Approaches to Evaluating and Selecting Information Systems Projects under Uncertainty

A thesis submitted in fulfilment of the requirements for the degree of Master of Business

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

Santoso Wibowo

14th April 2008
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Abstract

The rapid advance in information and communication technologies has effectively facilitated the development and implementation of information systems (IS) projects in modern organizations for reorganizing their business processes and streamlining the provision of their products and services in today’s dynamic environment. Such a development brings organizations with numerous benefits including fast business transactions, increasing automation of business processes, improved customer service, and timely provision of effective decision support. As a result, evaluating and selecting the most appropriate IS project for development and implementation from a pool of available IS projects becomes a critical decision to make in modern organizations.

Evaluating and selecting appropriate IS projects for development in an organization, however, is complex and challenging. The complexity of the evaluation and selection process is due to the multi-dimensional nature of the decision making process, the conflicting nature of the multiple selection criteria, and the presence of subjectiveness and imprecision of the human decision making process. The challenging of the evaluation and selection comes from the need for making transparent and balanced decisions based on a comprehensive evaluation of all available IS projects in a timely manner while effectively considering the interest of various stakeholders in the IS project evaluation and selection process.

Much research has been done on the development of various approaches for evaluating and selecting IS projects, and numerous applications of those developed approaches for addressing real world IS project evaluation and selection problems have been reported in the
literature. In general, existing approaches can be classified into (a) cost-benefit analysis based approaches, (b) utility based approaches, and (c) optimization oriented approaches. These approaches, however, are not totally satisfactory due to various shortcomings including (a) the inability to tackle the subjectiveness and imprecision of the selection process, (b) the failure to adequately handle the multi-dimensional nature of the problem, and (c) cognitively very demanding on the decision maker.

To address these issues above, this research has developed three novel approaches for effectively solving the problem of IS project evaluation and selection under uncertainty in an organization. The first approach is developed for helping the decision maker better model the subjectiveness and imprecision inherent in the decision making process with the use of linguistic variables approximated by fuzzy numbers. The second approach is designed to reduce the cognitive demanding on the decision maker in the IS project evaluation and selection process with the introduction of fuzzy pairwise comparison in the decision making process. The third approach is formulated with respect to the use of intelligent decision support systems (DSS) for facilitating the use of specific multi-criteria analysis approaches in relation to individual IS project evaluation and selection situations. The developed approaches have been applied for solving three IS project evaluation and selection problems in the real world settings. The results show that the three developed approaches are of practical significance for effectively and efficiently solving the IS project evaluation and selection problem due to (a) the simplicity and comprehensibility of the underlying concept, (b) the adequate handling of inherent uncertainty and imprecision, and (c) the ability to help the decision maker better understand the IS project selection problem and the implications of their decision behaviors to the organization.
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Chapter 1

Introduction

1.1 Background

The rapid advance in information and communication technologies has effectively facilitated the development and implementation of information systems (IS) projects in modern organizations for reorganizing their business processes and streamlining the provision of their products and services in today’s dynamic environment (Brynjolfsson, 1994; Callon, 1996; Bresnahan et al., 2002; Deng, 2005; Lientz and Larssen, 2006; Deng and Wibowo, 2008a). Such a development greatly helps organizations create and maintain their competitive advantages in an increasingly globalized environment. It often brings organizations with numerous benefits including (a) fast business transactions, (b) increasing automation of business processes, (c) improved customer service, and (d) effective decision support in a timely manner (Gonzalez et al., 2005; Ruddock, 2006; Ketikidis et al., 2008).

Theodorou and Florou (2008), for example, show that organizations can use IS projects to effectively improve the management of organizational information for enhancing their competitiveness and developing and maintaining strategic advantages. King (2007) points out that the use of IS projects in organizations leads to the improvement of employee productivity and business efficiency. Gonzalez et al. (2005) demonstrate that the development and implementation of IS projects in modern organizations help these organizations better control
their operations. Bhatt and Troutt (2005) prove that the implementation of IS projects in organizations can enhance their ability to provide improved customer service.

The significant benefits that IS projects can bring to modern organizations as shown above demonstrate the critical importance of designing, developing and implementing various IS projects in today’s dynamic environment. Ideally modern organizations should have developed and implemented whatever IS projects they want and need. The reality, however, is that there are always various constraints including the availability of financial resources, the support of management, and the nature of organizational culture, to name a few, that effectively stop these organizations from acting in an ideal manner. As a result, evaluating and selecting the most suitable IS project for development and implementation from a pool of available IS projects becomes a critical decision to make in modern organizations (Chu et al., 1996; Jiang and Klein, 1999; Deng, 2005).

Evaluating and selecting appropriate IS projects for development and implementation in an organization, however, is complex and challenging. The complexity of the evaluation and selection process is due to the multi-dimensional nature of the decision making process (Deng and Wibowo, 2004), the conflicting nature of the multiple selection criteria (Chen and Hwang, 1992), and the presence of subjectiveness and imprecision of the human decision making process (Yeh and Deng, 2004; Deng, 2005; Deng and Wibowo, 2008a). The challenge of the evaluation and selection process comes from the need for making transparent and balanced selection decisions based on a comprehensive evaluation of all available IS projects in a timely manner while effectively considering the interest of various stakeholders in the IS project evaluation and selection process.
There are multiple evaluation criteria that often have to be considered simultaneously in an IS project evaluation and selection process. These criteria can be (a) economical, (b) technical, (c) operational, and (d) political (Ghasemzadeh and Archer, 2000; Lee and Kim, 2001). Those criteria as a reflection of the interest of various stakeholders in the selection process are often contradictory (Deng and Yeh, 1998; Deng, 2005). Quite often, an improvement in one criterion can only be achieved at the expense of deterioration of another. As a result, a simultaneous consideration of those multiple criteria is required for making effective evaluation and selection decisions (Chu et al., 1996).

Subjectiveness and imprecision are always present in the human decision making process. Their existence is often due to (a) incomplete information, (b) abundant information, (c) conflicting evidence, (d) ambiguous information, and (e) subjective information (Chen and Hwang, 1992; Zimmermann, 2000; Deng and Yeh, 2006). The evaluation and selection of IS projects in an organization is subjective and imprecise. As a result, how to adequately model the subjectiveness and imprecision becomes a critical issue for effectively solving the IS project selection problem in a real world setting (Stamelos and Tsoukias, 2003; Deng and Wibowo, 2008a).

1.2 Problem Statement

The problem of interest in this study is the general IS project evaluation and selection problem. This study is mainly concerned about evaluating and selecting IS projects from a set of available IS projects (alternatives) with respect to multiple, usually conflicting criteria in a fuzzy environment. The IS project evaluation and selection problem usually consists of a set
of IS projects (alternatives) and a set of criteria and their associated sub-criteria if in existent. These alternatives, criteria and sub-criteria are often constructed in a multi-level hierarchy. The overall objective of the general IS project evaluation and selection problem is to construct an effective and efficient evaluation and selection procedure to rank the alternatives in order of the preference of the decision maker while comprehensively considering the interest of various stakeholders in the decision making process. This procedure enables the decision maker to choose one or more alternatives in the simultaneous accomplishment of more than one objective, while satisfying any imposed constraints (Zeleny, 1982; Chen and Hwang, 1992; Yoon and Hwang, 1995; Deng, 2005).

Mathematically, the general IS project evaluation and selection problem can be formulated as follows:

\[
\begin{align*}
& \text{Max} \quad f_i(u), \quad i = 1, 2, \ldots, k, \\
& \text{Subject to:} \quad g_j(u) \leq 0, \quad j = 1, 2, \ldots, n,
\end{align*}
\]

where \( u \) is a \( m \) dimensional decision variable vector. The problem consists of \( m \) decision variable, \( n \) constraints and \( k \) objectives (Hwang and Masud, 1979).

Two common approaches are available to address this decision problem (Hwang and Masud, 1979; Hwang and Yoon, 1981; Chen and Hwang, 1992). One is to optimize one of the objectives while appending the other objectives to a constraint set so that an optimal solution would satisfy these objectives at least up to a predetermined level. Following this idea, the IS project evaluation and selection problem can be formulated as:
\[
\text{Max} \quad f_i(u), \quad i = 1, 2, \ldots, k, \quad (1.2)
\]

\text{Subject to:} \quad g_j(u) \leq 0, \quad j = 1, 2, \ldots, n,

\quad f_i(u) \geq a_h, \quad h = 1, 2, \ldots, k, \ h \neq i.

where \(a_h\) is any acceptable predetermined threshold value for objective \(h\).

The other approach is to optimize a super-objective function created by multiplying each objective function by an appropriate weight coefficient, and then by adding them together based on the utility theory (Hwang and Yoon, 1981; Olson, 1996; Deng, 1999). With this approach, the decision problem can be formulated as follows:

\[
\text{Max} \quad \sum_{i=1}^{n} w_i f_i(u), \quad (1.3)
\]

\text{Subject to:} \quad g_i(u) \leq 0, \quad i = 1, 2, \ldots, n,

This research takes the second approach to tackle the IS project evaluation and selection problem. The underlying assumption of this approach is that the fuzzy set theory is more appropriate and effective as compared to the traditional approaches for dealing with uncertainty and the imprecision of the human decision making process (Bellman and Zadeh, 1970; Carlsson, 1982; Chen and Hwang, 1992; Zimmermann, 1996; Deng, 2005).
1.3 Objectives of the Research

Modern organizations frequently face the IS project evaluation and selection problem (Jiang and Klein, 1999; Lee and Kim, 2001; Deng and Wibowo, 2004). Numerous studies have shown that modern organizations are not able to function effectively without appropriate development and implementation of IS projects for satisfying their increasing expectation of the stakeholders for effectiveness and efficiency. As a result, making the right decision on which IS projects to develop and implement is of critical importance to every modern organization for their profitability and even survivability in today’s dynamic environment.

To select the most appropriate IS project for development and implementation, the decision maker usually needs to (a) evaluate the performance of all the available IS projects, (b) assess the relative importance of the selection criteria and sub-criteria if existent, and (c) aggregate the assessments for producing an overall performance index value for each available IS project alternative across all criteria on which a final selection decision can be made.

Much research has been done on the development of appropriate approaches for evaluating and selecting IS projects, and numerous applications of those developed approaches for addressing real world IS project selection problems have been reported in the literature (Lootsma et al., 1990; Muralidhar et al., 1990; Santhanam and Kyparisis, 1995; Chen and Gorla, 1998; Jiang and Klein, 1999; Badri et al., 2001; Lee and Kim, 2001; Stamelos and Tsoukas, 2003). In general, existing approaches can be classified into (a) cost-benefit analysis based approaches, (b) multi-criteria utility based approaches, and (c) multi-objective optimization oriented approaches (Lee and Kim, 2001; Deng, 2005). These approaches are
developed to address the IS project evaluation and selection problem from different perspectives depending on the circumstance that an organization is in.

Existing approaches, however, are not totally satisfactory for effectively addressing the IS project evaluation and selection problem in general. They often suffer from various shortcomings including (a) the inability to tackle the subjectiveness and imprecision of the IS project evaluation and selection process, (b) the failure to adequately handle the multi-dimensional nature of the problem, (c) the inability to ensure the consistency in the decision making process, and (d) cognitively very demanding on the decision maker.

In this regard, this research aims to develop novel approaches capable for effectively solving the IS project evaluation and selection problem in a simple and straightforward manner. More specifically, this research will:

(a) Conduct a comprehensive review of existing approaches to evaluating and selecting IS projects;
(b) Develop novel approaches for evaluating and selecting IS projects; and
(c) Demonstrate the applicability of the developments in real IS project evaluation and selection situations with real world applications.

1.4 Outline of the Research

Figure 1.1 shows the framework of the research in this study in relation to the overall organization of the thesis. It provides an overview of the whole research and illustrates the relationships of the methodology developments and their applications in the IS project
evaluation and selection. As shown in Figure 1.1, Chapter 1 provides a brief introduction to the IS project evaluation and selection problem that paves the way for the whole study.

Chapter 2 provides a comprehensive literature review on existing IS project evaluation and selection approaches. Such a review is organized along a typical classification of the existing IS project evaluation and selection approaches including (a) utility based approaches, (b) mathematical programming approaches, (c) outranking approaches, (d) pairwise comparison based approaches, and (e) hybrid approaches. To justify the need for the developments of novel approaches for effectively addressing the IS project evaluation and selection problem, the chapter has highlighted the major drawbacks of existing IS project evaluation and selection approaches.

To pave the way for the development of novel approaches to effectively address the IS project evaluation and selection problem, Chapter 3 formulates the general IS project evaluation and selection problem in a multi-criteria analysis context. The characteristics of the IS project evaluation and selection problem make it appropriate for the multi-criteria analysis methodology to address the IS project evaluation and selection problem.

Chapter 4 presents a linguistic approach for effectively solving the IS project evaluation and selection problem under uncertainty. This approach uses linguistic variables approximated by fuzzy numbers to express the decision maker’s subjective assessments in evaluating criteria importance and alternative performance. A novel algorithm is developed for efficiently aggregating the linguistic assessments of the decision maker so that an overall performance index value can be produced for each IS project alternative across all criteria and sub-criteria if existent on which the selection decision can be made.
Figure 1.1  The research framework
Chapter 5 develops a pairwise comparison approach for evaluating and selecting IS projects under uncertainty. Recognizing the cognitively demanding nature of the evaluation and selection process on the decision maker and the presence of inherent subjectiveness and imprecision of the human decision making process, this chapter proposes using the pairwise comparison technique with the help of fuzzy set theory for evaluating and selecting IS project under uncertainty. As a result, effective evaluation and selection decisions can be made due to the great reduction of the cognitive demanding on the decision maker and the adequate modeling of the uncertainty in the decision making process.

Chapter 6 illustrates an intelligent decision support systems (DSS) approach for facilitating the selection of appropriate multi-criteria analysis approaches in solving the IS project evaluation and selection problem. The development of such an approach recognizes the availability of numerous multi-criteria analysis approaches in the literature and the different requirements, expectation and skills of the decision maker on the use of these approaches for addressing the IS project evaluation and selection problem. A knowledge base consisting of IF-THEN production rules is developed for assisting a systematic selection of the most appropriate multi-criteria analysis approaches in a specific IS project evaluation and selection situation. Effective decision support can be provided with the development of a flexile multi-criteria analysis approach selection procedure capable of considering both the characteristics of the problem and the requirements of the decision maker with the provision of an interactive user interface between the decision maker and the DSS. A supply chain management (SCM) system project evaluation and selection at a steel mill in Taiwan is presented for exemplifying the applicability of the intelligent DSS approach for facilitating the selection of appropriate multi-criteria analysis approaches in solving the IS project evaluation and selection problem under uncertainty.
Chapters 7 and 8 present two real world applications in regard to the IS project evaluation and selection on the use of the two novel approaches developed in Chapters 4 and 5 respectively. The real IS project evaluation and selection situations are described, and the need for adopting a specific IS project evaluation and selection approach is justified. The empirical results from these two applications show that the developed approaches are of great practical significance for effectively addressing the general IS project evaluation and selection problem under uncertainty.

