-criteria decision analysis: A framework for structuring remedial decisions at contaminated sites. In I. Linkov & A. B. Ramadan (Eds.), *Comparative Risk Assessment and Environmental Decision Making* (pp. 15-54). Netherlands: Kluwer Academic Publishers.

Liu, J., Ding, F. Y., & Lall, V. (2000). Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. *Supply Chain Management: An International Journal, 5*(3), 143-150.

Lloyd-Evans, S. (2006). Focus groups. In V. Desai & R. B. Potter (Eds.), *Doing development research* (pp. 153-162). London: Sage publication.

Lorentziadis, P. L. (2010). Post-objective determination of weights of the evaluation factors in public procurement tenders. *European Journal of Operational Research, 200*(1), 261–267.

Luo, X., Wu, C., Rosenberg, D., & Barnes, D. (2009). Supplier selection in agile supply chains: An information-processing model and an illustration. *Journal of Purchasing & Supply Management, 15*(4), 249-262.

Lysons, K., & Gillingham, M. (2003). *Purchasing and Supply Chain Management* (6 ed.). Harlow: Financial Times Prentice Hall.

Mahdi, I. M., Riley, M. J., Fereig, S. M., & Alex, A. p. (2002). A multi-criteria approach to contractor selection. *Engineering, Construction and Architectural Management, 9*(1).

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems, 15*(4), 251-266.

Marshall, S. L., & While, A. E. (1994). Interviewing respondents who have English as a second language: challenges encountered and suggestions for other researchers. *Journal of Advanced Nursing, 19*(3), 566-571.

Martel, J.-M., & Matarazzo, B. (2005). Other outranking approaches. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 197-262). Boston: Springer.

Mateus, R., Ferreira, J. A., & Carreira, J. (2010). Full disclosure of tender evaluation models: Background and application in Portuguese public procurement. *Journal of Purchasing & Supply Management, 16*(3), 206-215.

Min, H. (1994). International supplier selection: A multi-attribute utility approach. *International Journal of Physical Distribution & Logistics Management, 24*(5), 24-33.

MoE. (2012). *School Statistics 2012*. Male': Ministry of Education.

Monczka, R. M., Handfield, R. B., Guinipero, L. C., Patterson, J. L., & Waters, D. (2010). *Purchasing and Supply Chain Management*. Hampshire: Centage.

Morgan, D. L. (1997). *Focus groups as qualitative research* (2nd ed.). London: SAGE.

Moshkovich, H., Mechitov, A., & Olson, D. (2005). Verbal decision analysis. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 609-637). Boston: Springer.

Myers, M. D., & Walsham, G. (1998). Exemplifying interpretive research in information systems: an overview. *Journal of Information Technology, 13*(4), 233-234.

NCIT. (2012). NCIT Mandate Retrieved 6th November 2012, 2012, from http://ncit.gov.mv/index.php/en/aboutus

Ng, W. L. (2008). An efficient and simple model for multiple criteria supplier selection problem. *European Journal of Operational Research, 186*(3), 1059–1067.

Nunes, M., McPherson, M., Annansingh, F., Bashir, I., & Patterson, D. (2009). The use of e-learning in the workplace: a systematic literature review. *Journal of Applied Research in Workplace E-learning, 1*(1), 97-112.

Olson, D. L. (2004). Comparison of weights in TOPSIS models. *Mathematical and Computer Modelling, 40*, 721-727.

Opricovic, S., & Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*(2), 445-455.

Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the "IT" in IT research - A call to theorizing the IT artifact. *Information Systems Research, 12*(2), 121-134.

Parthiban, P., Dominic, P. D. D., & Dhanalakshmi, R. (2010). *A simulated annealing approach to solve fuzzy multi-objective linear model for supplier selection in a supply chain*. Paper presented at the Information Technology (ITSim), 2010 International Symposium in, Kuala Lumpur.

Peng, G. C., & Nunes, M. (2008, 19-20 June 2008). *Issues and difficulties in doing participative research in China: lessons learned from a survey in information systems research.* Paper presented at the 7th European Conference on Research Methodology for Business and Management Studies, London, UK.

Pérez, J., Jimeno, J. L., & Mokotoff, E. (2006). Another potential shortcoming of AHP. *TOP, 14*(1), 99-111.

Podvezko, V. (2011). The comparative analysis of MCDA methods SAW and COPRAS. *Inzinerine Ekonomika-Engineering Economics, 22*(2), 134-146.

Pöyhönen, M., & Hämäläinen, R. P. (2001). On the convergence of multiattribute weighting methods. *European Journal of Operational Research, 129*(3), 569-585.

Purao, S. (2002). *Design research in the technology of information systems: Truth or dare*. Working paper. Computer Information Systems. Georgia State University. Atlanta.

Raju, K. S., & Pillai, C. (1999). Multicriterion decision making in river basin planning and development. *European Journal of Operational Research, 112*(2), 249-257.

Rossi, M., & Sein, M. K. (2003). *Design research workshop: A proactive research approach*. Paper presented at the Twenty-Sixth Information Systems Research Seminar in Scandinavia, Haikko, Finland.

Rowlinson, S., & McDermott, P. (Eds.). (1999). *Procurement Systems: A guide to best practice in construction*. London: E & FN Spon.

Roy, B. (2005). Paradigms and chappenges. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 3-24). Boston: Springer.

Saaty, T. L. (2005). *Theory and Applications of the Analytic Network Process: Decision Making With Benefits, Opportunities, Costs, and Risks*. Pittsburgh: RWS Publications.

San Cristóbal, J. R. (2011). A multi criteria data envelopment analysis model to evaluate the efficiency of the renewable energy technologies. *Renewable Energy, 36*, 2742–2746.

Sanayei, A., Mousavi, S. F., Abdi, M. R., & Mohaghar, A. (2008). An integrated group decision-making process for supplier selection and order allocation using multi-attribute utility theory and linear programming. *Journal of the Franklin Institute, 345*(7), 731–747.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (5th ed.). New York: Prentice Hall.

Schultze, U., & Leidner, D. E. (2002). Studying knowledge management in information systems research: discourses and theoretical assumptions. *MIS quarterly, 26*(3), 213-242.

Shih, H.-S., Shyur, H.-J., & Lee, E. S. (2007). An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling, 45*(7-8), 801-813.

Simon, H. A. (1996). *The Sciences of the Artificial* (3rd ed.). Cambridge: MIT Press.

Simpson, L. (1996). Do decision makers know what they prefer?: MAVT and ELECTRE II. *The Journal of the Operational Research Society, 47*(7), 919-929.

Siskos, Y., Grigoroudis, E., & Matsatsinis, N. F. (2005). UTA methods. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 297-343). Boston: Springer.

Spronk, J., Steuer, R. E., & Zopounidis, C. (2005). Multicriteria decision aid/analysis in finance. In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple criteria decision analysis : state of the art surveys* (pp. 799-857). Boston: Springer.

Stahl, B. C. (2014). Interpretive accounts and fairy tales: a critical polemic against the empiricist bias in interpretive IS research. *European Journal of Information Systems, 23*(1), 1-11.

Strauss, A. L., & Corbin, J. M. (1990). *Basics of qualitative research : grounded theory procedures and techniques*. London: Sage.

Triantaphyllou, E. (2000). *Multi-criteria decision making methods : a comparative study*. Dordrecht ; Boston, Mass.: Kluwer Academic Publishers.

Tsaur, R.-C. (2011). Decision risk analysis for an interval TOPSIS method. *Applied Mathematics and Computation*, *218*(8), 4295–4304.

Twinn, S. (1997). An exploratory study examining the influence of translation on the validity and reliability of qualitative data in nursing research. *Journal of Advanced Nursing, 26*(2), 418-423.