Chapter 9 provides a summary of the developments of the novel approaches and their applications in this research. The contribution of this study is restated, and the possible future research is suggested.
2.1 Introduction

The importance of IS project development and implementation in an organization has long been recognized by both the IS researchers and practitioners (Clemons, 1990; Brynjolfsson, 1994; Ballantine et al., 1998; Irani and Love, 2002; Duh et al., 2006; Neirotti and Paolucci, 2007; Mirchandania and Ledererb, 2008). Organizations of various kinds in the world have made tremendous investment in the implementation of different IS projects with the expectation of productivity gains, competitiveness enhancement, and the reduction of administrative and operational costs (Santhanam and Hartono, 2003; Feld and Stoddard, 2004).

The evaluation and selection of the most appropriate IS project to develop and implement in an organization, however, is complex and challenging. In evaluating available IS projects for selection, multiple criteria are usually present (Lee and Kim, 2001), and subjective and imprecise assessments of the decision maker are often used (Chen and Gorla, 1998; Avineri et al., 2000; Deng and Wibowo, 2004). To ensure that the most appropriate IS project in a specific decision making situation is selected, effective approaches are desirable for solving the IS project evaluation and selection problem.
Much research has been done on the development of various IS project evaluation and selection approaches for effectively addressing the IS project evaluation and selection problem. These approaches are developed from various perspectives aiming to help the decision maker deal with the IS project evaluation and selection problem with respect to special circumstances in the real world setting. Commonly used approaches include mathematical approaches, financial approaches, checklist approaches, scoring approaches, decision theory approaches, consensus approaches and portfolio approaches (Liberatore and Titus, 1983; Oral et al., 1991; Henriksen and Traynor, 1999; Neirotti and Paolucci, 2007; Mirchandania and Ledererb, 2008).

To present an overview of the development in the area of evaluating and selecting IS project for design and implementation in an organization, this chapter conducts a comprehensive review of existing IS project evaluation and selection approaches. Such a review facilitates a better understanding of existing approaches for addressing this critical decision making problem and help identify the drawbacks and concerns of these existing approaches in the applications of these approaches in the real world. These drawbacks and concerns then serve as the fundamental motivation for conducting this research. Before the conduct of the review on existing IS project evaluation and selection approaches, the complexity of IS project evaluation and selection process is first discussed in the following.
2.2 The Complexity of Information Systems Project Evaluation and Selection Process

Evaluating and selecting an appropriate IS project from numerous competing IS projects to develop and implement within the constraint of various resources in an organization is complex and challenging (Clemons, 1990; DeLone and McLean, 1992; Deng, 2005). The complexity of IS project evaluation and selection process is due to (a) the multiplicity of the evaluation and selection criteria, (b) the conflicting nature of the evaluation and selection criteria, (c) the subjectiveness and imprecision of the human decision making process, and (d) the size of the selection problem (Chen and Hwang, 1992; Yoon and Hwang, 1995).

IS project evaluation and selection is usually multi-dimensional (Ghasemzadeh and Archer, 2000; Lee and Kim, 2001; Deng and Wibowo, 2004). It typically involves the consideration of multiple selection criteria such as the ability of the project to meet the existing system requirements, the economical factors, the technical factors, the operational factors, and more importantly the overall impact of the IS project on the whole organization. Quite often, these evaluation and selection criteria are in conflict as they are the right reflection of the interest of various stakeholders in the IS project evaluation and selection process (Jiang and Klein, 1999; Lee and Kim, 2001). As a result, an improvement in one criterion can only be achieved at the expense of deterioration of another. This conflict between the evaluation and selection criteria is fundamental to the nature of the selection problem (Deng and Yeh, 1998). Adequately addressing the IS project evaluation and selection problem therefore requires simultaneous consideration of these multiple criteria in an effective and efficient manner (Chu et al., 1996).
Subjectiveness and imprecision are always present in the human decision making process (Zadeh, 1973; Zimmermann, 2000; Yeh and Deng, 2004). This is mainly due to the presence of (a) incomplete information, (b) abundant information, (c) conflicting evidence, (d) ambiguous information, and (e) subjective information in the human decision making process (Chen and Hwang, 1992; Deng and Yeh, 2006). The evaluation and selection of IS projects is subjective and imprecise. As a result, adequately modeling the subjectiveness and imprecision becomes critical for effectively solving the IS project evaluation and selection problem in a real world setting (Stamelos and Tsoukias, 2003; Deng, 2005).

The size of the IS project evaluation and selection problem is another source of complexity in the IS project evaluation and selection process (Deng and Wibowo, 2008a). The size of the decision problem is usually measured by the number of decision makers, the number of alternatives, and the number of criteria and sub-criteria involved. The amount of information that the decision maker needs to handle increases exponentially as the size of the problem increases. It is often difficult for the decision maker to give consistent assessments due to the limitation in processing the available information simultaneously (Deng and Yeh, 1998).

2.3 Existing Approaches to Information Systems Project Evaluation and Selection

IS project evaluation and selection problems are fundamentally multi-criteria analysis problems due to the multi-dimensional nature of the evaluation and selection process. The decision making process usually involves in the selection of an appropriate IS project from many competing IS projects with respect to multiple, usually conflicting criteria and sub-
criteria if existent. The characteristics of the IS project evaluation and selection problem suggest that the quality of the decision making process can be enhanced with the application of structured approaches.

Numerous approaches for solving the IS project evaluation and selection problem have been reported in the literature (Saaty, 1980; Hwang and Yoon, 1981, Chen and Hwang, 1992; Yoon and Hwang 1995; Olson, 1996; Triantaphyllou and Sanchez, 1997; Zanakis et al., 1998; Gal, 1999; Triantaphyllou, 2000; Lee and Kim, 2001; Figueira et al., 2005; Wei et al., 2005; Dey, 2006; Lin et al., 2007). These approaches are developed from various perspectives for addressing specific IS project evaluation and selection situations with respect to the circumstances that an organization is in. This leads to various classifications of these approaches for evaluating and selecting IS projects in modern organizations in the literature (Steuer, 1986; Shin and Ravindran, 1991; Korhonen et al., 1992; Hababou and Martel, 1998).

Hababou and Martel (1998), for example, classify existing IS project evaluation and selection approaches into (a) ordinal approaches, (b) ratio scale approaches, and (c) rating scale approaches. Such a classification is based on the characteristics of individual approaches, including the type of information required from the decision maker, the size of the problem, and the criteria aggregation method. The ordinal approaches, for example, are used for solving the IS project evaluation and selection problem where the available information on the IS projects to be prioritized is of ordinal nature. These approaches are appropriate when a large number of IS projects needs to be processed and minimal data on the preferences of the decision maker is available. The ratio scale approaches deal with the IS evaluation and selection problem when a small number of IS projects are to be evaluated, and pairwise comparison data on a ratio scale are available.
This study classifies existing approaches into (a) utility based approaches, (b) mathematical
programming approaches, (c) outranking approaches, (d) pairwise comparison based
approaches, and (e) hybrid approaches. To present a summarized view of existing approaches,
the following discussion presents a comparative analysis of these approaches with respect to
the classification of the approaches as above. Specific attention has been paid in the
discussion to the nature of these approaches, their applications for solving real IS project
evaluation and selection problems, the merits of individual approaches, and the issues and
concerns in applying these approaches in the real world setting.

Utility based Approaches

Utility based approaches are most commonly used approaches for effectively solving the IS
project evaluation and selection problem in an organization. These approaches are developed
along the line of the additive utility theory (Hwang and Yoon, 1981; Chen and Hwang, 1992;
Olson, 1996). The overall objective of these approaches is to generate a cardinal preference
index value for each alternative IS project across all criteria and sub-criteria if existent in a
given IS project evaluation and selection situation on which a selection decision can be made
in an organization (Deng, 2005). The representative approaches in this category for solving
the IS project evaluation and selection problem in the literature are the multi-attribute utility
theory (MAUT) approach, the simple additive weighting (SAW) approach, and the simple
multi-attribute rating technique (SMART) approach.

The MAUT approach is a systematic approach for identifying and analyzing multiple criteria
and sub-criteria of a multi-dimensional decision problem in order to provide a common basis
for making a decision (Keeney and Raiffa, 1976; 1993). This approach helps the decision
maker assign subjective assessments in numerous values with respect to the performance of each alternative IS project across all criteria and sub-criteria and the relative importance of the evaluation and selection criteria and sub-criteria in regard to the overall objective of the problem. The overall utility value of each alternative IS project across all evaluation and selection criteria and sub-criteria are obtained through aggregating the decision maker’s subjective assessments along the line of the additive utility theory (Pohekar and Ramachandran, 2004).

Mehrez (1988) uses the MAUT approach for evaluating and selecting research and development projects for a small university laboratory. The application of this approach in this situation takes into account the uncertainties on both the technological and the marketing risks through assigning appropriate utility values to the corresponding alternative projects. The project with the highest overall utility value is selected as the most appropriate project for development. This approach is found to be useful in dealing with a small project evaluation and selection problem. However, as the number of projects to be considered increases, the approach becomes impractical to use. As a consequence, the approach is not recommended for dealing with large-scale project evaluation and selection problems.

Stewart and Mohamed (2002) apply the MAUT approach for selecting IS projects in an organization. Their application of the approach considers the decision maker’s preferences based on the business value and risk criteria in relation to four IS projects involved. The performance of each alternative IS project with respect to each evaluation and selection criterion and the weights of the criteria are determined numerically by the decision maker. The overall utility of each project is determined. This approach is found to be simple in concept and use. This approach, however is criticized due to its inability to deal with the
subjectiveness and imprecision inherent in the decision making process and the cognitive demanding nature on the decision maker in the evaluation and selection process.

The MAUT approach is proved to be popular in real world applications due to the simplicity of the approach in concept and the easiness in use. The approach, however, usually requires the decision maker to provide all the information describing the decision situation in order to build an objective function that includes all the relevant aspects of the IS project evaluation and selection problem (Keeney and Raiffa, 1976; Brownlow and Watson, 1987). This often proves to be difficult. In addition, the decision maker has to identify the IS project alternatives to be analysed and their impact on the criteria under consideration in advance which is very demanding (Kirkwood, 1997). In particular, the approach is inadequate in dealing with the subjectiveness and imprecision in the IS project evaluation and selection process.

The SAW approach is the simplest and still the most widely used approach for solving multicriteria analysis problems (Hwang and Yoon, 1981; Chen and Hwang, 1992; Olson, 1996; Chang and Yeh, 2001; Virvou and Kabassi, 2004). This approach evaluates multicriteria alternatives using a numerical scale in relation to the performance of these alternatives and the importance of the criteria involved. The numerical scores are then aggregated for representing the overall preference of the decision maker in regard to individual alternatives (Chen and Hwang, 1992). The most appropriate alternative is chosen based on the highest total score obtained.

Buss (1983), for example, applies the SAW approach for evaluating and selecting IS projects in an organization. With the use of this approach, the decision maker is required to provide
scores on each IS project for development. The decision is based on the aggregated scores among existing IS projects for evaluation and selection. This approach is a natural way to addressing the IS project evaluation and selection problem. As a result, the approach is popular with wide applications in various areas in the real world setting (Chen and Hwang, 1992; Olson, 1996; Deng, 1999). The approach, however, obviously suffers from several limitations including the inadequacy in modeling the subjectiveness and imprecision of the human decision making process and the cognitive demanding on the decision maker in the subjective decision making process.

The SMART approach is a simplified version of MAUT, where the assessment scores are standardized with zero representing the worst expected performance on a given criterion and one representing the best expected performance (Edwards, 1977; Edwards and Barron, 1994). The preference of each alternative is determined by calculating an overall decision score in each criterion and multiplying this by the weight value assigned to that criterion based on the utility theory (Chen and Hwang, 1992). The overall decision score for each alternative is determined using a linear additive value function. The alternative that produces the highest weighted score over all criteria is the most desirable solution (Edwards and Barron, 1994).

Nelson (1986) and Lootsma et al. (1990) use the SMART approach to facilitate the selection of the most suitable IS project for design and development. Their application allows the decision maker to allocate scores for alternative IS projects with respect to each evaluation criterion. By aggregating these scores with the relative importance of the selection criteria, an overall ranking of IS projects can be obtained on which the selection decision can be made (Avineri et al., 2000). This approach is reported to be popular due to its simplicity in concept and its easiness to use. It is, however, very demanding cognitively on the decision maker in
the evaluation process. It cannot effectively handle imprecise data in the evaluation process (Santhanam and Kyparisis, 1995).

Henriksen and Traynor (1999) present an application of the SMART approach for solving a IS project evaluation and selection problem in a federal research laboratory. A number of criteria including the relevance, risk, reasonableness, and return on investment are considered in the process of assessing and selecting a number of IS projects in an organization. The approach incorporates the tradeoffs among the evaluation criteria in the evaluation and selection process in order to calculate a measure of the overall project performance value. Such a value takes into account the fact that value is a function of both merit and cost in the IS project evaluation and selection process. This approach is found to be flexible to use because the organization can customize the approach to suit the specific objectives desired (Chen and Hwang, 1992; Olson, 1996).

The SMART approach is popular due to its simplicity in concept. The approach is also attractive due to the responses required of the decision maker and the manner in which these responses are analyzed (Edwards and Newman, 1982). However, this approach is found to be very demanding cognitively on the decision maker and often ineffective while dealing with subjectiveness and imprecision (Chen, 2001; Kahraman et al., 2003).

**Mathematical Programming Approaches**

Mathematical programming approaches are commonly used for solving the IS project evaluation and selection problem from the perspective of tangible cost and benefit of
individual IS projects. Usually mathematical programming approaches require the decision maker to provide information on the desired levels of targets for various criteria in evaluating the attractiveness of individual IS projects. Prior to solving the IS project evaluation and selection problem, the decision maker needs to provide an ordinal or cardinal ranking of the criteria with respect to the overall objective of the organization. An optimal solution that comes as close as possible to the prescribed set of targets in the order of priorities specified can then be determined (Saber and Ravindran, 1993; Olson, 1996).

The application of mathematical programming approaches generally requires the preference information of the decision maker in relation to the priorities of the evaluation criteria and objectives and the relationships between the objectives and criteria in consideration. Often tangible cost and benefit data about individual IS projects should be available, and some kinds of linear relationships between the decision variables should be able to formalize in a given situation. The development in this area has been attributed to the decision problems where there is a large number of conflicting objectives that the decision maker has to incorporate in their decision making process (Iz and Jelassi, 1990).

Czajkowski and Jones (1986) present an integer programming approach for evaluating and selecting interrelated research and development projects in space technology planning. Their approach considers the maximization of the utility and the cost reduction of new research and development projects. A single linear objective function is applied for aggregating these assessments with a weighting factor used to accommodate for the fact that the objectives are of different priorities. By varying the weightings given to various objectives in the objective function, the approach can produce a list of different solutions that are non-dominated. This approach is proved to be useful in some situations. The effectiveness of the approach,
however, is often questioned due to the lack of a systematic approach to set priorities and trade-off among objectives and criteria in a decision making process (Olson, 1996).