Twinn, S. (2000). The analysis of focus group data: a challenge to the rigour of qualitative research. *Nursing Times Research*, *5*(2), 140-146.

University of Sheffield Library. (2014). Primo Central collection list Retrieved 12th January 2014, 2014, from http://www.shef.ac.uk/library/resourcediscovery/pclist

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research, 169*(1), 1-29.

Vaishnavi, V., & Kuechler, B. (2011). Design science research in information systems. Retrieved from Association for Information Systems website: http://desrist.org/design-research-in-information-systems/

Vogt, W. (2005). *Dictionary of statistics & methodology : a nontechnical guide for the social sciences*. London: SAGE.

Walsham, G. (1995). Interpretive case studies in IS research: nature and method. *European Journal of Information Systems*, *4*(2), 74-81.

Wang, Y.-M., Chin, K.-S., & Luo, Y. (2011). Cross-efficiency evaluation based on ideal and anti-ideal decision making units. *Expert Systems with Applications, 38*, 10312–10319.

Weele, A. J. v. (2000). *Purchasing and supply chain management : analysis, planning and practice* (2nd ed.). London: Business Press.

Weele, A. J. v. (2010). *Purchasing and supply chain management : analysis, strategy, planning and practice* (5th ed.). Andover: Cengage Learning.

Wu, D. (2009). Supplier selection: A hybrid model using DEA, decision tree and neural network. *Expert Systems with Applications, 36*(5), 9105–9112.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control, 8*(3), 338-353.

Zavadskas, E. K., & Antucheviciene, J. (2007). Multiple criteria evaluation of rural building's regeneration alternatives. *Building and Environment, 42*(1), 436–451.

Zavadskas, E. K., Kaklauskas, A., Turskis, Z., & Tamosaitiene, J. (2008). *Contractor selection multi-attribute model applying COPRAS method with grey interval numbers.* Paper presented at the 20th EURO Mini Conference, Neringa, Lithuania.

Appendix I

The University Of Sheffield.

RESEARCH INFORMATION SHEET

Dear Participant,

You are being invited to take part in the research project, *Designing a decision model for an e-procurement Decision Support System for public sector using Multi-Criteria Decision Analysis*.

Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

1 – What is the research project's purpose?
The objective of this research is to design a decision model for e-procurement decision support system (DSS) for public sector in Maldives especially focusing on education sector.

An understanding of criteria for public procurement decision making, applicable decision algorithms for public sector and a DSS design for e-procurement are the major contributions of the research.

2 – Why have I been chosen?
You are being invited to participate in this research as a member of the bid evaluation committee (BEC) who is directly engaged in the bid evaluation. Your knowledge as a practitioner in bid evaluation is essential to identify the bid evaluation practice in education sector in Maldives.

3 – Do I have to take part?
It is entirely up to you to decide whether or not to take part in this research. If you do decide to take part you will be given this information sheet to keep (and be asked to sign a consent form) and you can still withdraw at any time without fear or prejudice and without it affecting any benefits that you are entitled to in any way. You do not have to give a reason.

4 – What will happen to me if I take part?
Your participation in this study entails engaging in a semi-structured, open-ended discussion with the purpose of understanding the practice of procurement in your institution. The discussion may last between 30 to 60 minutes, during which you will be asked to speak openly about your experience of procurement processes and bid evaluation. Your interview will be digitally recorded. After the interview, the recording will be transcribed into Word documents and fully anonymised, as any reference to participants'

identity will be eliminated. Additionally, all information disclosed in the interview process will remain strictly confidential.

5 – What do I have to do?
To avoid disruption or restrictions to your lifestyle, discussions will be scheduled to your best convenience, in a free and comfortable environment.

6 – What are the possible disadvantages and risks of taking part?
Your participation in this study does not imply any identifiable risks or disadvantages. As the identity and affiliation of participants will not be recorded, there is minimal risk that the study will constitute an invasion of your privacy. Questions were designed as not cause harm, anguish or discomfort. If you feel uncomfortable answering any of the questions, feel free to express your concerns. You are, of course, free to decline to answer such questions. You are moreover encouraged to refrain from disclosing any information that you may consider defamatory, incriminating, or otherwise sensitive.

7 – What are the possible benefits of taking part?
Your participation in this research will contribute to enlarge the scope of knowledge available about the procurement in Maldives. An understanding of the contexts in which procurement takes place, from the practitioner's perception, will facilitate to design a better system for public sector.

From a broader perspective, the results of this analysis can help identify better decision making models and a systematic approach for procurement through information systems.

8 – What happens if the research study stops earlier than expected?
It is not anticipated that the research project may go over the planned time frame or stops earlier than expected. In this is the case, participants will be informed of reasons and consequences.

9 – What if something goes wrong?
If you wish to express any concern or make a complaint regarding the conduct of the research project, please contact the researcher's supervisor as in contact details. If needed, verification of serious adverse events can be obtained by reporting research misconduct to the University of Sheffield's Registrar and Secretary Office. Contact details are listed at the end of the document.

10 – Will my taking part in this project be kept confidential?
All the information that is collected about you, as well as any information that you give during the course of the research will be kept strictly confidential, as ensured to all participants in the consent form. You will not be able to be identified in any reports or publications. During analysis, you will be assigned a number allowing complete anonymity. Your discussion but not your name will be recorded and transcribed, with all records being kept for a period of 5 years with the researcher or the project supervisor in a secure place. After this period all transcripts will be destroyed.

11 - What type of information will be sought from me and why is the collection of this information relevant for achieving the research project's objectives?
Because the objective of this research is to develop a design and a prototype for e-procurement decision support system the contribution of your professional knowledge, genuine experiences, on procurement and bid evaluation is essential to choose and model such a system.

12 - Will I be recorded, and how will the recorded media be used?
The recordings of your activities made during this research will be subject to participants' informed consent and used only for transcription and analysis purposes. No other use will be made of them without the participant's written permission, and no one excluding the researcher and his supervisor will be allowed access to the original recordings. Recordings and all digital documentation will be stored in a password protected account accessible by a user account for the researcher. Back-ups will be onto removable storage located within a lockable cabinet or else onto password protected networks at the University. All electronic files will be stored in a password protected account for a period of 5 years.

13 - What will happen to the results of the research project?
The results of this research will be published in a doctoral thesis. Information gained during the research project may additionally be published, in the form of interview transcripts, in academic journals, books and conference papers; and used for subsequent research. In all of the aforementioned circumstances, the participant's name, affiliation and position title will never be used in relation to any of the information provided.

Participants will be notified upon publication of results in the doctoral thesis, and copies will be forwarded upon request.

14 - Who is organising and funding the research?
This research was awarded by Islamic Development Bank, with the reference 36/2870.

15 - Who has ethically reviewed the project?
This research operates under the rigorous research ethics protocols of the University of Sheffield. It has been ethically reviewed and approved by the Ethics Review Panel of the Information Studies Department.

Contact for further information:
If you have a question about any aspect of this project, please speak to the researcher concerned or his supervisor, who will do their best to answer your query. Contact details are listed at the end of the document.

Thank you for your help with this research.

Kind regards,

Mohamed Adil

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Appendix II

Participant Consent Form

Title of Research Project: **Designing a decision model for an e-procurement Decision Support System for public sector using Multi-Criteria Decision Analysis**

Name of Researcher: **Mohamed Adil**

Participant Identification Number for this project: Please initial box

1. I confirm that I have read and understand the information letter dated *[insert date]* explaining the above research project and I have had the opportunity to ask questions about the project. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐

Lead Researcher contact details:

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3. I understand that my responses will be kept strictly confidential.
I give permission for members of the research team to have access to my anonymised responses, and to publish anonymised excerpts of my interview.
I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. ☐

4. I agree for the data collected from me to be used in future research ☐

5. I agree to take part in the above research project. ☐

_____	_____	_____
Name of Participant (*or legal representative*)	Date	Signature
_____	_____	_____
Name of person taking consent (*if different from lead researcher*)	Date	Signature
_____	_____	_____
Lead Researcher	Date	Signature

To be signed and dated in presence of the participant

To be signed and dated in presence of the participant

Copies:

Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/pre-written script/information sheet and any other written information provided to the participants. A copy of the signed and dated consent form should be placed in the project's main record (e.g. a site file), which must be kept in a secure location.

Appendix III

Code definition list

Themes	Interpretive Codes	Descriptive Codes	Definition
Preparation process	Legal boundary	Maximum tender	The maximum cost of tender that could be allowed to handle by BECs of the Education Sector.
		Minimum tender	The minimum cost of tender that could be allowed to handle by BECs of the Education Sector.
		Cost bands	The division of procurement costs and the mode of procurement applied to it.
		Bid announcement criteria	The criterion that is required to publicly announce for bids.
	Evaluation criteria	Price	Cost of the procurement used as a bid evaluation criteria.
		Duration of delivery	Duration of delivery used as a bid evaluation criteria.
		Experience	Experience of the bidder used as a bid evaluation criteria.
		Financial capacity	Financial capacity of the bidder used as a bid evaluation criteria.
		Quality	Quality of the product used as a bid evaluation criteria.
		Technical capacity	Technical capacity of the bidder used as a bid evaluation criteria.
		After sales services	Availability of the after sales services used as a bid evaluation criteria.
		Warrantee	Warrantee of the product used as a bid evaluation criteria.
		Human capacity	Human capacity of the bidder used as a bid evaluation criteria.
		Other criteria	Involvement of other criteria for bid evaluation.
		Criteria establishment	The way how the criteria is established.
		Allocation of criteria and weights	The basis for allocation of criteria and its weights to specific procurement.
Bidding process	Pre-bid meeting	Announcement of pre-bid meeting	Informing the public through public announcement for pre-bid meeting and bidding when public procurement is necessary.
		Compulsory pre-bid meeting	Obligatory requirement to have an information session for bidders before bidding.

		Provision of specification	Requirement to provide specific details of the required procurement to the bidders before bidding.
		Provision of marking criteria	Requirement to provide evaluation criteria of the required procurement to the bidders before bidding.
		Recoding of pre-bid attendants	Recording of the attendees of the pre-bid information session.
		On the spot information provided	Provision of information and answering the bidders' queries during the pre-bid information session.
		Specialised information	Provision of specific information on the specific product or services under procurement.
		Explanation of calculations	Explanation of the bid evaluation calculations to the bidders.
	Additional information	Request to submit all documents	Request to the bidders to submit all relevant required information.
		Information through email	Provision of information to the bidders through email after pre-bid information session.
		Information through phone	Provision of information to the bidders through telephone after pre-bid information session.
	Bid submission	Verification of bid submission	Recording of the bids submitted with its price and duration in the presence of bidders and provision of the information to all the bidders.
Evaluation process	Evaluation analysis	required minimum members	The number of members required to evaluate the bids announced by education sector.
		Basis for evaluation	The basis for evaluation of bids.
		verification of suppliers proposal	Procedures used to verify the information provided by the suppliers.
		Evaluation of suppliers previous jobs	Evaluation of the available information on the past completed jobs by the suppliers.
		Evaluation of support documents	The need to use documents provided by the suppliers for evaluation.
		Importance of acceptable price	Consideration of acceptable price in bid evaluation.
		Evaluation of suppliers' performance	Procedures used to evaluate the information provided by the suppliers.
		Marks allocation	Explanation of the calculations and how the marks are allocated to different levels of supplier performances.
		Use of technical expertise	Use of expert help in the bid evaluation process.
		Check for standard specification	Requirement to align the evaluation with the procurement specification provided.

		Evaluate every criterion independently	Evaluation of criteria in isolation without influence from other factors.
		Evaluate all criteria	Need to evaluate every criterion announced.
		No ranking	Inappropriateness to use ranking of criteria based on the performance values of it and avoidance of out ranking.
		No pair-wise comparison	Inappropriateness to use pair-wise comparison of criteria of different suppliers.
		No changes to criteria and requirements	Lack of possibility to change the criteria and specification during the evaluation and after bid submission stage.
		Disqualifying bids	Provision of disqualifying bids.
		Showing calculations to bidders	Informing the bidders how the evaluation calculations are done with the results.
	Awarding	Requires approval	The necessary requirement to get approval.
		Confirmation and reason for selection	The responsibility on bid evaluation committee on confirmation of bids.
		Informing bidders	The procedures used to inform the bidders after winner is established.
	Bidders complaints	clarification to bidders	Clarification of the doubts of evaluation to the requested bidders after evaluation process.
		Complaints to authorities	Possibility of complaints by bidders to the investigating authorities.
		Misconceptions of bidders	Possible misconceptions of bidders how the marking is done.
	Use of other MCDA methods	Lack of knowledge of other MCDA methods	Indication of lack of knowledge of BECs on other MCDA methods to evaluate procurement.
	Expected method	No discrimination	Expectation that any evaluation method applied should not discriminate bidders.
		Accurate method	Expectation that any evaluation method applied should be accurate.
		Reasonable	Expectation that any evaluation method applied should be reasonable.
		comply with regulations	Expectation that any evaluation method applied should comply with regulations.
		No chance of manipulation	Expectation that any evaluation method applied should minimise any chance of manipulation from both sides; bidders and education sector.
		Minimise complaints	Expectation that any evaluation method applied should minimise complaints.

		support utility concept	Expectation that any evaluation method applied could be a utility theory method.
		Clear and good understanding	Expectation that any evaluation method applied should be clear and easily understandable

Appendix IV

Quotation list

Category	Theme	Code	Quotation
Preparation process	Legal boundary	Maximum tender	"we handle procurement value less than MVR1.5 million" ML2
		Minimum tender	"If [the cost of] procurement is greater than MVR25000 we have to gazette it" ML2
		Cost bands	"Items less than MVR1000 would be purchased after checking prices from three vendors. Items between MVR1000 to 25000 will be purchased after getting quotations from three vendors. If [the cost of] procurement is greater than MVR25000 we have to gazette it" ML2
			"If [cost] is less than MVR25000 we award to the lowest cost supplier. Otherwise there are cases we don't award to the lowest price but to the most competitive bidder" ML2
		Bid announcement criteria	"If [the cost of procurement is] greater than MVR25000 we have to gazette it, publically announce it. Nowadays, we usually gazette it" ML2
	Evaluation criteria	Price	"Generally price is a criteria" ML2
			"There are mainly 4 criteria. They are: price, duration of supply, their financial capacity and experience" ML2
			"Price, duration, technical capacity, financial capacity is checked" DL1
			“Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance, provision of after-sales services, a warrantee is required. Different procurements have different ones (criteria). "IL3
			"mainly, price, duration and experience are evaluated" IL4
		Duration of delivery	"Points are awarded for duration [of delivery], experience [of the suppler] and financial capacity [of the supplier] as well" ML2
		Experience	"Points are awarded for duration [of delivery], experience [of the suppler] and financial capacity [of the supplier] as well" ML2
			"we look for bidders experience as well" DL1