Santhanam et al. (1989) present a zero-one mathematical programming approach for helping IS managers decide which IS projects should be selected for development and implementation in a resource constrained environment. The approach is developed for addressing a decision making situation in which the IS project evaluation and selection goals are conflicting in nature and measured in incommensurable units. It is capable of considering both objective and subjective data simultaneously. The approach is proved to be effective for addressing the IS project evaluation and selection problem involving constrained resource allocation (Deng and Wibowo, 2004). This approach, however, is undesirable in some situations due to its inability for the decision maker to set up priorities among the objectives.

Schniederjans and Santhanam (1993) demonstrate the application of a zero-one mathematical programming approach for evaluating and selecting IS projects. Their approach incorporates both the relative ranking of the IS project selection criteria and resource limitations of an organization in order to select the most suitable IS project for development. The approach is capable of generating a superior solution in a given IS evaluation and selection situation. It is attractive for addressing IS project evaluation and selection problem because this approach can (a) avoid the possible solution bias, (b) consider all resource constraints, and (c) allow relative rankings of the evaluation and selection criteria in an easy manner. This approach, however, is often criticized due to the increased mathematical computation required when the number of criteria increases in a real decision making situation.
Santhanam and Kyparisis (1996) propose a non-linear zero-one mathematical programming approach for solving the IS project evaluation and selection problem. This approach is novel as it can consider the technical interdependencies among the IS projects in the IS project evaluation and selection process. A linearization procedure is applied for formulating the problem as a linear mixed integer programming approach. Although this approach is capable of considering the interdependencies inherent in the IS project evaluation and selection process, the procedure involved in obtaining the solution is likely to get complicated as the number of IS project alternatives increases.

Badri et al. (2001) develop a goal programming approach for solving the IS project evaluation and selection problem in the health care industry. Their approach considers the interdependence between the IS projects for evaluation with a specific focus on the resource optimization in an organization. The approach is very much realistic as it can consider multiple objectives and multiple constraints with a certain degree of flexibility. More importantly, this approach is capable of being applied for addressing various types of IS projects evaluation and selection situations in real world situations. However, this approach like all other mathematical programming approaches requires tedious mathematical computation in the IS project evaluation and selection process.

Kameshwaran et al. (2007) present a revised goal programming approach for solving the IS project evaluation and selection problem in e-procurement. The approach is developed to help the decision maker deal with decision making problem where the IS project evaluation and selection goals measured in incommensurable units are conflicting. An example is used to illustrate the flexibility of this revised goal programming approach and its effectiveness in obtaining a satisfying solution with respect to the presence of various goals in a given
situation. The limitation of this approach is that it requires the decision maker to specify the goals before the evaluation and selection process.

Mathematical programming approaches in general are proved to be popular for solving the IS project evaluation and selection problem with respect to resource optimization. This approach is capable of incorporating multiple objectives while producing an optimal solution in a given situation in the decision making process (Chen and Hwang, 1992; Olson, 1996). This approach, however, is often criticized due to a number of limitations that the approach has in real world applications. For example, the decision maker has to specify goals and priorities before applying the approach which often is undesirable. In addition, the mathematical programming approach lacks a systematic procedure for setting priorities and trade-off among objectives and criteria (Lee and Kim, 2001; Gabriel et al., 2005). This limitation is even more evident while addressing the IS project evaluation and selection problem when (a) both tangible and intangible selection criteria need to be considered, (b) interdependent criteria and subcriteria are involved, and (c) several decision makers are present in the evaluation and selection process (Olson, 1996).

Outranking Approaches

Outranking approaches are developed along the line of the outranking relation used to rank a set of alternatives (Chen and Hwang, 1992; Olson, 1996). The main feature of these approaches is to compare all feasible alternatives by pair which leads to the development of some binary relations, crisp or fuzzy. Such binary relations are then exploited in an appropriate manner in order to produce a final decision on the attractiveness of available IS project alternatives (Vincke, 1992; Roy, 1996; Wang and Triantaphyllou, 2008). The representative outranking approaches include the elimination and et choice translating reality
(ELECTRE) approach, the technique ordered preference by similarity to the ideal solution (TOPSIS) approach, and the preference ranking organization method for enrichment evaluation (PROMETHEE) approach.

The ELECTRE approach is developed on the analysis of the dominance relation among the IS project alternatives in a given situation. The approach focuses on the study of outranking relations among IS project alternatives through exploiting the notion of concordance and discordance among the IS project alternatives (Vincke, 1992; Roy, 1996; Belton and Stewart, 2002). These outranking relations are determined based on the concordance and discordance indexes in order to analyze the outranking relations among the alternatives. The information required with the use of the ELECTRE approach includes the information among the criteria and the information within each criterion (Roy, 1996).

The ELECTRE approach comprises of two main procedures including (a) the construction of outranking relation(s) and (b) the exploitation of such outranking relations. The construction of outranking relation(s) aims at comparing IS project alternatives pairwisely in a comprehensive manner. The exploitation process is used to elaborate recommendations from the results obtained in the first phase. The nature of the recommendations depends on the problem. Each approach in this category in the literature is characterized by its construction and its exploitation process (Vanderpooten, 1990; Roy, 1991; Olson, 1996). To demonstrate how this approach is developed and used for addressing the evaluation and selection problem, an analysis of several developments in this area is presented in the following.

Zhang and Yuan (2005) use the ELECTRE approach for addressing a power distribution system planning problem. Such a power distribution system planning problem involves
multiple, conflicting criteria. It involves the consideration of the decision maker’s subjective assessments which have to be considered simultaneously. The outranking relations are constructed for incorporating the decision maker’s subjective assessments with respect to the multiple selection criteria in the decision making process. The result shows that the ELECTRE approach has the flexibility in utilizing the information provided by the decision maker. Such flexibility allows the decision maker to express, test and modify his/her subjective assessments in the interactive decision making process. The approach is proved to be practical and feasible for facilitating the decision making process in power distribution system planning.

Aguezzoul et al. (2006) apply the ELECTRE approach for evaluating and selecting third-party logistics providers in organizational supply chain management. The approach incorporates multiple selection criteria which are often in conflict with one another. The approach classifies third-party logistics providers from the best ones to the less important ones in relation to the selection criteria used. This approach is found to be effective in solving this decision problem. It is flexible to incorporate additional criteria as required by the decision maker in the decision making process.

Shanian and Savadogo (2006) apply the ELECTRE approach for addressing a material selection problem in an organization. A decision matrix is introduced for the selection of the appropriate materials based on the design criteria. The weighted coefficients are obtained for every criterion using the entropy technique (Deng et al., 2000). The decision matrix and weighted coefficients are then taken as the input for the ELECTRE approach for the development of the outranking relation. The study shows that ELECTRE is a suitable and efficient approach that can be used successfully in selecting a suitable material.
The ELECTRE approach is widely used in solving different evaluation and selection problems in the literature (Olson, 1996). This approach, however, still has several shortcomings. For example, the ranking irregularities are a major issue that the ELECTRE approach suffers from. The ranking irregularities tend to occur when the alternatives appear to be very close to each other (Wang and Triantaphyllou, 2008). In addition, the outranking relation does not consider any interaction or dependence between criteria. It is purely based on the performance of each alternative against a given set of criteria. The concordance and dis-concordance index does not take into account the relative importance of the associated subcriteria (Figueira et al., 2005; Wang and Triantaphyllou, 2008).

A variant of the ELECTRE approach is the TOPSIS approach. The TOPSIS approach is developed by Hwang and Yoon (1981) as an alternative to the ELECTRE approach. The TOPSIS approach is based on choosing on the best alternative having the shortest distance to the ideal solution and the farthest distance from the negative ideal solution (Hwang and Yoon, 1981). The TOPSIS approach helps the decision maker organize the problems to be solved, and carry out analysis, comparisons and rankings of the alternatives based on the concept of distance between alternatives. The TOPSIS approach has been widely adopted to solve the evaluation and selection problem in many different fields.

Tsaur et al. (2002) use the TOPSIS approach for assessing the service quality in an airline industry. The evaluation procedure in their study consists of several steps. First, the service quality criteria that customers consider important are identified. After constructing the evaluation criteria hierarchy, the criteria weights are determined by applying the analytical hierarchy process (AHP) approach. The measurement of performance of individual airlines
with respect to each criterion is conducted under the setting of fuzzy set theory. Finally, the overall rankings of these airlines regarding their service quality are determined.

Chen et al. (2006) apply the revised TOPSIS approach for solving the supplier selection problem in a fuzzy environment. Linguistic variables are used to assess the weights of all selection criteria and the performance of each alternative with respect to each criterion. The decision matrix is converted into a fuzzy decision matrix, and a weighted-normalized fuzzy decision matrix is constructed once the decision maker’s fuzzy ratings have been pooled. Based on the concept of the TOPSIS approach, a closeness coefficient is defined for determining the ranking order of all suppliers by calculating the distances to both the fuzzy positive-ideal solution and the fuzzy negative-ideal solution simultaneously. The proposed approach is proved to be a useful decision making tool for solving the supplier selection problem. The approach is found to be very flexible which is capable of providing more objective information in the supplier selection and evaluation process.

Ertugrul and Gunes (2007) extend the TOPSIS approach for machine evaluation and selection in order to effective model the subjectiveness and imprecision of the decision making process. Linguistic variables are used for representing the subjective assessments of the decision maker. Fuzzy numbers are used to approximate the linguistic variables due to their capacities of handling the ambiguity associated with the decision maker’s judgements. To determine the overall order of the alternatives, a closeness coefficient is defined by calculating the distances to the fuzzy positive ideal solution and the fuzzy negative ideal solution. With the use of this extended TOPSIS approach, the uncertainty and vagueness from subjective perception and the experiences of decision maker is effectively represented, leading to effective decisions being made.
Garg et al. (2007) present an empirical study of applying the TOPSIS approach for evaluating and selecting an optimum power plant. The study shows that this approach allows a rapid convergence from a very large number of alternative plants to a manageable shortlist of potentially suitable plants. A computer software package is developed to assist the decision maker in establishing priorities and to oversee the selection process. It starts from the identification, classification and coding of the plant criteria, to a comparative evaluation and ranking based on certain criteria and concludes with the optimum selection of a power plant for a particular application. The TOPSIS approach provides a complete and thorough comparison and ranking for all the available power plants. The algorithm proposed for the TOPSIS approach includes the entire procedure with an easy access to the requirements of the decision maker. The approach is user friendly. It does not require an extensive technical knowledge for its use in the decision making process.

Wang and Chang (2007) apply the TOPSIS approach for evaluating and selecting training aircrafts under a fuzzy environment. The approach is used to deal with the training aircraft selection problem involving several alternatives with multiple conflicting criteria. The vagueness and subjectivity of the decision maker assessments are handled with the use of linguistic terms approximated by triangular fuzzy numbers. The approach is employed to obtain a crisp overall performance value for each alternative on which a final decision is made. This approach is employed for four reasons: (a) the logic of the TOPSIS approach is rational and understandable; (b) the computation processes are straightforward; (c) the concept permits the selection of best alternatives for each criterion in a simple mathematical form, and (d) the importance weights are incorporated into the comparison procedures (Deng et al., 2000; Chu and Lin, 2002; Olson, 2004).
The TOPSIS approach is found to be intuitive and easy to understand and implement. It allows a straight linguistic definition of weights and ratings under each criterion without the need of cumbersome pairwise comparisons and the risk of inconsistencies. However, this approach is unable to provide mechanisms for weight elicitation and consistency checking for the subjective assessment process.

The PROMETHEE approach is developed by Brans (1982) and further extended by Brans and Vincke (1985) and Brans and Mareschal (1994). This approach is based on a quite simple ranking concept with the introduction of the evaluation table. The implementation of the PROMETHEE approach requires two additional types of information including (a) information on the relative importance of the criteria, and (b) information on the decision maker’s preference when comparing the contribution of the alternatives in terms of each criterion (Albadvi et al., 2007). This approach is well suitable to problems where a finite number of alternatives are to be ranked with respect to conflicting criteria.

Goumas and Lygerou (2000) use the PROMETHEE approach for evaluating and ranking alternative energy exploitation projects. The approach is applied for the evaluation and ranking of alternative energy exploitation schemes of a low temperature geothermal field in Greece. The study shows that this approach is realistic capable of producing a reliable ranking for alternative energy exploitation scenarios, where the input data are subjective and imprecise. However, it is found that the approach is cognitively demanding on the decision maker in the evaluation process.

Albadvi et al. (2007) present a study of the PROMETHEE approach for evaluating and selecting superior stocks in stock trading. The required information for the evaluation and
selection process are gathered and analyzed through the use of a structured questionnaire that is filled in by the experts. This approach is then applied to assess the superior stocks in Tehran Stock Exchange. The limitation of this approach is that it does not consider the conditions that govern the stock market such as political conditions and market situation.

Araz and Ozkarahan (2007) apply the PROMETHEE approach for supplier evaluation and selection. The approach evaluates the performance of alternative suppliers by simultaneously considering supplier capabilities and other performance metrics indicated by the decision maker. As a result of this, the suppliers can be assessed and sorted based on their preference relations. The approach is flexible to use and can be used to identify the differences in performances across supplier groups. The approach is also useful in monitoring the suppliers’ performances.

The PROMETHEE approach, however, does not provide structuring possibilities in the problem solving process. In the case of multiple evaluation and selection criteria, this approach may become very difficult for the decision maker to obtain a clear view of the problem and to evaluate the results (Goumas and Lygerou, 2000). The PROMETHEE approach also requires specific guidelines for determining the weights and the generalized criteria which may be difficult to achieve by an inexperienced decision maker (Pohekar and Ramachandran, 2004).
**Pairwise Comparison based Approaches**

The pairwise comparison based approaches allow the decision maker to first formulate the evaluation and selection problem in a hierarchical structure consisting of the objectives, criteria, sub-criteria, and alternatives (Saaty, 1990). On the basis of the hierarchical structure of the problem, the pairwise comparison technique is used for assessing the performance of alternatives with respect to each criterion and the relative importance of the evaluation and selection criteria. The best known approach in this category is the AHP approach (1980, 1990). The AHP has been applied to solve unstructured problems in a various decision making situations, ranging from the simple personal decision making problem to the complex capital intensive decision making situation (Vaidya and Kumar, 2006).