			"We look into the bidders' previous level of performances for us, if they have ever done any job for us. If it is bad, it will be considered [in evaluation]" DL3
			"Then we look for experience, right? In everyday life, we also know some of them. But experience of the bidder is based on submitted documented evidences" IL3
		Financial capacity	"Points are awarded for duration [of delivery], experience [of the suppler] and financial capacity [of the supplier] as well" ML2
			"There are mainly 4 criteria. They are: price, duration to supply, their financial capacity and experience" ML2
			"Price, duration, technical capacity, financial capacity is checked" DL1
		Quality	As such [we] give higher importance to bidders' experience. Need to think about quality of work. Based on experience, it is evaluated"DL1
			"We assess similar work done by the bidders in other places to check for their quality of work"DL2
		Technical capacity	"Price, duration, technical capacity, financial capacity is checked" DL1
			"[Criteria include] number of qualified people for the job and number of available machineries for the job as well" DL2
		After sales services	"Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance provision of after sales services, warrantee. Different ones are different"IL3
			"As said earlier, there may be, for instance, after sales services as a criterion for things like machinery"IL3
		Warrantee	"Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance provision of after sales services, warrantee. Different ones are different"IL3
		Human capacity	"[Criteria include] number of qualified people for the job and number of available machineries for the job as well" DL2
		Other criteria	"Depending on the procurement there may be other allocated points (weights)" ML2
			"Some jobs have additional criteria other than the major 4 [criteria], but in most of the cases, these 4 criteria are used" ML2

			"Usually price is a criteria, next is the duration of delivery. For some cases, based on the procurement, for instance provision of after sales services, warrantee. Different ones are different"IL3
		Criteria establishment	"Points are allocated for price, duration and experience too"ML2 "The Public Finance Act says to use these criteria. Need to ensure before ordering" ML2
			"Criteria are established based on the work and situation analysis" DL2
			“Duration is highly considered when the work needs to be done in a short period of time. In some projects we may not assess the component. But it (duration) is considered for all the work which needs to be done during the school annual holidays. Some jobs are given ample time to be done to higher quality standards.” " DL3
		Allocation of criteria and weights	"If we need the item to be delivered urgently, allocated points for delivery can be almost equal to that of cost. Otherwise if we have enough time, we do not allocate higher weight to the item" ML2
			"Compared to price, quality, duration, if there is less time [to get the job done], priority is given to duration. Otherwise it may cause disruption to the education of many students" DL2
			"There may not be a standard to allocate weights. The norm is as DL2 mentioned, since we are a school we have a limited time to get the work done. So we pay attention to duration "DL1
			“Before it comes to evaluation, during information sessions it will be thought out. For instance, we may have had a bad experience with duration. The winning bidder for a job may have had a short duration for the job and could not deliver within the time. Next time, we will know that we need to allocate less weight to the duration for such jobs. Similarly, based on our experiences, weights increase for other criteria.”IL3
Bidding process	Pre-bid meeting	Announcement of pre-bid meeting	"public announcement made for the bids will have a specified date and time for an information session" ML2
			"at first it is publically announced" DL2

			"An announcement is made for specific jobs. It states we want these jobs to be done and bid submissions are open only for those jobs. First it will be an invitation to attend information session"DL1
			"First it is announced and when information is provided, it will state point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points"IL3
			"An announcement will state a time for information session, right? We have only small jobs which could be managed internally. An information sheet with the details is provided to attendees of the information session"IL4
		Compulsory pre-bid meeting	"It is an obligation to have a pre-bid meeting if the value is more than MVR25000" ML2
			"Yes, if we announce for bids, we have to have the information session" DL1 & DL2
			"A pre-bid meeting is compulsory. That is the time information is provided. Otherwise it is missed."IL3
		Provision of specification	"an information sheet is provided during the [pre-bid] meeting" ML2
			"When information is provided, the information sheet will have criteria and specific details of the work to be done" DL1
			"The information is provided in writing" DL1 & DL2. "Both verbal and written" DL3. "Explained verbally and given in writing" DL1
			if we announce for bids, we provide an information sheet" DL1 & DL2
			"An information sheet with the details is provided to attendees of the information session"IL4
		Provision of marking criteria	"The information sheet should state how (many) points (weights) are allocated (for each criteria) for making" ML2
			"The information Sheet will have marking criteria. It states the allocated points for price, allocated points for delivery, and how many points for their [suppliers'] experience. In some cases there are other allocated points. Point allocation standards should be stated in the information sheet" ML2.
			"That [marking criteria] is provided with the information sheet during the information session on the same day " ML2

			"A set of criteria is given while providing information [on specification] saying that those criteria are the ones to be used for marking. It is given to them [attendees of pre-bid meeting]. Evaluation is based on it [given set of criteria]" DL1
			"yes, we must provide [marking criteria] in the information sheet when we provide information" DL1 & DL2
			"First it is announced and when information is provided, it will state the point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points" IL3
			"Previously the [bid] announcement was with marking criteria but now it is not provided with the announcement but with the provision of information." IL3
		Recoding of pre-bid attendants	"Therefore, we have list of attendees to the pre-bid information session" DL2. "it has name, signature and time" DL1 & DL3
			"Without attending the information session, when someone takes the information sheet to a bidder, based on that, those who did not attend information session submit bids. After winning the bid, they may say that we were not clear about it" DL2.
		On the spot information provided	“Questions raised in the information session will be answered at the time. If answers are not available, they are provided later, either by email or by phone." ML2
			"They will get the opportunity to get answers for misunderstood information. They will also be given the opportunity to ask for additional information or questions. That is how it goes" DL3
		Specialised information	"The procurement unit handles jobs for many different sections. Therefore, in the pre-bid session a person from the requested department will attend to provide information" ML2
			"Some of them (procurement staff), by experience, have good knowledge to provide information to bidders. However, for IT, we bring a person from the IT section because IT is critical" ML2
		Explanation of calculations	"Sometimes (calculation) are also explained. Generally bidders know how it is calculated" ML2
			[calculations are] explained rarely." ML2

			"We don't really explain how the calculations are done. Marking criteria is there, but how the calculations carried out are not"DL1. "We assume that they know how the calculations are done" DL1 & DL2. "since it is routine and it is seen in papers" DL1
			"How the calculations are done is not explained as such [in the pre-bid meeting]. Attendees of the information session don't make any complaints about it[not explaining how calculations are done]. All of them will see the prices and other information submitted. When they see, they don't ask questions about it. So we also don't explain [calculations]. But if anyone complains we will provide that information. They would know how calculations are done. Everybody does these calculation in the same way" IL3
			"After evaluation, if bidders want to see the calculations, we provide it"IL3. "but hardly, anybody wants it" IL4
	Additional information	Request to submit all documents	"During information session bidders are requested to submit every document to support the bid" DL1
			"In addition to pre-bid meeting, information is provided through different means. But we have standard regulations to follow" IL4
		Information through email	“Questions raised in the information session will be answered at the time. If answers are not available, they are provided later, either by email or by phone." ML2
		Information through phone	“Questions raised in the information session will be answered at the time. If answers are not available, they are provided later, either by email or by phone." ML2
	Bid submission	Verification of bid submission	"Therefore, we have list of attendees to the pre-bid information session. We accept bids from them" DL2
			"On the day (when bids are submitted) qualified bids with their figures [cost and duration] are given to all the bidders. So they know who will probably win" ML4
			"in the presence of all the bidders, bids are received and the submission sheet is signed by all the bidders and a photocopy of the sheet is provided to every bidder" ML2
Evaluation process	Evaluation analysis	Required minimum members	"three people need to evaluate"ML2

		Basis for evaluation	"A set of criteria is given while providing information [on specification] saying that those criteria are the ones to be used for marking. It is given to them [attendees of pre-bid meeting]. Evaluation is based on it [given set of criteria]" DL1
			"[evaluation is] based on provided information during the information session. Based on the provided information, sometimes, even a higher cost bid can win" IL3
		Verification of suppliers' proposal	"when lowest cost bidders are to be awarded, the board [BEC] will check whether they can do the job" ML2
			"sometimes calls are made to bidders to verify whether they can do [the job], while the board [BEC] is in sitting" ML3
			"The price of shifting a container [full of goods] may be stated as MRV9000, but based on the committee analysis we don't find it possible. If the price is too low we ask before [awarding]." ML2
			“Some bidders put a shorter duration, unrealistic [duration], to win the bid. [Bidders are] trying to win [the bid] by allocating shorter duration to finish the work. We analyse whether it is possible to finish the work for the said period of time. All committee members analyse and then decide on it." DL2
			“Sometimes, when we announce for bids to paint the outer walls of this big school, we get bids priced for MVR5000. Painting all around the fence of the school [repeated with sarcastic expression to show that it is impossible to do the job for the said cost]. So we check for the market price of the paint and other items required. When we work it out MVR5000 is not enough for a single wall. So the committee analyses these issues to verify whether the work could be done [by the bidder]. We assess similar work done by the bidders in other places to check for their quality of work.” DL2
			"Then we look for experience, right? In everyday life, we also know some of them. But experience of the bidder is based on submitted documented evidences" IL3
		Evaluation of suppliers' previous jobs	"We assess similar work done by the bidders in other places to check for their quality of work" DL2
			"we take note of suppliers who misled us too"

			DL3
			"We look into the bidders' previous level of performances for us, if they have ever done any job for us. If it is bad, it will be considered" DL3
			"Previous jobs are considered in evaluation" DL2. "Based on previous work, there may be reduced points [for the bidder]. Such concerns are considered by us" DL3
		Evaluation of support documents	"in first attempt we check company profiles, audit reports and their tools and so on" DL2
			“Bids will be checked for the presence of all required documents. If the documents are not complete [in a bid], the bid will be disqualified " DL1 & DL2
			"In this everyday life, we also know some of them. But experience of the bidder is based on submitted documented evidences" IL3
		Importance of acceptable price	"we verify the price of the job, and check whether the job could be done with the stated cost [by the bidder] or not" ML2
			"[...] there are cases we don't award to the lowest price but to the most competitive bidder. It is done when we see the price of the lowest cost bid is too low to complete the job" ML2
			"The lowest cost bidder is not taken [for granted]. Most important is to look for acceptable price. For instance, a cheaper bid may have an item that may not well fit the purpose. In such cases we cannot consider it" DL1
			"Some bidders put a shorter duration, unrealistic [duration], to win the bid. [Bidders are] trying to win [the bid] by allocating shorter duration to finish the work. We analyse whether it is possible to finish the work for the said period of time. All committee members analyse and then decide on it. It is the same for price too" DL2
			"Yes, not to the cheapest bid. But price takes bigger chunk [of points]. When points are allocated, price is given a higher priority"IL3 &IL4
		Evaluation of suppliers' performance	"For instance, we wanted plastic chairs. We may have a bidder who has no experience in working with [supplying] plastic chairs. So they will get zero [marks on experience]. Even if their cost is the lowest, another bidder may

			win by gaining points [from other than cost]" ML2
			"The lowest [cost] bid may not be the bid gaining maximum points. Based on delivery, experience and financial capacity, the higher cost bid may gain more points. But lower cost bidder will get higher marks for the cost criteria" ML3
			As such [we] give higher importance to bidders' experience. Need to think about quality of work. Based on experience, it is evaluated"DL1
			“Sometimes, when we announce for bids to paint the outer walls of this big school, we get bids priced for MVR5000. Painting all around the fence of the school [repeated with sarcastic expression to show that it is impossible to do the job for the said cost]. So we check for the market price of the paint and other items required. When we work it out MVR5000 is not enough for a single wall. So the committee analyses these issues to verify whether the work could be done [by the bidder]. We assess similar work done by the bidders in other places to check for their quality of work.” DL2
			"… But price is not only the criteria, there are several other criteria. All those criteria are considered and the bid which gets the maximum marks is offered [the job]" DL1
			“Most consideration is given to price. Cheap, look for the cheapest. But for repair jobs, several things are considered: the machinery used, the number of workers, and some information is collected by contacting other parties, like the bidder’s previous performance, and whether the bidder has misled others, etc. Such hidden agendas are there too. Bidders don't expect that we would gather that information. But we do. We check for bidders who cheat. We had a loss in the year before previous year (2 years back) when the bidders left without fixing the doors. Still the doors are not fixed. Chairs are not supplied. So these [issues] are considered priorities for the second attempt [bid evaluation]" DL3
			"mainly, price, duration and experience are

			evaluated" IL4
		Marks allocation	"For instance, this bidder (pointing to an evaluated sheet) states 5 days to deliver, the other 7 days. The shortest period will get the best marks. [explained the calculations]"ML2
			"For instance, if the total marks for price is 35, the lowest cost bid will get 35 marks for the price. Others will get lesser marks based on the proportion. No bid gets zero, because it is proportional to submitted price. For instance, the highest cost bid may get 7" DL2
			"It is the same case for duration too. For instance, we have bids with duration of delivery within 20 days, 15 days and 10 days. So the shortest period will get the highest marks. Bids are awarded based on the total calculated by addition of all such marks" DL2
			"First it is announced and when information is provided, it will state the point allocation standard. Points are allocated accordingly. [The winner is] the bidder who gets the maximum points"IL3
			"Submitted price and other criteria are evaluated to allocated points. If MVR1000 and MVR500 are there, then the one with MVR500 will be in the first position. Based on the calculations, there will be marks for it [highest cost]. However, highest marks will be for the one with MVR500"IL3
		Use of technical expertise	"For instance, when buying computers, there will be an IT person in the bid committee. [Bids are] evaluated based on the IT person's advice" ML2
		Check for standard specification	"Some products have specific standards. If it is up to standard, marks are allocated" ML2
			"At first we check if it fits to our provided criteria (specification). For instance, there may be an item requested with standard 992 [...] If the item fits the standard, it is fine for us" ML2
			"If we bring something, check for quality, we check for alignment with our spec" ML1
			"For instance, a supplier whose delivery is fastest may not meet our spec. But the highest cost bid may exactly meet our spec. In such cases, we go for the one which meets the spec" ML1
			"To illustrate, if we get a short-sleeved shirt when we announced [the requirement] for a long-sleeved shirt, will not be fine. We have

			specific requirements" ML2
			“An announcement should be followed, right? For instance announcement is for 100 chairs. So we have to follow that requirement given. Otherwise, it is a change. It never happens" DL1.
			"evaluated as the prescribed requirements given in the information session"IL4
			"In that case, if we announce and buy 100 chairs, then we can buy only 100 chairs, even if we get cheaper by buying 150. If we want, we need to announce again for 150 chairs. We cannot change [pre-announced quantity]." IL3
		Evaluate every criterion independentl y	"Every criterion is evaluated on its own. No influence to one criterion from other criteria [are allowed] to allocate marks" ML1
			"each and every criterion is evaluated independently in isolation [from other criteria]" ML2
			"Evaluation is based on the submitted information for the specific bid [no case based reasoning]"DL2
			"Each criterion gets its own points. Nothing else, no other criteria is influenced by it" IL3
			"[for instance, someone would think if the cost is higher, the quality will be high], but marks for quality will not be influenced by price" IL2
			"No marks differentiation can be done based on previous bids [no case based reasoning]. Information is provided with that understanding. We have to evaluate all the criteria and cannot put aside some of it. But if there are inappropriate issues and if there are warnings issued to the bidder, it may be considered, otherwise the announcement is followed"IL3
		Evaluate all criteria	"all the criteria are evaluated" ML2
			"The committee checks all the areas. [We] cannot do ranking [in evaluation of criteria]"ML2
			"We have to evaluate every criterion for every bid. Even if the supplier submits unreasonable value, the bid should be evaluated" ML2