The application of AHP consists of two stages including (a) hierarchic design, and (b) evaluation. The hierarchic design involves in formulating all the problem elements into a multi-level structure for a given evaluation and selection problem. At each level, the elements are broken down into components, which constitute the level below. The evaluation stage involves in comparing all elements at a level of the hierarchy in a pairwise manner with respect to each of the elements in the level directly above. A rating scale of 1 to 9 is used for representing the subjective assessments. The process of the pairwise comparison produces a relative ranking of priorities of the elements with respect to the criterion element they are compared against. The final ranking of the elements at the bottom level (the alternatives) is obtained by aggregating the contribution of the elements at all levels to each of the alternatives (Al Khalil, 2002).
Muralidhar et al. (1990) present an application of the AHP approach for IS project evaluation and selection. With the use of this approach, the IS project evaluation and selection problem is formulated in a hierarchical structure, and pairwise comparison is used for determining the performance of each IS project with respect to each criterion and the importance of the evaluation and selection criteria (Byun, 2001). The overall performance of each IS project across all criteria is determined based on the utility theory (Chen and Hwang, 1992; Lee and Kim, 2001).

Vellore and Olson (1991) apply the AHP approach for computer aided design and drafting systems selection. The evaluation and selection of these systems requires the consideration of a number of objectives that warrants the use of this approach. The AHP approach is used to consider (a) the cost factor, (b) the human factor, and (c) the impact of a new computer aided design and drafting system on the end-users in the organization concerned. The study shows that the use of the AHP approach enables a consistent and thorough study of all factors involved in this evaluation and selection process. The approach provides a sound methodology to support complex decision making as it identifies the relative importance of all relevant factors in a simple manner.

Min (1992) applies the AHP approach for evaluating and selecting logistics softwares. The evaluation and selection problem is structured into a four-level hierarchy consisting of goals, criteria, sub-criteria, and alternatives. The relative importance of the decision elements is estimated under each node of the hierarchy. After identifying the most appropriate logistics software with the given weights of decision criteria, sensitivity analyses are applied to examine the response of the overall priority of alternatives in relation to the changes in the relative importance of each criterion.
Al Khalil (2002) uses the AHP approach to evaluate and select the most appropriate method for project delivery. This study shows that the AHP approach is capable of incorporating subjective assessments of the decision maker while assigning the relative importance of all the evaluation and selection criteria. Based on this information, the most appropriate project delivery method can be determined. The approach is simple to use and the computations can be run using available specialized software or using any spreadsheet program.

Wei et al. (2005) propose the AHP approach for evaluating and selecting enterprise resource systems. The AHP approach is applied for dealing with the ambiguities involved in the assessment of enterprise resource systems alternatives and for determining the relative importance weightings of all criteria. The approach is capable of assessing all criteria systematically. In addition, it can incorporate additional criteria or decision makers in the evaluation process.

Braglia et al. (2006) present a study of the application of the AHP approach for evaluating and selecting computer maintenance system softwares. The approach is used to determine the performance of each project with respect to each criterion and the importance of the selection criteria pairwisely. This approach enables the decision maker to restrict the evaluation and selection process to a limited number of software programmes that better suit the actual requirements of an organization. As a result, decision makers can effectively select the most appropriate software for development.

The AHP approach has been widely used to address the IS project evaluation and selection problems in the literature. This approach, however, is often criticized for its inconsistent ranking outcomes, inappropriateness of the crisp ratio representation, and tedious comparison
processes when many criteria are involved (Yeh et al., 2000). With the use of the AHP approach, the decision maker is asked to give judgments about either the relative importance of the evaluation and selection criteria or its preference of one alternative on one criterion against another. This sounds simple and logic in real decision making situations. However, the pairwise comparison process becomes cumbersome, and the risk of generating inconsistent assessments increases when the number of alternatives and criteria increases, hence jeopardizing the practical applicability of the AHP approach (Chen and Hwang, 1992).

**Hybrid Approaches**

The approaches discussed above are developed and applied for addressing various evaluation and selection problems in real world with some success. These approaches are often developed with respect to specific characteristics of a specific evaluation and selection situation. In practice, a specific IS project evaluation and selection problem may require the use of several approaches in order to adequately handle the problem effectively. This is due to the restriction of a specific approach in dealing with the whole IS project evaluation and selection problem and the potential benefits from making use of multiple approaches in the decision making process. Following this logic, there are some developments of hybrid approaches to help overcome the weaknesses of an individual approach for solving the IS project evaluation and selection problem.

For example, Schniederjans and Wilson (1991) propose a hybrid approach through integrating AHP and goal programming for evaluating and selecting IS projects in an organization. The AHP is used first to prioritize the IS projects under consideration on the basis of the pertinent criteria of the organization involved. The goal programming approach
then explicitly considers the relative importance of the IS projects and the important resource availability constraints faced by the organization. The combined AHP and goal programming approach offers a systematic way to address the IS project evaluation and selection problem. This approach, however, is often criticized due to the mathematical computation involved with the use of the goal programming approach.

Teltumbde (2000) develops a hybrid approach based on the nominal group technique (NGT) and AHP for evaluating and selecting IS projects. The NGT is used to identify suitable evaluation criteria from the decision maker and other stakeholders. The AHP is then applied to determine the relative weights of these criteria, to rank the alternatives, and to finally select the most suitable IS project for development. The limitation of this approach is that the NGT approach can be time consuming due to the multiple activities involved in the evaluation and selection process.

Lee and Kim (2001) present a hybrid approach for evaluating and selecting IS projects that is interdependent with the combination of zero-one goal programming, the analytic network and the Delphi approach. The zero-one goal programming is used to handle the multi-dimensional nature of the selection problem (Lee, 1972). The AHP is applied to set priorities for the selection criteria. The Delphi approach is a systematic procedure for collecting group opinion (Dalkey, 1969; Lee and Kim, 2001). As a result this approach can handle the evaluation and selection problem with multiple criteria in which the projects concerned are interdependent and multiple decision makers are present. The limitation of the proposed approach is that the Delphi approach is time consuming and relatively complex to use.
Greiner et al. (2003) present a hybrid approach consisting of AHP and the zero-one integer programming for screening weapon systems development projects. The AHP allows the decision maker to establish evaluation criteria and derive criteria weights. The zero-one integer programming allows the decision maker to evaluate alternative projects against these established criteria. The hybrid approach is extremely flexible in which the decision maker can tailor the hybrid approach to represent a specific decision making situation. The weakness of this approach lies with the tedious mathematical computation involved in the use of zero-one integer programming in the problem solving process.

Hsu et al. (2003) integrate the AHP, the group decision process, and the fuzzy set theory for evaluating and selecting government-sponsored technology projects. The AHP is used to integrate various expectations from the decision maker into evaluating the criteria. The group decision process is performed by multiple decision makers to predetermine the criteria. The fuzzy set theory is applied for representing the subjective judgements of the decision maker. The result shows that the hybrid approach is suitable for solving the government-sponsored technology project selection problem in an effective manner. However, the group decision process is found to be time consuming as it requires the determination of all criteria from different decision makers.

Lin and Hsu (2003) propose the use of NGT and AHP for evaluating and selecting networks. The proposed hybrid approach first adopts the NGT to identify suitable evaluation criteria for selecting Internet networks from a group of decision makers. The AHP is then applied to determine the relative weights of these criteria, to rank the alternatives, and finally to select the ideal Internet networks. The proposed approach provides an objective way for advertisers
to use in evaluating and selecting an Internet advertising network. The limitation of this approach is that the approach is very time consuming with the use of NGT.

Sarkis and Talluri (2004) apply the AHP and goal programming for evaluating and selecting inter-organizational IS projects across a number of organizations. The AHP is used by the decision maker to establish evaluation criteria and to derive criteria weights. The goal programming is then used to evaluate and select the best pairing of software system and communication system based on the preferences of each organization. The approach has a number of limitations including data intensiveness and the requirement to include substantial managerial inputs.

Yurdakul (2004) uses the combined AHP and goal programming to evaluate and select the optimal combination of computer-integrated manufacturing technologies. The AHP is used first to obtain the relative importance weightings of alternative technologies with respect to four criteria consisting of innovation, customization, product proliferation, and price reduction. The AHP weightings are then incorporated into the goal programming approach which evaluates alternative projects against the established criteria. The major weakness of this approach is due to the tedious mathematical computation required on the use of the goal programming approach.

Gabriel et al. (2006) develop a hybrid approach consisting of multi-objective optimization, Monte Carlo simulation, and the AHP for addressing the IS project evaluation and selection problem. This hybrid approach is applied for determining an optimal project selection that accounts for multiple objectives in an organization. It also considers probabilistic aspects by directly incorporating them as part of the multi-objective optimization process, as well as
incorporating the AHP in evaluating the overall project ranks. The hybrid approach is found to be effective in solving the IS project evaluation and selection problem highlighted in their study. However, this hybrid approach is not suitable to solve the large scale IS project evaluation and selection problem as it is more computationally challenging.

Shyur and Shih (2006) present a hybrid approach using the analytical network process (ANP) and the TOPSIS for solving the vendor evaluation and selection problem. The ANP is used to obtain a set of suitable weights for the evaluation and selection criteria involved. The TOPSIS is adopted to rank competing products in terms of their overall performances. The approach can effectively deal with interdependent criteria and provide organizations with a way to devise and refine adequate criteria in a given decision making situation. The underlying concept of this approach is both rational and comprehensible. The proposed approach is found to be practical for ranking competing vendors in terms of their overall performance with respect to multiple interdependence criteria. The limitations of the proposed approach include (a) the inability to handle the inherent subjectiveness and imprecision of the human decision making process, and (b) the computationally challenging nature of the problem solving process.

Araz et al. (2007) apply the PROMETHEE and fuzzy goal programming for evaluating and selecting outsourcing projects faced by an organization. In the initial phase, the evaluation criteria and the objectives of the company are determined, and the existing outsourcers available to the organization are evaluated by using the PROMETHEE. In the second phase, fuzzy goal programming is used to select the most appropriate outsourcers for the organization while simultaneously allocating the quantities to be ordered from them. The proposed approach is found to be beneficial as it allows the incorporation of the decision
maker’s imprecise assessments. However, this hybrid approach can be computationally challenging for the decision maker especially when the number of criteria is large.

Ayag (2007) proposes a hybrid approach that integrates the AHP with simulation techniques to determine the best machine tool. The AHP is used to narrow down all possible machine tool alternatives in the market by eliminating those whose weights are smaller than a determined value obtained under certain circumstances. A simulation generator is used to (a) automatically model a manufacturing organization where the ultimate machine tool will be used, and (b) try each alternative remaining from the AHP as a scenario on the generated model. Finally, the most suitable alternative is selected by using the unit investment cost ratio. This approach is found to be very time consuming as the simulation process needs to be performed for each alternative.

Wang and Hwang (2007) develop a fuzzy approach to deal with the uncertainty commonly found in the evaluation and selection of research and development projects. Fuzzy set theory is applied to model the uncertain and flexible project information. A fuzzy zero-one integer programming approach is used to evaluate the value of each research and development project and determine the optimal project portfolio since traditional project valuation approaches often underestimate the risky project. This approach, however, involves in tedious mathematical computations during the selection process.

Wang and Yang (2007) use the hybrid AHP and PROMETHEE in making IS outsourcing decisions. The AHP is used to analyze the structure of the outsourcing problem and determine the weights of the criteria. The PROMETHEE is used for the determination of the final ranking. The approach is very well suited as a decision making tool for the IS
outsourcing decision as it involves the consideration of several conflicting performance criteria. The proposed approach can help the decision maker choose the evaluation and selection criteria in a systematic simple manner. However, this approach is questioned on the subjective nature of the weighting process.

Wey and Wu (2007) apply an integrated approach using fuzzy Delphi, ANP and zero-one goal programming for solving an interdependent project selection problem. The approach deals with problems having multiple criteria, interdependence and resource feasibility. The fuzzy Delphi approach is used to evoke expert group opinions and to determine a degree of interdependence relationship between the evaluation and selection criteria. The ANP is applied to set priorities and trade-off among objectives and criteria. The information obtained from the fuzzy Delphi and ANP is then used in the zero-one goal programming approach for determining the final outcome. This integrated approach is capable for solving an interdependent project evaluation and selection problem. The Delphi process, however, can be very time consuming in the problem solving process.

Sun et al. (2008) propose a hybrid approach based on the AHP and the scoring approach for project evaluation and selection. The AHP is applied to determine the relative weights for projects with respect to each evaluation criterion. The scoring approach allows the decision maker to aggregate these scores with the relative importance of the selection criteria. As a result the overall rankings of IS projects can be obtained on which the selection decision can be made. However, the pairwise comparison process becomes cumbersome, and the risk of generating inconsistencies increases as the number of alternatives and criteria increases.
The discussion above shows that there are numerous hybrid approaches for solving the IS project evaluation and selection problem. These hybrid approaches are found to be useful in dealing with the IS project evaluation and selection problem as they are capable of overcoming the restriction of a specific approach in dealing with the IS project evaluation and selection problem. However, most of these approaches can be very demanding cognitively on the decision maker in the evaluation and selection process. Tedious mathematical computation may also be involved which is undesirable.

2.4 Concluding Remarks

This chapter has reviewed related literature on IS project evaluation and selection approaches and identified the drawbacks of these existing approaches. Before the review on existing IS project evaluation and selection approaches, the complexity of IS project evaluation and selection process is discussed.

The review shows that most existing IS project evaluation and selection approaches suffer from various drawbacks in handling the complexity of the IS project evaluation and selection process. These shortcomings include (a) requirements of complicated mathematical programming, (b) inability to handle the subjectiveness and imprecision present in the evaluation process, (c) unreliability and complexity of the ranking procedures in comparing the utility values, and (d) cognitively demanding on the decision maker. To address these shortcomings, this study aims to develop effective approaches for IS project evaluation and selection.
Chapter 3

Formulating the Information Systems Project

Evaluation and Selection Problem

3.1 Introduction

Multi-criteria analysis refers to selecting or ranking alternative(s) from available alternatives with respect to multiple, usually conflicting criteria. Multi-criteria analysis problems are commonly encountered in our daily lives (Chen and Hwang, 1992). Dealing with multi-criteria analysis problems is complex and challenging. Every multi-criteria analysis problem is different in terms of the nature of the problem, the size of the problem, the amount of information available, the decision maker’s experience and knowledge, and the time available for making the decision. The subjectiveness and imprecision is often present in a given situation (Deng and Yeh, 1998).

Evaluating and selecting IS projects is fundamentally a multi-criteria analysis problem as it involves the evaluation and selection of an appropriate IS project in the presence of a multiple, usually conflicting criteria and sub-criteria if existent (Deng and Wibowo, 2004). The characteristics of the IS project evaluation and selection problem suggest that the quality of the decision making process can be enhanced with the application of multi-criteria analysis methodology for evaluating and selecting the appropriate IS project in an organization.
The purpose of this chapter is to formulate the general IS project evaluation and selection problem to pave the way for the methodology development. To facilitate the understanding the developments to be presented in later chapters, an overview of the development is also presented in this chapter.