			"each and every criterion is evaluated independently in isolation [from other criteria]" ML2
			"[Outranking] cannot be used. Everything needs to be evaluated" DL2
			"Every criterion of everything (bids) needs to be evaluated" DL1 & DL2
			"If a bid is not submitted with requested information, then it will be disqualified. Otherwise everything will be evaluated" IL3
		No ranking	"The committee checks all the areas. [We] cannot do ranking [in evaluation of criteria]"ML2
			"Based on suppliers' submitted values for a criterion, we cannot position it by giving frist, second and third"ML2. "Yes [agreed by DL1]" DL1
			"[Outranking] cannot be used. Everything needs to be evaluated" DL2
			"No outranking. Evaluation is done proportionate to all the criteria" DL1
			"we cannot even do ranking [within a criteria]"IL4
			"Ranking may have used earlier when only cost criterion is used but not anymore. Even now, price is a criteria but ranking is not used"IL3
			"No outranking also used. If they meet all the criteria, we cannot do outranking. We follow our procedures of marking"IL3
		No pair-wise comparison	"No, we cannot do pair-wise comparison" IL3
		No changes to criteria and requirements	"No [bulk buy] advantage (even if there is discount when order exceeds the announced number of items)" ML1, ML2, ML3
			"We cannot change quantity by saying it will be cheaper. For instance, we want 3000 chairs for 3 schools. The approval will be for those 3 schools. Based on future needs, if we have storage, in the long run it is an advantage. But when a bulk of money goes out, the government will look to spread the expenses because, finances are set and checked in advance for monthly basis" ML2

			"So far that never happens [changes in requirements]. But, for instance, we check what would happen if we were to buy 100 items of the same. When bidding is done, even if we need to bear a loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation which should not be violated. If we take advantage of such discounts, it violates the regulations" DL3. "Cannot do that" DL1, DL2 & DL3
			"Such increases [in number of items to be purchased] would be a corruption" DL2. "It is corruption. That is how it is considered" DL1
			"In that case, if we announce and buy 100 chairs, then we can buy only 100 chairs, even if we get cheaper by buying 150. If we want, we need to announce again for 150 chairs. We cannot change [pre-announced quantity]." IL3
		Disqualifying bids	"If bids are not qualified, it can be disregarded. For instance, when teachers are recruited there is required information such as police report" ML2
			"[… suppliers] can withdraw their bid after bidding. However, after agreement, if they reject, the bid committee may suspend them for 6 months" ML2
			"The jobs will not be awarded to those who did not attend the information session, even though they submit the bids on time" DL1. "They will be disqualified. The bid announcement will state the same [that they will be disqualified] DL1
			"A bid is not awarded to bidders who did not attend the pre-bid information session" DL3.
			"Without attending the information session, when someone takes the information sheet to a bidder, based on that, those who did not attend information session submit bids. After winning the bid, they may say that we were not clear about it …" DL2. " That is why we disqualify bids when [the bidder] has not attended the information session " DL3
			"Therefore, we have list of attendees to the pre-bid information session. We accept bids from them" DL2
			"Bids will be checked for the presence of all required documents. If the documents are not complete [in a bid], the bid will be disqualified " DL1 & DL2
			"if a bid is not submitted with requested information, then it will be disqualified" IL3

		Showing calculations to bidders	"If bidders want [calculations done for evaluation], [we] have to show them. We show them this sheet [evaluated sheet]. Hardly any bidder comes [to check the evaluation sheet]" ML2
			“To illustrate, if we get a short-sleeved shirt when we announced [the requirement] for a long-sleeved shirt, will not be fine. We have specific requirements. [... when they do not win] they may complain. In such cases we do not show the evaluation sheet but explain what has happened" ML2
			"If they want to know why they did not win, we show them marks sheet. Then they know where their problem is"ML2
			"If they [bidders] want to see, we show them the final written decision" DL2. "it is not provided to all bidders, but to bidders who want to see" DL1 & DL2
			"if someone is not happy, and wants to see [marks allocation], it can be shown to them"DL2
			"All of them will see the prices and other information submitted [...]. But if anyone complains we will provide that information. They would know how calculations are done. Everybody does this calculation in the same way" IL3
	Awarding	Requires approval	“Even after evaluation it cannot be awarded. [It is] awarded when decided by the board, the procurement committee" ML2
		Confirmation and reason for selection	"[...] at the end of evaluation sheet there will be a written section saying that, based on the evaluation on all the aspects, the best bidder is this (name the bidder). Then all the attendees to the BEC sitting will sign it" ML2
		Informing bidders	"A letter of award is sent to the successful bidder. Instead of sending individual letter to unsuccessful bidders, the [awarding] letter is copied to them" ML2
			"when bid committee finish [evaluation and confirmation], we inform the winning bidder that the bidder has won" ML2
	Bidders complaints	Clarification to bidders	"If bidders want [calculations done for evaluation], [we] have to show them. We show them this sheet [evaluated sheet]. Hardly any bidder comes [to check the evaluation sheet]" ML2
			"if someone is not happy, and wants to see [marks allocation], it can be shown to them"DL2

		Complaints to authorities	"[...] They may think they are the lowest bidder and why they did not win. In that situation they complain"ML2
			"[they] go to anti-corruption [commission]" ML2 and ML3
			"[bidders] complain to anti-corruption commission and they (anti-corruption commission] investigate the case. We are also called for further inquiry" ML2
			"We now even have a court case"DL3. "It has happened recently too. But it is rare" DL1. "They complain, not only about the bid evaluation stage, but sometimes after the bid submission too they complain to the Anti-Corruption Commission (ACC). The complaint procedure is accessible. Everything is open through regulations. Sometimes without proper analysis they complain. On the other hand, the authority [ACC], without collecting proper information, considers it to be a huge case. Anybody can complain about anything. Even if they assume there could be a problem, they go and complain" DL3
			"Bidders complain. There should be an authority to listen and investigate their complaints too. If the authority says that there is a problem in the evaluation, we have to cancel it and announce again"IL3. "Bidders can go to court too. They should be allowed to get their rights through all the avenues available" IL4
		Misconceptions of bidders	"Some of the bidders think that they should win when the lowest price is submitted by them. This is their misconception" DL1
			"Such complaints are put forward for instance when their price is lower than the price of the winning bid. But price is not only the criteria, there are several other criteria. All those criteria are considered and the bid which gets the maximum marks is offered [the job]. Possibly, such complains are without proper consideration of the evaluation" DL1
	Use of other MCDA methods	Lack of knowledge of other MCDA methods	"[that method] would provide nearly the same result" ML3
			"Can be done, but may not be so accurate. This will show figures only" ML2
			"we would choose the best [if pair-wise comparison is used]" DL2

			[When explained and asked about use of utility theory methods, there was total silence. Then interviewer commented just to break the silence by saying that it will be based on the information sheet, right?] "It will be based on the information provided"IL4
	Expectation of evaluation method	No discriminatio n	"for instance, two companies bid 4 days for duration and 4 days is the minimum duration. So both of the bidders will get 35 points, the maximum allocated points" ML3
			"every bid needs to be evaluated" DL2
			"No outranking. Evaluation is done proportionate to all the criteria" DL1
		Accurate method	"Can be done, but may not be so accurate. This will show figures only" ML2
			"[a method which provides] good results is expected"DL1
		Reasonable	"it should be reasonable" ML2
		Comply with regulations	"When bidding is done, even if we need to bear loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation, which should not be violated. If we take advantage of such discounts, it violates the regulations" DL3.
			"Such [quantity discount] advantages are basically not taken because it contradicts laws and regulations. It violates public finance regulations" DL3
		No chance of manipulation	"We cannot change quantity by saying it will be cheaper. For instance, we want 3000 chairs for 3 schools. The approval will be for those 3 schools." ML2
			"So far that never happens [changes in requirements]. But, for instance, we check what would happen if we were to buy 100 items of the same. When bidding is done, even if we need to bear a loss [on quantity discounts] there is the Public Finance Act and Public Finance Regulation which should not be violated. If we take advantage of such discounts, it violates the regulations" DL3. "Cannot do that" DL1, DL2 & DL3
			"Such increases [in number of items to be purchased] would be a corruption" DL2. "It is corruption. That is how it is considered" DL1
		Minimise complaints	"If they want to know why they did not win, we show them marks sheet. Then they know where their problem is"ML2