3.2 The General Information Systems Project Evaluation and Selection Problem

The general IS project evaluation and selection problem usually consists of a set of available IS project alternatives $A_i (i = 1, 2, \ldots, n)$, to be evaluated against multiple selection criteria $C_j (j = 1, 2, \ldots, m)$. Each criterion $C_j$ may be broken down into $p_j$ sub-criteria $C_{jk} (k = 1, 2, \ldots, p_j)$. The decision maker is usually required to make subjective assessments to evaluate the performance of each alternative project with respect to each criterion, denoted as $x_{ij} (i = 1, 2, \ldots, n, j = 1, 2, \ldots, m)$. As a result a decision matrix for all the alternative projects can be obtained as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$$  \hspace{1cm} (3.1)

If sub-criteria $C_{jk} (k = 1, 2, \ldots, p_j)$ are existent for criterion $C_j$, a lower-level decision matrix can be determined for all the IS project alternatives, given as in (3.2) where $y_{ik}$ are the decision maker’s assessments of the performance rating of alternative $A_i$ with respect to sub-criteria $C_{jk}$.
\[
Y_c = \begin{bmatrix}
  y_{11} & y_{21} & \cdots & y_{n1} \\
  y_{12} & y_{22} & \cdots & y_{n2} \\
  \vdots & \vdots & \ddots & \vdots \\
  y_{1p_j} & y_{2p_j} & \cdots & y_{np_j}
\end{bmatrix}
\] (3.2)

In general, the weighting vectors \(W\) and \(W_j (j = 1, 2, \ldots, m)\) for the criteria and their associated sub-criteria respectively can be represented as

\[
W = (w_1, w_2, \ldots, w_j, \ldots, w_m)
\] (3.3)

\[
W_j = (w_{j1}, w_{j2}, \ldots, w_{jk}, \ldots, w_{jg})
\] (3.4)

where \(w_j\) and \(w_{jk}\) are the weights of criteria \(C_j\) and sub-criteria \(C_{jk}\) if existent.

Given the decision problem structure described as above, the overall objective of the IS project evaluation and selection problem is to rank all alternatives available by giving each of them an overall performance rating with respect to all criteria and the associated subcriteria. This overall performance rating is usually determined by effectively and efficiently aggregating the criteria weights and alternative performance ratings described as above with respect to the requirements of a specific IS project evaluation and selection problem.

### 3.3 An Overview of the Developments

The requirements of each specific IS project evaluation and selection problem are different from one situation to another. These requirements are often reflected in various forms including (a) the problem nature, (b) the problem size, (c) the data format presented, (d) the
degree of the decision maker’s involvement in the decision making process, and (e) the time available in making the decision (Chen and Hwang, 1992; Deng, 2005).

To effectively solve the IS project evaluation and selection problem as described above, effective approaches that can address the requirements of a specific IS problem are required for aggregating the criteria weights and alternative ratings in a simple and reliable manner (Deng and Yeh, 1998). As identified in Chapter 2, existing IS project evaluation and selection approaches are not totally satisfactory due to various shortcomings that they suffer from. The development of novel approaches is therefore desirable for assisting the decision maker to make effective decisions. To this end, three novel approaches have been developed in this study for facilitating the decision making process for effectively solving the problem of IS project evaluation and selection under uncertainty.

A linguistic approach is developed in Chapter 4 for helping the decision maker better model the subjectiveness and imprecision inherent in the decision making process with the use of linguistic variables approximated by fuzzy numbers. A novel algorithm is developed for efficiently aggregating the linguistic assessments of the decision maker so that an overall performance index value can be produced for each IS project alternative across all criteria and sub-criteria if existent on which the selection decision can be made.

To reduce the cognitively demanding nature of the IS project evaluation and selection process on the decision maker in the presence of inherent subjectiveness and imprecision of the human decision making process, a novel approach is developed in Chapter 5. This approach uses the pairwise comparison techniques with the help of fuzzy set theory for evaluating and selecting IS projects under uncertainty. As a result, effective evaluation and selection
decisions can be made due to the great reduction of the cognitive demanding on the decision maker and the adequate modelling of the uncertainty in the decision making process.

A novel approach is developed in Chapter 6 with respect to the use of an intelligent DSS for facilitating the use of specific multi-criteria analysis approaches in relation to individual IS project evaluation and selection situations. The development of such an approach recognizes the availability of numerous multi-criteria analysis approaches in the literature and the different requirements, expectation and skills of the decision maker on the use of these approaches for addressing the IS project evaluation and selection problem. A knowledge base consisting of IF-THEN production rules is developed for assisting a systematic selection of the most appropriate multi-criteria analysis approaches in a specific IS project evaluation and selection situation. Effective decision support can be provided with the development of a flexile multi-criteria analysis approach selection procedure capable of considering both the characteristics of the problem and the requirements of the decision maker with the provision of an interactive user interface between the decision maker and the DSS.
Chapter 4

A Linguistic Approach for Evaluating and Selecting Information Systems Projects under Uncertainty

4.1 Introduction

Uncertainty and imprecision always exist in the IS project evaluation and selection process due to the subjective nature of the human decision making process. They usually originate from assessing criteria importance and alternative performance in the face of (a) incomplete information, (b) non-obtainable information, and (c) partial ignorance in the multiple evaluation process (Chen and Hwang, 1992; Deng and Yeh, 1998). To ensure effective decision outcomes of the IS project evaluation and selection being made, it is important to adequately handle the uncertainty and imprecision inherent in the decision making process.

The purpose of this chapter is to present an effective linguistic approach for solving the IS project evaluation and selection problem in which both the criteria importance and alternative performance are presented subjectively. Linguistic variables approximated by fuzzy numbers are used to represent the subjective assessments of the decision maker. In this way, the approach is capable to effectively handle the uncertainty and imprecision inherent in the IS project evaluation and selection process. This leads to effective decisions being made in IS project evaluation and selection.
In what follows, linguistic variables and their applications in approximating the decision maker’s judgments and preferences are first discussed to pave the way for the development of the new linguistic approach. The linguistic based approach is then presented to show its implementability for solving practical IS project evaluation and selection problem.

4.2 Linguistic Variables and Linguistic Hedges

A linguistic variable is characterized by a quintuple \((x, T(x), X, G, M)\). \(x\) is the name of the variable. \(T(x)\) denotes the term-set of \(x\), that is, the set of terms of linguistic values of \(x\), with each value being a fuzzy variable denoted generically by \(x\) and ranging over a universe of discourse \(X\) which is associated with the base variable \(x\). The variable \(G\) is a syntactic rule (usually in grammatical form) for generating the term, \(X\), of value \(x\); and \(M\) is a semantic rule for associating with each \(X\) its meaning, \(M(x)\), which is a fuzzy subset of \(X\). The base variable could also be vector-valued (Zimmermann, 1987; Tseng et al, 1988; Chen and Hwang, 1992).

A linguistic hedge or a modifier is an operation, which modifies the meaning of a term or more generally of a fuzzy set. Linguistic hedges are usually adjectives, such as “very”, “quite”, “more or less”, “slightly”, “somewhat”, “rather”, and “approximately” (Deng and Yeh, 1998).

Linguistic values of linguistic variables and linguistic hedges are effective in approximating qualitative assessments of the decision maker and in describing complex phenomena which are hard to defined precisely (Deng and Yeh, 1998). They form the basis for approximate reasoning in fuzzy decision making and fuzzy controlling. The motivation for using words or
sentence rather than numbers is that linguistic characterizations are, in general, less specific than numerical ones (Zadeh, 1973).

Linguistic variables enable the representation of the decision maker’s knowledge, experience, and subjective view in an intuitive way and in a natural language format. To facilitate the adequate handling of the subjectiveness and imprecision of the IS project evaluation and selection process, linguistic variables are used to represent the decision maker’s assessments in the IS project evaluation and selection process (Yeh et al., 2000).

4.3 A Linguistic Approach

This section presents a linguistic approach for dealing with the IS project evaluation and selection situation in which the decision maker’s assessments for criteria importance and alternative performance are fuzzy. Linguistic variables approximated by fuzzy numbers are used to represent the subjective assessments of the decision maker so that the uncertainty and imprecision inherent in the IS project evaluation and selection process is adequately handled in a cognitively less demanding manner.

To facilitate the making of subjective assessments, linguistic variables defined as in Table 4.1 can be used. For computational simplicity, fuzzy numbers represented as \((a_1, a_2, a_3)\), where \(1 < a_1, 1 < a_2 < a_3 < 9\) are used to approximate these linguistic variables, in which \(a_2\) is the most possible value of a linguistic variable, and \(a_1\) and \(a_3\) are the lower and upper bounds respectively which are used to reflect the fuzziness of the situation (Zadeh, 1973; Cheng and Mon, 1994; Yeh et al., 2000).
To reduce the cognitive demanding on the decision maker, linguistic variables approximated by fuzzy numbers defined as in Table 4.2 can be used for determining the relative importance of the criteria and sub-criteria with respect to the overall objective of the IS project evaluation and selection problem.

The linguistic approach developed uses the utility theory to aggregate the fuzzy assessments of each alternative with respect to the sub-criteria of each criterion in order to constitute the fuzzy assessments regarding their corresponding higher level criteria. The concept of the degree of optimality is used to defuzzify the weighted fuzzy performance matrix so that the complex and unreliable process of comparing fuzzy utilities often required in fuzzy multi-criteria analysis (Deng and Yeh, 1998; Yeh et al., 2000) is avoided. The ideal solution concept (Zeleny, 1998) is applied for calculating the overall performance index for each alternative IS project across all criteria. As a result, effective IS project evaluation and selection decisions can be made.
The fuzzy approach starts at the generation of a weighted fuzzy performance matrix, which is the multiplication of decision matrix in (3.1) and the criteria weightings in (3.3) based on interval arithmetic (Kaufmann and Gupta, 1991). If criterion $C_j$ consists of sub-criteria $C_{jk}$, the decision vector $(x_{1j}, x_{2j}, \ldots, x_{nj})$ across all the alternatives with respect to criteria $C_j$ in (3.1) can be determined by

$$(x_{1j}, x_{2j}, \ldots, x_{nj}) = \frac{W_j \cdot Y_{C_j}}{\sum_{k=1}^{n_j} w_{j,k}}.$$  

(4.1)

where $W_j$ is the weighting vector for the sub-criteria and $Y_{C_j}$ is the assessments of the performance rating of alternative $A_i$ with respect to sub-criteria $C_{jk}$.

Given the fuzzy vector $(w_{x1j}, w_{x2j}, \ldots, w_{xnj})$ of the performance matrix for criterion $C_j$, a fuzzy maximum ($M_{\text{max}}^j$) and a fuzzy minimum ($M_{\text{min}}^j$) (Chen, 1985) can be determined as in (4.2)-(4.5) which represent respectively the best and the worst fuzzy performance ratings among all the alternatives with respect to criterion $C_j$ (Chen, 1985; Yeh et al., 2000).

$$
\mu_{M_{\text{max}}^j}(x) = \begin{cases} 
\frac{x - x_{\text{min}}^j}{x_{\text{max}}^j - x_{\text{min}}^j}, & x_{\text{min}}^j \leq x \leq x_{\text{max}}^j, \\
0, & \text{otherwise}
\end{cases},
$$  

(4.2)

$$
\mu_{M_{\text{min}}^j}(x) = \begin{cases} 
\frac{x_{\text{max}}^j - x}{x_{\text{max}}^j - x_{\text{min}}^j}, & x_{\text{min}}^j \leq x \leq x_{\text{max}}^j, \\
0, & \text{otherwise}
\end{cases},
$$  

(4.3)

where $i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$.

$$
x_{\text{max}}^j = \sup_{i=1}^{n} \left\{ x, x \in R \text{ and } 0 < \mu_{w_{xj_i}}(x) < 1 \right\},
$$  

(4.4)

$$
x_{\text{min}}^j = \inf_{i=1}^{n} \left\{ x, x \in R \text{ and } 0 < \mu_{w_{xj_i}}(x) < 1 \right\}.
$$  

(4.5)
The degree to which alternative \( A_i \) is the best alternative with respect to criterion \( C_j \) can then be calculated by comparing its weighted fuzzy performance \( (w_j x_{ij}) \) with the fuzzy maximum \( (M_{\text{max}}^j) \), given as in (4.6). \( u_{Rj}(i) \) represents the highest degree of approximation of alternative \( A_i \)’s weighted performance on criterion \( C_j \) to the fuzzy maximum, thus reflecting the decision maker’s optimistic view. This setting is in line with the optimal decision of Bellman and Zadeh (1970) who state that “in a fuzzy environment, objective and constraints formally have the same nature and their confluence can be represented by the intersection of fuzzy sets”.

\[
u_{Rj}(i) = \sup_{x \in R} \{ w_j x_{ij} \ I \ M_{\text{max}}^j \}.
\]  

(4.6)

Similarly, the decision maker’s pessimistic view can be represented by the degree to which alternative \( A_i \) is not the worst alternative with respect to criterion \( C_j \). This is calculated by comparing the weighted fuzzy performance \( (w_j x_{ij}) \) of alternative \( A_i \) with the fuzzy minimum \( (M_{\text{min}}^j) \), as

\[
u_{Lj}(i) = 1 - \sup_{x \in R} \{ w_j x_{ij} \ I \ M_{\text{min}}^j \}.
\]  

(4.7)

In actual decision settings, the decision maker’s attitude is not necessarily to be absolutely optimistic or pessimistic, but somewhere in between. To handle this situation, the concept of the degree of optimality (Zeleny, 1998) is introduced which is capable of incorporating an optimism index \( \lambda \) \((0 \leq \lambda \leq 1)\) for representing the decision maker’s attitude towards risk. In line with this concept, the degree of optimality of alternative \( A_i \) with respect to criterion \( C_j \) is determined by

\[
r_{ij} = \frac{\lambda u_{Rj}(i) + (1-\lambda) u_{Lj}(i)}{2}.
\]  

(4.8)
where \( r_{ij} \) indicates the degree of optimality of alternative \( A_i \) over all other alternatives in regard to criterion \( C_j \).

A fuzzy singleton matrix (Zadeh, 1973) can be obtained from the weighted fuzzy performance matrix based on (4.2)-(4.8), given as

\[
R = \begin{bmatrix}
    r_{11} & r_{12} & \ldots & r_{1m} \\
    r_{21} & r_{22} & \ldots & r_{2m} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{n1} & r_{n2} & \ldots & r_{nm}
\end{bmatrix}
\]  

(4.9)

To rank all the alternatives based on the fuzzy singleton matrix in (4.9), the concept of the positive ideal solution and the negative ideal solution is used. The positive (or negative) ideal solution consists of the best (or worst) criteria values attainable from all the alternatives (Hwang and Yoon, 1981; Deng and Yeh, 1998; Yeh et al., 2000). The most preferred alternative should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution (Hwang and Yoon, 1981; Zeleny 1998; Yeh et al., 2000).

Based on the concept of the ideal solution above, the positive ideal solution \( A^+ \) and the negative ideal solution \( A^- \) can be determined as in (4.10) and (4.11) as follows:

\[
A^+ = (r_1^+, r_2^+, \ldots, r_m^+), \quad A^- = (r_1^-, r_2^-, \ldots, r_m^-),
\]  

(4.10)

where

\[
a_j^+ = \sup (r_{1j}, r_{2j}, \ldots, r_{nj}), \quad a_j^- = \inf (r_{1j}, r_{2j}, \ldots, r_{nj}),
\]  

(4.11)

From (4.9) to (4.11), the Hamming distance between alternative \( A_i \) and the positive ideal solution and the negative solution can be calculated respectively as follows:
\[ s_i^+ = \sum_{j=1}^{m} (r_j^+ - r_j^-), \quad s_i^- = \sum_{j=1}^{m} (r_{ij}^- - r_j^-), i = 1, 2, \ldots, n. \] (4.12)

As a result, an overall performance index for each alternative \( A_i \) across all the criteria can be determined by

\[ P_i = \frac{s_i^-}{s_i^+ + s_i^-}, \quad i = 1, 2, \ldots, n. \] (4.13)

The larger the performance index, the more preferred the alternative.

### 4.4 Concluding Remarks

The IS project evaluation and selection process is complex and challenging as the decision maker has to take into account the uncertainty and imprecision inherent in the decision making process in an appropriate manner. To ensure effective decision outcomes of the IS project evaluation and selection being made, it is important to adequately handle the uncertainty and imprecision inherent in the decision making process.

This chapter has presented a linguistic approach capable for effectively solving the IS project evaluation and selection process in which both the criteria importance and alternative performance are presented subjectively. The linguistic approach is capable to effectively handle the uncertainty and imprecision associated with the human decision making process respectively by considering the decision maker’s subjective assessments in the IS project evaluation and selection process. As a consequence, effective decisions can be made based on the proper consideration of the decision maker’s subjective assessments.
Chapter 5

A Pairwise Comparison Approach for Evaluating and Selecting Information Systems Projects under Uncertainty

5.1 Introduction

In practical situations, the vague nature of the IS project evaluation and selection problem makes it difficult for the decision maker to assign exact numerical values in assessing the relative importance of the selection criteria and the performance ratings of the alternative IS projects with respect to each criterion. For example, when evaluating different IS project alternatives, the decision maker is usually unsure about their level of preferences due to incomplete and uncertain information about possible IS project alternatives and their performances and the number of alternatives involved. As a result, inconsistent criteria weightings and alternative ratings are often produced, which may lead to unreliable decision outcomes being made in the IS project evaluation and selection situation.

The decision to evaluate and select an appropriate IS project in an organization is further complicated due to the availability of numerous alternative IS projects, the increasing complexities of these sophisticated alternative projects, and the pressure to consider all multiple evaluation criteria simultaneously in a timely manner (Deng and Wibowo, 2004). Effective decision making requires a balanced consideration of all these issues in the IS project evaluation and selection process (Deng and Yeh, 1998).
The purpose of this chapter is to present a pairwise comparison approach for evaluating and selecting IS projects under uncertainty. Recognizing the cognitively demanding nature of the evaluation and selection process on the decision maker and the presence of inherent subjectiveness and imprecision of the human decision making process, this chapter proposes to use the pairwise comparison technique for evaluating the performance of alternative IS projects and the relative importance of the selection criteria. To effectively model the subjectiveness and imprecision of the decision making process, linguistic variables approximated by triangular fuzzy numbers are used. To avoid the complicated and unreliable process of comparing and ranking fuzzy utilities often required in dealing with multi-criteria analysis problems, the concept of the degree of dominance between alternatives is introduced for calculating an overall performance index for every alternative IS project across all criteria.

To pave the way for the development of the pairwise comparison approach, the concept of fuzzy synthetic extent analysis is first discussed. Linguistic variables originally defined by Saaty (1990) in the development of the AHP approach are used to facilitate the making of pairwise comparison. The pairwise comparison approach is then presented to show its capability for solving the IS project evaluation and selection problem under uncertainty in an organization.

5.2 Fuzzy Synthetic Extent Analysis

Fuzzy numbers are widely used to approximate the linguistic variables used for expressing the decision maker’s subjective assessments in the human decision making process. To
facilitate the making of pairwise comparison, linguistic variables originally defined by Saaty (1980, 1990) in the development of the AHP approach are used. These linguistic variables are approximated by triangular fuzzy numbers as defined in Table 5.1.

Table 5.1 Linguistic variables and their fuzzy number approximations for making pairwise comparison assessments

<table>
<thead>
<tr>
<th>Linguistic Variables</th>
<th>Fuzzy Number</th>
<th>Membership Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal Importance</td>
<td>1</td>
<td>(1, 1, 3)</td>
</tr>
<tr>
<td>Moderate Importance</td>
<td>3</td>
<td>(1, 3, 5)</td>
</tr>
<tr>
<td>Strong Importance</td>
<td>5</td>
<td>(3, 5, 7)</td>
</tr>
<tr>
<td>Very Strong Importance</td>
<td>7</td>
<td>(5, 7, 9)</td>
</tr>
<tr>
<td>Extreme Importance</td>
<td>9</td>
<td>(7, 9, 9)</td>
</tr>
</tbody>
</table>

To solve the pairwise comparison matrices, the concept of fuzzy synthetic analysis can be used. Assume that \(X= \{x_1, x_2, ..., x_n\}\) is an object set, and \(U= \{u_1, u_2, ..., u_m\}\) is a goal set. Fuzzy assessments are performed with respect to each object for each goal respectively, resulting in \(m\) extent analysis values for each object, given as \(\mu^1_i, \mu^2_i, ..., \mu^m_i, i=1,2,...,n\), where all \(\mu^j_i (i = 1, 2, ..., n; j = 1, 2, ..., m)\) are fuzzy numbers representing the performance of the object \(x_i\) with regard to each goal \(u_j\).

By using fuzzy synthetic extent analysis, the value of fuzzy synthetic extent with respect to the \(i^{th}\) object \(x_i (i = 1, 2, ..., n)\) that represents the overall performance of the object across all goals involved can be determined by
\[ S_i = \frac{\sum_{j=1}^{m} \mu_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{m} \mu_{ij}}, \quad i = 1, 2, ..., n. \]  

(5.1)

5.3 A Pairwise Comparison Approach

The multi-dimensional nature of the selection process, the presence of subjectiveness and imprecision, and the need for conducting a comprehensive evaluation on all alternative IS projects in a timely manner justify the use of multi-criteria analysis approaches for solving the IS project evaluation and selection problem. The main concerns with the existing multi-criteria analysis approaches lie with (a) the inappropriateness of handling the subjectiveness and imprecision of the decision making process, (b) the cognitive demanding on the decision maker in making subjective assessments, and (c) the complex and unreliable process of comparing fuzzy utilities (Deng, 1999). To effectively overcome these concerns, this chapter presents a pairwise comparison approach on the fusion of the concepts including (a) fuzzy theory, (b) AHP, (c) extent analysis, (d) degree of dominance, and (e) ideal solution.

The decision process starts with the determination of the performance of alternative IS projects with respect to each criterion and the relative importance of the selection criteria. To greatly reduce the cognitive demanding on the decision maker in the evaluation and selection process, the pairwise comparison technique commonly used in the AHP is applied. Using the linguistic variables described as in Table 5.1, a pairwise judgment matrix can be obtained for alternative performance or criteria importance respectively as in (5.2) where \( k = n \) or \( m \) and \( a_{12} = a_{21} \).
Using the fuzzy synthetic extent analysis as described in (5.1), the criteria weights \( w_j \) and the performance rating \( x_{ij} \) with respect to criterion \( C_j \) can be obtained, resulting in the determination of the fuzzy decision matrix for the alternative IS projects and the fuzzy weighting vector for the selection criteria as

\[
A = \begin{bmatrix}
1 & a_{12} & \ldots & a_{1k} \\
a_{21} & 1 & \ldots & a_{2k} \\
\vdots & \vdots & \ddots & \vdots \\
a_{k1} & a_{k2} & \ldots & 1
\end{bmatrix}
\]  

(5.2)

\[
X = \begin{bmatrix}
x_{11} & x_{12} & \ldots & x_{1m} \\
x_{21} & x_{22} & \ldots & x_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
x_{n1} & x_{n2} & \ldots & x_{nm}
\end{bmatrix}
\]  

(5.3)

\[
W = (w_1, w_2, \ldots, w_m)
\]  

(5.4)

With the use of interval arithmetic (Kaufmann and Gupta, 1991), the weighted fuzzy performance matrix for representing the overall performance of all alternatives in regard to each criterion can then be determined by multiplying the criteria weights \( w_j \) and the alternative performance ratings \( x_{ij} \), given as follows:

\[
Z = \begin{bmatrix}
w_1 x_{11} & w_2 x_{12} & \ldots & w_m x_{1m} \\
w_1 x_{21} & w_2 x_{22} & \ldots & w_m x_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
w_1 x_{n1} & w_1 x_{n2} & \ldots & w_m x_{nm}
\end{bmatrix}
\]  

(5.5)

To avoid the complicated and unreliable process of comparing and ranking fuzzy utilities for determining the overall performance of each alternative across all criteria, the concept of the degree of dominance between alternatives is introduced (Yeh and Deng, 2004). The degree of dominance concept is originally used to compare fuzzy numbers \( A \) and \( B \) as to how much
larger $A$ is than $B$. The fuzzy set difference $D_{A,B}$ between $A$ and $B$ can be calculated by fuzzy subtraction (Kaufmann and Gupta, 1991; Chen and Hwang, 1992) as

$$D_{A-B} = A - B = \{ (z, \mu_{A-B}(z)), z \in R \}$$

(5.6)

where the membership function of $D_{A,B}$ is defined as

$$\mu_{D_{A,B}}(z) = \sup_{z=x-y} (\min(\mu_A(x), \mu_B(y)), x, y \in X).$$

(5.7)

To determine how much larger $A$ is than $B$, a defuzzification process is required to extract a single scalar value from $D_{A,B}$, which can best represent $D_{A,B}$. Using the centroid method commonly regarded as an effective defuzzification technique (Chen and Hwang, 1992), the degree of dominance of $A$ over $B$ is determined by

$$d(A-B) = \frac{\int_{S(D_{A,B})} z\mu_{D_{A,B}}(z) \, dz}{\int_{S(D_{A,B})} \mu_{D_{A,B}}(z) \, dz}$$

(5.8)

where $S(D_{A,B}) = \{ z, \mu_{A-B}(z) > 0, z \in R \}$ is the support of $D_{A,B}$. $A$ dominates $B$ if $d(A-B) > 0$, and $A$ is dominated by $B$ if $d(A-B) < 0$. The larger the value of $d(A-B)$, the higher the degree of dominance of $A$ over $B$.

To apply the concept of the degree of dominance, a common comparison base needs to be set with respect to the weighted performance matrix in (5.5). In this regard, the fuzzy maximum and the fuzzy minimum are introduced. Given the fuzzy vector $(w_jx_{1j}, w_jx_{2j}, \ldots, w_jx_{nj})$ of the weighted performance matrix for criterion $C_j$, a fuzzy maximum ($M_{\max}$) and a fuzzy minimum ($M_{\min}$) (Chen, 1985; Chen and Hwang, 1992) can be determined as in (5.7)-(5.10) which represent respectively the best and the worst fuzzy performance ratings among all the alternatives with respect to criterion $C_j$. 

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\(\mu_{\mu_{j\min}}(x) = \begin{cases} \frac{x - x^-}{x^- - x_-}, & x^- \leq x \leq x_-, \\ 0, & \end{cases}\) (5.9)

\(\mu_{\mu_{j\max}}(x) = \begin{cases} \frac{x - x^+}{x^+ - x_+}, & x^- \leq x \leq x_+, \\ 0, & \end{cases}\) (5.10)

where \(i = 1, 2, ..., n\); \(j = 1, 2, ..., m\); \(x_+ = \sup_x \{x, x \in R \text{ and } 0 < \mu_{w_jx_j} < 1 \}\), and \(x_- = \inf_x \{x, x \in R \text{ and } 0 < \mu_{\nu_{j\min}} < 1 \}\).

With the determination of a fuzzy maximum \((M_{\max})\) and a fuzzy minimum \((M_{\min})\) as above, the degree to which the fuzzy maximum dominates the weighted fuzzy performance \((w_jx_{ij})\) of alternative \(A_i\) with respect to criterion \(C_j\) can be expressed as

\[d^*_j = d(M_{\max} - w_jx_{ij}) = \int D_{(M_{\max} - w_jx_{ij})}(\alpha) \, d\alpha\] (5.11)

where

\[D_{(M_{\max} - w_jx_{ij})}(\alpha) = \begin{cases} \frac{d^{La}_{(M_{\max} - w_jx_{ij})} + d^{Ra}_{(M_{\max} - w_jx_{ij})}}{2}, & 0 \leq \alpha \leq 1, \\ 0, & \text{otherwise.} \end{cases}\] (5.12)

in which \(d^{La}_{(M_{\max} - w_jx_{ij})}\) and \(d^{Ra}_{(M_{\max} - w_jx_{ij})}\) are the lower bound and upper bound of the interval respectively, resulting from the \(\alpha\) cut on the difference set \((M_{\max} - w_jx_{ij})\).

Similarly, the degree of dominance of the weighted fuzzy performance \((w_jx_{ij})\) of alternative \(A_i\) over the fuzzy minimum \(M_{\min}^{j\min}\) with respect to criterion \(C_j\) is given as

\[d_j = d(w_jx_{ij} - M_{\min}^{j\min}) = \int D_{(w_jx_{ij} - M_{\min}^{j\min})}(\alpha) \, d\alpha\] (5.13)

where
\[ D_{\min} (\alpha) = \left\{ \begin{array}{ll} \frac{d^{L\alpha}_{(w_{ij} - M_{min}^j)} + d^{R\alpha}_{(w_{ij} - M_{min}^j)}}{2} & , 0 \leq \alpha \leq 1, \\ 0, & \text{otherwise}. \end{array} \right. \] (5.14)

in which \( d^{L\alpha}_{(w_{ij} - M_{min}^j)} \) and \( d^{R\alpha}_{(w_{ij} - M_{min}^j)} \) are the lower bound and upper bound of the interval respectively, resulting from the \( \alpha \) cut on the difference set \((w_{ij} - M_{min}^j)\).

Zeleny (1982) first introduces the concept of the ideal solution in decision analysis as the best or desired decision outcome for a given decision situation. Hwang and Yoon (1981) further extend this concept to include the negative ideal solution in order to avoid the worst decision outcome in the decision making process. This concept has since been widely used in developing various methodologies for solving practical decision problems (Deng et al., 2000; Yeh et al., 2000). This is due to (a) its simplicity and comprehensibility in concept, (b) its computation efficiency, and (c) its ability to measure the relative performance of the decision alternatives in a simple mathematical form.