			"On the day (when bids are submitted) qualified bids with their figures [cost and duration] are given to all the bidders. So they know who will probably win" ML3
		Support utility concept	"Should check both sides [inputs and outputs]" DL2
		Clear and good understanding	"That is a good thing [to explain the method]. The bidders could be discussed and explained about how it is done and what should be done. So that both sides have a good understanding" DL2

Appendix V

Electronic resources used for the systematic literature review of MCDA methods

Primo Central collection list (Source: University of Sheffield Library (2014))

Provider	Resource
ACM Digital Library	ACM Digital Library
Adam Matthew Digital	Victorian Popular Culture: Circuses, Sideshows and Freaks
Adam Matthew Digital	Victorian Popular Culture: Music Hall, Theatre and Popular Entertainment
Alexander Street Press	Garland Encyclopedia of World Music
Alexander Street Press	Social Theory
American Council of Learned Societies (ACLS)	ACLS Humanities E-Books
American Institute of Physics	AIP Conference Proceedings
American Institute of Physics	AIP Journals
American Institute of Physics	National Institute of Standards & Technology
American Institute of Physics	Society for Industrial and Applied Mathematics (SIAM) Journals Online
American Mathematical Society	AMS Current Journals
American Psychological Association	PsycARTICLES
Annual Reviews	Annual Reviews
ASTM International	ASTM International - Books & STPs
ASTM International	ASTM Standards
Australian National Data Service (ANDS)	Research Data Australia
Bentham Science Publishers	Bentham Science - Journals
Bioline International	Bioline International
BioMed Central Ltd.	BioMed Central
BioOne	BioOne
BioScientifica Ltd.	BioScientifica Journals
Bloomsbury Qatar Foundation Journals	QScience.com Journals
Bloomsbury Qatar Foundation Journals	QScience.com Proceedings
BMJ Publishing Group	BMJ Journals
British Library	EThOS - Electronic Theses Online Service
Cambridge University Press	Cambridge University Press Journals
Center for Research Libraries	Online Catalog
Central and Eastern European Online Library (C.E.E.O.L.)	Central and Eastern European Online Library (C.E.E.O.L.) Journals - Free access
Centre pour la Communication Scientifique Direct (CCSd)	HAL (Hyper Article en Ligne)

Consorci de Biblioteques Universitàries de Catalunya (CBUC)	RACO (Revistes Catalanes amb Accés Obert)
Consorci de Biblioteques Universitàries de Catalunya (CBUC)	RECERCAT (Diposit de la Recerca de Catalunya)
Consorci de Biblioteques Universitàries de Catalunya (CBUC)	TDX (Tesis Doctorals en Xarxa)
Consortium Érudit	Érudit Journals
Cornell University	Arxiv
Cranfield University	CERES (Cranfield Collection of E-Research)
CrossRef	American Accounting Association (AAA)
CrossRef	American Chemical Society
CrossRef	American Geophysical Union
CrossRef	American Institute of Aeronautics and Astronautics
CrossRef	American Mathematical Society
CrossRef	American Medical Association
CrossRef	American Physical Society (APS)
CrossRef	American Statistical Association
CrossRef	Annual Reviews
CrossRef	ASME International
CrossRef	Association for Computing Machinery
CrossRef	ASTM International
CrossRef	Bentham Science
CrossRef	Duke University Press
CrossRef	Edinburgh University Press
CrossRef	EDP Sciences
CrossRef	Elsevier
CrossRef	IEEE
CrossRef	Informa - Informa Healthcare
CrossRef	Informa - Taylor & Francis
CrossRef	Institution of Engineering and Technology (IET)
CrossRef	Mary Ann Liebert
CrossRef	MIT Press
CrossRef	National Association of Geoscience Teachers (NAGT)
CrossRef	Nature Publishing Group
CrossRef	Organisation for Economic Co-Operation and Development
CrossRef	S. Karger AG
CrossRef	Sage Publications
CrossRef	Springer
CrossRef	University of California Press
CrossRef	Walter de Gruyter
CrossRef	Wiley
Curtain University of Technology	espace @ Curtin

Dandy Booksellers Ltd	National Assembly for Wales (Public Information Online)
Dandy Booksellers Ltd	Non-Parliamentary Publications (Public Information Online)
Dandy Booksellers Ltd	Northern Ireland Assembly (Public Information Online)
Dandy Booksellers Ltd	Scottish Government (Public Information Online)
Dandy Booksellers Ltd	Scottish Parliament (Public Information Online)
Dandy Booksellers Ltd	UK Parliament (Public Information Online)
DataCite	DataCite
Dawson Books Limited	Dawsonera
Defense Technical Information Center	DTIC Technical Reports
Directory of Open Access Journals (DOAJ)	Directory of Open Access Journals (DOAJ)
EconPapers (RePEc)	Working Papers
Edinburgh University Press	Edinburgh University Press Journals
Elsevier	SciVerse ScienceDirect Journals
Elsevier	SciVerse Scopus
Emerald Group Publishing Limited	Emerald e-Journals Backfiles
Emerald Group Publishing Limited	Emerald Journals
Freie Universitat Berlin	Dokumentenserver der FU Berlin
Future Science Group	Expert Reviews
Future Science Group	Future Medicine
Future Science Group	Future Science
Gale	Eighteenth Century Collections Online I
Gale	Eighteenth Century Collections Online II
Ghent University	Ghent University Academic Bibliography
Harvard University, Office for Scholarly Communication	Digital Access to Scholarship at Harvard (DASH)
HathiTrust	HathiTrust (outside US)
Hindawi Publishing Corporation	Hindawi Books
Hindawi Publishing Corporation	Hindawi Journals
Hong Kong University of Science and Technology Library	Hong Kong Institutional Repositories
ICE Publishing	ICE Virtual Library - Journals
IEEE Publishing	IEEE Periodicals
IEEE Publishing	IEEE Proceedings
IEEE Publishing	IEEE Standards
IGI Global	InfoSci-Journals
Inderscience Publishers	Inderscience Journals
Ingram Digital	Myilibrary
Institute for Operations Research and the Management Sciences	INFORMS Journals
Inter-American Development Bank	IADB Repository
International Monetary Fund	IMF Videos
IOP Publishing (Institute of Physics)	IOP Electronic Journals

Iowa State University	Digital Repository @ Iowa State University
Japan Society of Applied Physics (JSAP)	Japan Society of Applied Physics Journals
John Wiley & Sons, Inc.	Wiley Online Library
John Wiley & Sons, Inc.	Wiley Open Access
Johns Hopkins University Press	Project MUSE
JSTOR	19th Century British Pamphlets
JSTOR	Arts & Sciences I
JSTOR	Arts & Sciences II
JSTOR	Arts & Sciences III
JSTOR	Arts & Sciences IV
JSTOR	Arts & Sciences V
JSTOR	Arts & Sciences VI
JSTOR	Arts & Sciences VII
JSTOR	Arts & Sciences VIII
JSTOR	Arts & Sciences IX
JSTOR	Arts & Sciences X
JSTOR	Arts & Sciences XI
JSTOR	Biological Sciences
JSTOR	Ecology & Botany
JSTOR	Ireland
JSTOR	Life Sciences
JSTOR	Music
Korea Institute of Science & Technology Information	Korea Science
KoreaMed	KoreaMed Synapse
Leeds Metropolitan University	Leeds Met Open Search
Leiden University	Leiden University Repository
Library of Congress	Library of Congress Collections of Historical Content
Library of Congress	Library of Congress Digitized Serials
Library of Congress	Library of Congress Maps, Atlases
Library of Congress	Library of Congress Motion Pictures
Library of Congress	Library of Congress Photos
Library of Congress	Library of Congress Posters
Library of Congress	Library of Congress Printed Ephemera Selections
Library of Congress	Library of Congress Selected Digitized Books
Library of Congress	Library of Congress Sheet Music
Library of Congress	Library of Congress Still Visual Materials
London School of Hygiene and Tropical Medicine	LSHTM Research Online
Luna Imaging, Inc.	David Rumsey Historical Maps
Luna Imaging, Inc.	Farber Gravestone Collection
Luna Imaging, Inc.	Japanses Historical Maps
Luna Imaging, Inc.	National Palace English