In line with the above concept, the positive fuzzy ideal solution consisting of the fuzzy maximum with respect to each criterion across all alternatives and the negative fuzzy ideal solution consisting of the fuzzy minimum in regard to each criterion across all alternatives can be determined as follows:

\[
A_{\max} = (M_{\max}^1, M_{\max}^2, \ldots, M_{\max}^m) \quad A_{\min} = (M_{\min}^1, M_{\min}^2, \ldots, M_{\min}^m) \] (5.15)

Using the fuzzy ideal solutions as the common base for comparison, the degree of dominance that the positive ideal solution is on alternative \( A_i \) (\( i = 1, 2, \ldots, n \)) can be calculated as follows:

\[
d_i^+ = \sum_{j=1}^{m} d_{ij}^+ \] (5.16)
Similarly, the degree of dominance that each alternative $A_i$ ($i = 1, 2, ..., n$) has on the negative ideal solution can be determined as

$$d_i^- = \sum_{j=1}^{m} d_{ij}^-$$  \hspace{1cm} (5.17)

An alternative is preferred if it is dominated by the positive fuzzy ideal solution by a smaller degree, and at the same time dominates the negative fuzzy ideal solution by a larger degree (i.e. farther away from the negative fuzzy ideal solution) (Deng et al., 2000; Yeh et al., 2000). Following this principle, an overall performance index for each alternative $A_i$ ($i = 1, 2, ..., n$) across all criteria can be calculated by

$$P_i = \frac{(d_i^+)^2}{(d_i^+)^2 + (d_i^-)^2}$$  \hspace{1cm} (5.18)

The larger the performance index $P_i$, the more preferred the alternative $A_i$.

## 5.4 Concluding Remarks

The complexity of the IS project evaluation and selection process is due to the multi-dimensional nature of the decision making process, the conflicting nature of the multiple selection criteria, and the presence of subjectiveness and imprecision of the human decision making process. The challenging of the selection process comes from the need for making transparent and balanced selection decisions based on a comprehensive evaluation of all available IS projects in a timely manner.
This chapter has presented the development of a pairwise comparison approach to effectively deal with the IS project evaluation and selection problem in a simple and straightforward manner. To greatly reduce the cognitive demanding on the decision maker, the pairwise comparison technique is adopted for evaluating the performance of alternative IS projects and the relative importance of the selection criteria. To avoid the complicated and unreliable process of comparing and ranking fuzzy utilities often required in solving multi-criteria analysis problem, the concept of the degree of dominance between alternatives is introduced for calculating an overall performance index for every alternative IS project across all criteria.

The pairwise comparison approach developed in this chapter has several advantages including (a) its simplicity and comprehensibility of the underlying concept, (b) its consistencies in deriving the criteria weights, (c) its ability to adequately handle the subjectiveness and imprecision of the weighting process, and (d) its ability to adequately handle the multi-dimensional nature of the selection process.
Chapter 6

An Intelligent Decision Support Systems Approach for Selecting Information Systems Projects

6.1 Introduction

A DSS is a computer-based IS used to support decision making activities in situation where it is not possible or not desirable to have an automated system for performing the entire decision making process. A DSS uses computers to (a) assist managers in their decision processes in semi-structured problems, (b) support, rather than replace, managerial judgments, and (c) improve the effectiveness of decision making rather than its efficiency.

The application of a DSS approach for solving structured and semi-structured problems has become more and more popular nowadays due to its flexibility and adaptability for tackling various decision situations (Jelassi et al., 1983; Korhonen et al., 1992; Eom et al., 1993; Turban and Aronson, 2000). The attractiveness of the DSS in real world settings is even more enhanced with the provision of a convenient user interfaces and a direct control of the problem solving process by the decision maker with the availability of various decision making approaches. This allows the decision maker to select appropriate approaches and models with respect to the characteristics of a specific decision making situation for effective and efficient decision making.
Multi-criteria analysis refers to selecting or ranking alternative(s) from available alternatives with respect to multiple, usually conflicting criteria. Tremendous efforts have been spent and significant advances have been made in multi-criteria analysis, resulting in the development of numerous approaches for solving various evaluation and selection problems (Lin and Hsieh, 2004; Sarkis and Talluri, 2004; Tian et al., 2005; Dey, 2006; Wei et al., 2007; Papadopoulos and Karagiannidis, 2008). These approaches are often difficult to classify, evaluate, and compare, because they are developed on various assumptions about the decision maker’s preferences with the use of different types of preference information in the problem solving process. Several approaches may often appear to be useful for a particular problem. However, different approaches usually represent radically different philosophies in problem solving, and choosing an appropriate approach for addressing a specific IS project evaluation and selection problem may be complex and challenging due to the nature of a particular problem under consideration and the decision maker’s requirements and preference in the decision making process (Deng and Yeh, 1998; Deng and Wibowo, 2008b). An intelligent DSS capable of facilitating the process of selecting the appropriate multi-criteria analysis approach in a specific IS project evaluation and selection situation is obviously desirable.

This purpose of this chapter is to present an intelligent DSS approach for facilitating the adoption of appropriate multi-criteria analysis approaches in solving the IS project evaluation and selection problem. A knowledge base consisting of IF-THEN production rules is developed for assisting with a systematic adoption of the most appropriate multi-criteria analysis approach through considering the decision maker’s requirements in solving the IS project selection problem with the efficient use of the powerful reasoning and explanation capabilities of DSS. The idea of letting the problem to be solved determines the approach to be used is incorporated into the development of the DSS framework. As a result, effective
decisions can be made in real world situations for solving the IS project evaluation and selection problem.

In what follows, the need for an intelligent DSS for evaluating and selecting IS projects is first discussed. This is followed by a presentation of the DSS framework for IS project evaluation and selection. A knowledge base consisting of IF-THEN production rules is developed for assisting a systematic selection of the most appropriate multi-criteria analysis approach in a specific IS project evaluation and selection situation. Finally, a practical example is presented for demonstrating the applicability of the proposed DSS for solving the real IS project evaluation and selection problem.

6.2 Needs for an Intelligent Decision Support System for Selecting Information Systems Projects

With the multi-dimensional nature of the IS project evaluation and selection problem and the availability of various multi-criteria analysis approaches for addressing this problem, the development of DSS capable of integrating existing multi-criteria analysis approaches into a DSS framework is obviously an effective means to help the decision maker select specific multi-criteria analysis approaches in solving a given IS project evaluation and selection problem. The application of such a DSS would greatly reduces the difficulty and the complexity in the process of selecting specific multi-criteria analysis approaches for solving the IS project evaluation and selection problem.
Much research has been devoted to the development and application of DSS for solving various decision problems. Archer and Hasemzadeh (2000), for example, develop a DSS for solving the project portfolio selection problem. Bastos et al. (2005) apply an intelligent DSS for helping the decision maker solve a resource allocation problem. Ozbayrak and Bell (2003) utilize a rule-based DSS for managing manufacturing parts and tools in a production line. Wen et al. (2005) apply an intelligent DSS in analysing a decision situation for enterprise acquisition that shows promising results. All these efforts demonstrate that the development and adoption of DSS for addressing various decision problems is of great benefits in real world settings.

The application of DSS for solving the IS project evaluation and selection problem, however, is not a straightforward solution. This is due to the limitations of the existing DSS including the inadequacy in addressing both the characteristics of the problem and the requirements of the decision maker, the lack of flexibility and interactivity required by the decision maker to address a wide range of decision making situations, and the lack of capability to match the most appropriate multi-criteria analysis approach with the problem involved (Deng, 2005). To address these limitations, it is desirable to have an intelligent DSS capable of (a) matching the nature of the problem with the requirements of the decision maker, (b) facilitating the adoption of the most appropriate multi-criteria analysis approach for a specific IS project selection situation, and (c) giving the control of the approach selection process to the DSS.
6.3 A Decision Support Systems Framework

Applying a DSS for effectively tackling IS project evaluation and selection problem is not only desirable, but also important. The DSS provides the decision maker with effective mechanisms to better understand the decision problem and the implications of their decision behaviors to the organization by allowing them to interactively exchange information between the system and themselves (Deng and Liu, 2001). Due to the diversity and complexity of the selection criteria, their inter-relationships, and the volume of information available, the DSS has to be efficient, effective and flexible for effectively solving the general IS project evaluation and selection problem.

This section presents a DSS framework for solving the IS project evaluation and selection problem. The DSS is designed to help the decision maker choose the appropriate IS project in a flexible and user-friendly manner by allowing the decision maker to input values to express his/her requirements and to fully explore the relationships between the criteria, the alternatives, the approaches available and the outcome of the selection process. Through interactive exchange of information between the decision maker and the DSS, the DSS helps the decision maker adopt a problem-oriented approach in the problem solving process in which the DSS lets the problem that it is trying to solve determines the appropriate approach it is going to apply (Simon, 1987; Deng and Liu, 2001). This problem-oriented approach is vital for effectively and efficiently solving the IS project evaluation and selection problem in an organization.

The DSS consists of three major subsystems, namely, (a) the dialogue subsystem, (b) the input management subsystem, and (c) the knowledge management subsystem which is
consistent with the general architecture of DSS (Turban and Aronson, 2000). The dialogue subsystem serves to integrate various other subsystems as well as to be responsible for user-friendly communications between the DSS and the decision maker. This subsystem coordinates all functions or commands selected by the decision maker. The interface allows the decision maker not just to apply one of the available multi-criteria analysis approaches, but also to edit or visualize the data in the database. To provide the decision maker with the flexibility for customizing the system, the interface is designed in such a way so that the decision maker can create, modify or eliminate criteria, or even define which criteria he/she intends to inquire about. The decision maker utilizes the database through the dialogue subsystem for analyzing project alternatives using the knowledge management subsystem.

The input management subsystem organizes and manages all the inputs for solving the IS project evaluation and selection problem. The type and the quantity of data inputs for solving the problem vary typically from one problem to another. These input data can be classified into primary and secondary types. The primary input data include the alternatives, the criteria, the decision matrix, and the pairwise comparison matrices. The secondary data include the criteria weightings and alternative performance ratings. The input data are entered into the DSS for processing. These data can be edited after they have been entered into the system. It should be noted that the system is flexible to allow new data types to be added to the system due to the possible addition of new multi-criteria analysis approaches in the DSS.

The knowledge management subsystem manages all the multi-criteria analysis approaches available in the DSS. For the sake of describing the proposed DSS, six MA approaches have been included in the proposed DSS for helping assist the decision maker in selecting the most appropriate multi-criteria analysis approach in solving a specific IS project evaluation and selection problem. These six approaches include the SAW approach, the TOPSIS approach,
the ELECTRE approach, the AHP approach, the linguistic approach presented in Chapter 4 and the pairwise comparison approach developed in Chapter 5. One of these multi-criteria analysis approaches can be invoked directly by the decision maker or selected automatically by the proposed DSS through the knowledge management subsystem.

The application of the proposed DSS consists of six phases, including (a) identification of the decision maker’s requirements, (b) determination of criteria weights, (c) determination of the performance ratings of alternative IS projects with respect to each criterion, (d) selection of the most appropriate multi-criteria analysis approach, (e) evaluation of the IS project, and (f) selection of the appropriate IS project alternative. Figure 6.1 shows the overall DSS framework for solving the IS project evaluation and selection problem.

The first phase starts with the identification of the decision maker’s requirements in an IS projects evaluation and selection situation in an organization. Some of these requirements include (a) the decision maker’s preference of a specific multi-criteria analysis approach, (b) the time availability of the decision maker, (c) the decision maker’s desire to interact with the system, and (d) the desire to allow the system to select one satisfactory solution or for the decision maker to select the best solution (Tecle and Duckstein, 1992).

The DSS presents two modes of guidance for the decision maker, namely (a) a novice mode, and (b) an advanced mode. The novice mode is designed for the decision maker who is totally unfamiliar with the multi-criteria analysis approaches. In the novice mode, the knowledge management subsystem first questions the decision maker on the characteristics of his/her problem and the type of solution he/she expects to receive. The advanced mode is used when the decision maker is highly familiar with various multi-criteria analysis approaches so that he/she is capable of selecting a specific approach.
Figure 6.1 The DSS framework for IS project evaluation and selection

- Identify decision maker’s requirements
- Determine the mode of guidance
- Determine the basic criteria weights
- Determine the performance ratings of alternative IS projects
- Evaluate IS project alternatives
- Select the most appropriate approach
- Determine the basic criteria weights
- Determine the performance ratings of alternative IS projects
- The most appropriate IS project
The second phase continues with the determination of basic criteria weights in a specific decision situation. To establish the basic criteria weights, the user interface in the DSS allows the decision maker to experiment with different values of the weights for the criteria and observe the respective effects on the outcome obtained. In practical applications, all assessments with respect to criteria importance and alternative performance are not always fuzzy. Both crisp and fuzzy data are often present simultaneously in a specific multi-criteria analysis problem (Deng, 2005). Each criteria weight can be assigned as crisp numbers or linguistic terms depending on the preference of the decision maker. To maintain the effectiveness of data evaluated, crisp numbers in the range of 1 to 9 can be used to represent the decision maker’s quantitative assessments. Linguistic terms are available for use to the decision maker with a need to know their corresponding fuzzy representations. In case the decision maker is not sure which linguistic values to choose, a defaulted linguistic value scale is presented. If the terms used in the scale are different from the terms that the decision maker wants for criteria weighting, the proposed DSS tries to match the scale the decision maker wants with the existing scale in the knowledge base according to the number of terms used in the scale. Therefore, even the verbal terms used in our knowledge base are in the universe \( U = \{ \text{excellent, very high, high to very high, high, fairly high, medium, fairly low, low, low to very low, very low, none} \} \), it can easily be adjusted to accommodate the nature of the criteria in the decision making process.

The performance ratings of alternative IS projects with respect to each criterion are to be determined next. In practical situations, the criteria may include both quantitative and qualitative measures that satisfy the requirements of the decision maker. To reduce the cognitive burden on the decision maker, a knowledge base consisting of IF-THEN production rules is used for assisting with a systematic selection of the most appropriate multi-criteria analysis approaches in a specific IS project evaluation and selection situation. These IF-
THEN rules explicitly reflect the effect of the requirements of the decision maker, and the characteristics of the IS project evaluation and selection problem on the most suitable multi-criteria analysis approach for handling the IS project evaluation and selection problem. Each rule takes the form of: IF \(<\text{requirement}\>\) THEN \(<\text{outcome}\>\) where \text{requirement} describes the requirements of the decision makers and the characteristics of the IS project evaluation and selection problem, and \text{outcome} represents the most suitable multi-criteria analysis approach. The multi-criteria analysis approaches have different characteristics, different requirements for information and information type as well as different required stages (Hwang and Masud, 1979). All these characteristics and requirements are coded in the IF-THEN statements for execution in the DSS. They will be suitable for different types of applications and different requirements and knowledge levels of the decision maker. Table 6.1 shows the characteristics of the multi-criteria analysis approaches available with the requirements of specific IS project evaluation and selection problems. It provides a basis for the decision maker to choose the appropriate multi-criteria analysis approach for a specific IS project evaluation and selection problem. With the development of the knowledge base, the DSS becomes intelligent in the process of selecting the most appropriate multi-criteria analysis approach in a given IS project evaluation and selection situation.