Luna Imaging, Inc.	The AMICA Library
M.E. Sharpe	M.E. Sharpe Journals
Mannheim University Library	MADOC Publikationsserver
Massachusetts Medical Society	New England Journal of Medicine (NEJM)
McMaster University Library	DigitalCommons@McMaster
Medknow Publications and Media Pvt. Ltd.	Medknow Journals
Mintel Group Ltd.	Mintel Reports
Modern Language Association (MLA)	MLA International Bibliography (Bibliographic records - CSA)
Modern Language Association (MLA)	MLA International Bibliography (Website records - CSA)
NASA Center for AeroSpace Information (CASI)	NASA Technical Reports Server (NTRS)
National and University Library of Iceland	Timarit
National Bureau of Economic Review (NBER)	National Bureau of Economic Review
National Library of Sweden	SwePub
National Library of the Czech Republic	Manuscriptorium
National University of Ireland Galway	ARAN
Nature Publishing Group	Nature Precedings
Nature Publishing Group	nature.com
Newfound Press	Newfound Press Books
Norwegian Open Research Archives (NORA)	Norwegian Open Research Archives (NORA)
Oakland University	OUR@oakland
OAPEN: Open Access Publishing in European Networks	Directory of Open Access Books (DOAB)
OAPEN: Open Access Publishing in European Networks	OAPEN Library
Oxford University Press	Oxford Journals
Oxford University Press	Oxford Journals Open Access
Oxford University Press	Oxford Medicine Online
Oxford University Press	Oxford Scholarship Online
Palgrave MacMillan	Palgrave Connect
Palgrave Macmillan	Palgrave Macmillan Journals
Pontificia Universidad Catolica del Peru	Portal de Revistas PUCP
Pontificia Universidad Catolica del Peru	Repositorio Digital de Tesis PUCP
Project Gutenberg	Project Gutenberg
Public Library of Science (PLoS)	PLoS
Publishing Technology (IngentaConnect)	Brill
Publishing Technology (IngentaConnect)	Hart Publishing
Publishing Technology (IngentaConnect)	Institute for Fiscal Studies
Publishing Technology (IngentaConnect)	Maney Publishing
Publishing Technology (IngentaConnect)	Martinus Nijhoff Publishers, an imprint of Brill
Repositório Cientfico de Acesso Aberto de Portugal	Repositório Cientfico de Acesso Aberto de Portugal
Réseau des Bibliothèques de lUniversité de Liège	PoPuPS: Portail de Publication de Periodiques Scientifiques

Royal Society of Chemistry Publishing	RSC Journals
Royal Society Publishing	Royal Society Journals
Royal Society Publishing	Royal Society Open Access Journals
S. Karger AG	Karger Open Access Journals
SAGE Publications	SAGE Journals
SAGE Publications	SAGE Research Methods
Scholars Portal	Scholars Portal Open Content Alliance Canadian Texts
SciELO	SciELO Brazil
SciELO	SciELO Chile
SciELO	SciELO Espanha
SciELO	SciELO Mexico
SciELO	SciELO Uruguay
Smithsonian Institution Libraries	Smithsonian Research Online
Society for Industrial and Applied Mathematics (SIAM)	Society for Industrial and Applied Mathematics - SIAM Journals
SpringerLink	SpringerLink Journals - All
SpringerLink	SpringerOpen
Swets Information Services BV	Swetswise Online Content
Swinburne University of Technology	Swinburne ImageBank
Swiss Electronic Academic Library Service (SEALS)	Retrodigitized Journals
Taylor & Francis Group	Taylor & Francis Online - Journals
Telemark University College	TEORA
Thomson Reuters	Web of Science - Arts & Humanities Citation Index: 1989-2014
Thomson Reuters	Web of Science - Science Citation Index Expanded: 1989-2014
Thomson Reuters	Web of Science - Social Sciences Citation Index: 1989-2014
U.S. Department of Education	ERIC (Education Resources Information Center)
U.S. Dept. of Energy - Office of Scientific and Technical Information	Energy Citations Database
U.S. National Library of Medicine (NLM)	MEDLINE / PubMed
U.S. National Library of Medicine (NLM)	PubMed Central
Unitec Institute of Technology	Unitec Research Bank
Universidad de La Rioja	Dialnet
Universita Degli Studi di Salerno	ELEA
Universitat de Barcelona	Diposit Digital
Université du Québec à Chicoutimi	SDEIR
University College London	UCL Discovery
University of Bath	Opus: Online Publications Store
University of Birmingham	UBIRA ePapers
University of Birmingham	UBIRA eTheses

University of California, California Digital Library	eScholarship
University of Cambridge	DSpace@Cambridge
University of Chicago Press	University of Chicago Press Journals
University of East London	ROAR
University of Edinburgh	Edinburgh Research Archive
University of Kent	Kent Academic Repository
University of Liège	ORBi (Open Repository and Bibliography)
University of Manchester	Manchester eScholar
University of Minnesota	AgEcon Search: Research in Agricultural and Applied Economics
University of North Texas	Portal to Texas History
University of North Texas	UNT Digital Library
University of Pardubice	Digital Library of the University of Pardubice
University of South Florida	Scholar Commons
University of Sydney	Sydney eScholarship Repository
University of Zurich	ZORA
Upper Austrian Federal State Library	Die digitale Landesbibliothek Oberosterreich
Uppsala University Library	DiVA - Academic Archive Online
VŠKP - University of Economics, Prague	ETDs Repository
Walter de Gruyter GmbH (and hosted publishers)	Walter De Gruyter Books
Walter de Gruyter GmbH (and hosted publishers)	Walter De Gruyter Journals/Yearbooks
White Rose University Consortium	White Rose Research Online
Wikimedia Foundation	Wikipedia, The Free Encyclopedia
Wolters Kluwer Health, Ovid Technologies	Lippincott Williams & Wilkins - Journals
World Scientific Publishing Co.	World Scientific Books
World Scientific Publishing Co.	World Scientific Journals

Appendix VI

Ethics approval letter

Information School Research Ethics Panel

Letter of Approval

Date: 27th February 2013

TO: Mohamed Adil

The Information School Research Ethics Panel has examined the following application:

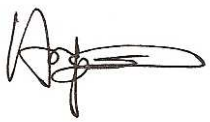
Title: Systems Design for E-Procurement DSS in Public Sector

Submitted by: Mohamed Adil

And found the proposed research involving human participants to be in accordance with the University of Sheffield's policies and procedures, which include the University's '*Financial Regulations*', '*Good Research Practice Standards'* and the '*Ethics Policy Governing Research Involving Human Participants, Personal Data and Human Tissue'* (Ethics Policy).

This letter is the official record of ethics approval by the School, and should accompany any formal requests for evidence of research ethics approval.

Effective Date: 14th May 2012



Dr Angela Lin
Research Ethics Coordinator