A multi-criteria analysis approach such as SAW requires transforming the various values of the attributes to a common scale for comparison. Approaches such as ELECTRE and TOPSIS, on the other hand, require only a normalized scale. Another example is that TOPSIS deals with crisp criteria weights and alternative rating while linguistic approach handles both fuzzy data and crisp data. Example of the rules used to match the specific approach to the requirements of the decision maker is shown as in Table 6.2. These rules form the knowledge base for the proposed DSS in solving the IS project evaluation and selection problem.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>SAW</th>
<th>TOPSIS</th>
<th>ELECTRE</th>
<th>AHP</th>
<th>Linguistic approach</th>
<th>Pairwise Comparison approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria Weight</td>
<td>Crisp</td>
<td>Crisp</td>
<td>Crisp</td>
<td>Fuzzy</td>
<td>Fuzzy</td>
<td>Fuzzy</td>
</tr>
<tr>
<td>Alternative Rating</td>
<td>Crisp</td>
<td>Crisp</td>
<td>Crisp</td>
<td>Fuzzy</td>
<td>Fuzzy</td>
<td>Fuzzy</td>
</tr>
<tr>
<td>Criteria information</td>
<td>Compensatory</td>
<td>Compensatory</td>
<td>Compensatory</td>
<td>Non-compensatory</td>
<td>Compensatory</td>
<td>Compensatory</td>
</tr>
<tr>
<td>processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>Scoring</td>
<td>Ideal solution</td>
<td>Outranking</td>
<td>Pairwise</td>
<td>Ideal solution</td>
<td>Pairwise</td>
</tr>
<tr>
<td>Solution aimed to</td>
<td>Evaluate, prioritize and select</td>
<td>Evaluate, prioritize and select</td>
<td>Evaluate, prioritize and select</td>
<td>Evaluate, prioritize and select</td>
<td>Evaluate, prioritize and select</td>
<td>Evaluate, prioritize and select</td>
</tr>
<tr>
<td>Transformation of values to</td>
<td>Common scale</td>
<td>Normalized scale</td>
<td>Normalized scale</td>
<td>Normalized scale</td>
<td>Normalized scale</td>
<td>Normalized scale</td>
</tr>
</tbody>
</table>

Table 6.1 Problem requirements and characteristics of different approaches
Table 6.2  An example of the rules

<table>
<thead>
<tr>
<th>Rules</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 5: IF Mode of guidance = “Advanced” THEN Present all MA approaches for selection</td>
<td></td>
</tr>
</tbody>
</table>
Once the most appropriate multi-criteria analysis approach is selected, the next phase in the proposed DSS performs the evaluation of the input values given by the decision maker. The overall performance of each IS project alternative is usually determined by effectively and efficiently aggregating the criteria weights and alternative performance ratings using a specific multi-criteria analysis approach. The most suitable IS project alternative that fulfils the requirements of the decision maker in a specific problem situation will then be recommended to the decision maker. This leads to effective decisions being made based on the recommendation by the DSS supported by valuable explanation from the DSS.

6.4 A Practical Application

To demonstrate the applicability of the proposed DSS above, a problem of evaluating and selecting a SCM system project at a steel mill in Taiwan is presented. This integrated steel mill produces plates, bars, wire rods, semi-finished products, and other steel products. Severe market competition has dramatically transformed the business environment that the mill is in. To be competitive, the mill has to reduce its total costs, maximize its return on investment, shorten the lead times and be more responsive to customer demands (Wei et al., 2007). Highly dynamic markets call for effective enterprise IS to enhance its competitive advantage. A SCM system can improve the business effectiveness by collaborating different stages of a supply chain and providing real-time analytical capabilities in production planning. As a result, the top management has made a decision to implement a SCM system to enhance the effectiveness of its global supply chain (Sahay and Gupta, 2003).
The SCM project starts with the formation of a project team involving seven senior managers in the mill. Representatives of user departments, information experts and consultants are invited to participate in the team. The team has gathered information about the problems in the existing supply chain, industry characteristics, changes of the business environment, and client demands for determining the scope of this project. Based on their findings, four criteria are determined for evaluating and selecting potential SCM projects including Strategic Capability, Project Characteristics, IS Project Capability, and Vendor Characteristics (Wei et al., 2007). Figure 6.2 shows the hierarchical structure of the SCM project evaluation and selection problem in the mill.

Strategic Capability ($C_1$) reflects the perception of the decision maker on how individual IS project alternatives serve the overall long term business strategy and organizational objectives in a competitive environment (Callon, 1996). This is often measured by customer demand support ($C_{11}$), supply chain capability ($C_{12}$), domain knowledge ($C_{13}$), and supply chain model design ($C_{14}$).

Project Characteristics ($C_2$) concern with the assessment of the decision maker about the economical and financial feasibilities of IS project alternatives with respect to the resource limitation of an organization and its business strategy for the organization (Earl, 1989; Callon, 1996). It is measured by the total costs ($C_{21}$), implementation time ($C_{22}$), benefits ($C_{23}$), and risks ($C_{24}$).

IS Project Capability ($C_3$) reflects on the expectation of the management of an organization towards the technical specification of an IS project alternative with respect to the overall IS function and architecture for the organization (Earl, 1989; Jiang and Klein, 1999). It is
measured by the function and technology \((C_{31})\), the system flexibility \((C_{32})\), and the system integration \((C_{33})\).

Vendor Characteristics \((C_4)\) concern about the assessment of the decision maker regarding his/her confidence of the qualities and attitudes portrayed by different vendors in delivering their service and products to the organization. This is measured by the vendor’s ability \((C_{41})\), the implementation and maintenance \((C_{42})\), the consulting service \((C_{43})\), and the vendor’s reputation \((C_{44})\).

To facilitate the making of subjective performance assessments, the decision maker assigned linguistic variables for the criteria variables, consisting of \{Very Poor (VP), Poor (P), Fair (F), Good (G), and Very Good (VG)\} to effectively handle uncertainty and subjectiveness in the decision making process. Table 4.1 shows the linguistic variables used to describe the values of ratings.

The weights assigned to each criterion can be adjusted according to the specific concerns of the decision maker. Each criteria weight is also determined by directly assigning linguistic expressions. The decision maker can use a set of five linguistic terms in weighting to describe the weight of each criterion, \(W = \{\text{Very Low (VL)}, \text{Low (L)}, \text{Medium (M)}, \text{High (H)}, \text{and Very High (VH)}\}\). Table 4.2 shows the linguistic variables used to describe weights of the evaluation and selection criteria. If the decision maker does not agree with the assumed numerical approximation system, he/she can define his/her own ratings and the corresponding fuzzy numbers to express their subjective assessments.
Figure 6.2 The hierarchical structure of the SCM project evaluation and selection
The DSS evaluation process starts with instructing the decision maker to enter the set of alternatives and criteria to be used for the SCM project selection problem. The decision maker enters the required alternatives and criteria into the proposed DSS. This is followed by selecting either a novice mode or an advanced mode in solving the IS project evaluation and selection problem. If the decision maker selects a novice mode, the decision maker goes through a series of dialogue boxes which raises questions such as the criteria weight, the alternative rating, and type of solution expected, and the use of transformation for criteria. As a result, the system will recommend the decision maker with a specific approach for dealing with the IS project evaluation and selection problem. If the decision maker accepts the recommended approach, the specific module for the approach will be invoked automatically. The required inputs for the problem are then prompted from the decision maker for determining the overall rankings of all the IS project alternatives.

If the decision maker selects an advanced mode, the decision maker can directly select the preferred approach for evaluating and selecting the IS project alternative. The system will then automatically activate the corresponding input modules to acquire the necessary data required by the selected approach. Here, the decision maker has indicated to the system that there are three alternatives available and entered the subjective performance assessments of each alternative with respect to each criterion as shown in Table 6.3.
Table 6.3  The performance assessments of alternatives SCM projects

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$A_1$</td>
<td>$A_2$</td>
<td>$A_3$</td>
</tr>
<tr>
<td>Customer demand support ($C_{11}$)</td>
<td>G</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Supply chain capability ($C_{12}$)</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Domain knowledge ($C_{13}$)</td>
<td>G</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Supply chain model design ($C_{14}$)</td>
<td>VG</td>
<td>G</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Total costs ($C_{21}$)</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Implementation time ($C_{22}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Benefits ($C_{23}$)</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Risks ($C_{24}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Function and technology ($C_{31}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>System flexibility ($C_{32}$)</td>
<td>G</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>System integration ($C_{33}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Vendor’s ability ($C_{41}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Implementation and maintenance ($C_{42}$)</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
<tr>
<td>Consulting service ($C_{43}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Vendor’s reputation ($C_{44}$)</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td></td>
</tr>
</tbody>
</table>

Based on the linguistics variables used by the weighting vectors as defined in Table 4.2, the criteria weights for selecting the SCM project is also obtained directly from the decision maker to reflect on his/her subjective assessments on the relative importance of each criterion. The criteria weights for SCM project evaluation and selection criteria are shown in Table 6.4.
Table 6.4  Criteria weights for SCM project evaluation and selection

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$A_1$</td>
</tr>
<tr>
<td>Customer demand support ($C_{11}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Supply chain capability ($C_{12}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Domain knowledge ($C_{13}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Supply chain model design ($C_{14}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Total costs ($C_{21}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Implementation time ($C_{22}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Expected benefit ($C_{23}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Project risks ($C_{24}$)</td>
<td>VH</td>
</tr>
<tr>
<td>System functionality ($C_{31}$)</td>
<td>VH</td>
</tr>
<tr>
<td>System flexibility ($C_{32}$)</td>
<td>VH</td>
</tr>
<tr>
<td>System integration ($C_{33}$)</td>
<td>H</td>
</tr>
<tr>
<td>Vendor’s ability ($C_{41}$)</td>
<td>VH</td>
</tr>
<tr>
<td>Implementation and maintenance ($C_{42}$)</td>
<td>H</td>
</tr>
<tr>
<td>Consulting service ($C_{43}$)</td>
<td>H</td>
</tr>
<tr>
<td>Vendor’s reputation ($C_{44}$)</td>
<td>H</td>
</tr>
</tbody>
</table>

The decision maker then chose a novice mode of guidance. This causes the DSS system to request for more information from the decision maker including (a) the decision maker’s preference of a specific multi-criteria analysis approach, (b) the time availability of the decision maker, (c) the decision maker’s desire to interact with the system, and (d) the desire...
to allow the system to select one satisfactory solution or for the decision maker to select a desired solution.

Based on the information provided by the decision maker, the IF-THEN rules explicitly match the specific approach to the requirements of the decision maker. In this case, the DSS has selected the linguistic approach developed in Chapter 4 based on the information given by the decision maker to handle this specific SCM project evaluation and selection problem. As a result, an overall performance index for each alternative across all the criteria can be determined. Based on Table 6.5, $A_2$ is the most suitable project alternative for the mill as it has the highest index of 0.92.

### Table 6.5 The overall performance index and ranking of SCM projects alternatives

<table>
<thead>
<tr>
<th>SCM Projects</th>
<th>Index</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>0.77</td>
<td>3</td>
</tr>
<tr>
<td>$A_2$</td>
<td>0.92</td>
<td>1</td>
</tr>
<tr>
<td>$A_3$</td>
<td>0.81</td>
<td>2</td>
</tr>
</tbody>
</table>

### 6.5 Concluding Remarks

This chapter has presented an intelligent DSS for facilitating the selection of appropriate multi-criteria analysis approaches in solving IS project evaluation and selection problem in organizations. A knowledge base consisting of IF-THEN production rules is developed for assisting systematic selection of the most appropriate multi-criteria analysis approaches in a
specific IS project evaluation and selection situation. Effective decision support is provided with the development of a flexible multi-criteria analysis approach selection procedure capable of considering both the characteristics of the problem and the requirements of the decision maker and the provision of interactive user interfaces between the decision maker and the DSS.

A SCM project evaluation and selection example at a steel mill in Taiwan is presented for demonstrating the applicability of the proposed intelligent DSS framework for facilitating the selection of the most appropriate multi-criteria analysis approach in solving the IS project evaluation and selection problem. The example shows that the proposed DSS framework has a number of advantages for solving the IS project evaluation and selection problems include the flexibility to respond quickly to the decision maker’s questions, the ability to help the decision maker better understand the decision problem and the implications of their decision behaviors, and the capability to accommodate various requirements of the decision problem and the decision maker in the problem solving process.
An Application of the Linguistic Approach for Evaluating and Selecting Data Warehouse Systems

7.1 Introduction

In today’s dynamic business environment, modern organizations face tremendous challenge in expanding their market shares and improving their competitiveness through effective customer relationship management. To achieve this, organizations of various kinds have been looking for strategies including implementing enterprise-wide data automation systems to facilitate effective decision making process through the provision of the right information at the right time in a timely manner. One of these strategies is the development and implementation of data warehouse systems which has become a popular option for organizations (Shin, 2002; Watson et al., 2002).

To facilitate the development and implementation of a specific data warehouse system in an organization, organizations have to comprehensively evaluate all the available data warehouse systems before selecting one data warehouse system for implementation in a transparent and timely manner. The process of evaluating and selecting data warehouse systems in an increasingly competitive environment, however, is complex and challenging. It is common for the decision maker to use subjective assessments with respect to the criteria importance and the data warehouse system’s performance with respect to each criterion. This
results in the use of qualitative data for determining the most appropriate data warehouse system. To ensure that the data warehouse system evaluation and selection process is carried out in a consistent manner, a comprehensive evaluation of the data warehouse system’s overall performance is required.

The AHP approach has been used for solving the data warehouse system evaluation and selection problem (Zhu and Buchmann, 2002; Lin and Hsu, 2007; Lin et al., 2007). With the use of this approach, the relative importance of the selection criteria, sub-criteria for evaluating and selecting data warehouse systems and individual performance ratings of alternative data warehouse systems are assessed pairwisely based on the numerical scale of 1 to 9. An eigenvector method is used to solve the reciprocal matrix for determining the criteria importance and alternative performance. The SAW approach (Chen and Hwang, 1992; Deng, 1999) is used to calculate the utility for each alternative across all criteria. However, this approach is not totally satisfactory due to the inability to adequately handle the subjective and imprecise nature of the evaluation process and the risk of generating inconsistent assessments increases when the number of alternatives and criteria increases.

This purpose of this chapter is to formulate the data warehouse system evaluation and selection problem as a multi-criteria analysis problem and to apply the linguistic approach developed in Chapter 4 to effectively solve the problem. With the presentation of an empirical study of a data warehouse system evaluation and selection problem in a specific organization, this chapter aims to demonstrate the applicability of the proposed linguistic approach in Chapter 4 for addressing the general IS project evaluation and selection problem.
7.2 Data Warehouse Systems Evaluation and Selection at Taiwan

Owing to the competition involved in joining the World Trade Organization, Taiwan has faced challenges in the agricultural section (Lin et al., 2007). For Taiwan to retain its competitive advantage, it must reduce the production costs and increase sales of agricultural products. Against this background, the Council of Agriculture has delegated a County Farmers’ Association to execute a three year Bar Code Implementation Project for marketing Agricultural Products in Taiwan. The aims of this project are to (a) computerize the transaction processes, and (b) integrate the supply chain of agricultural products. The system, however, requires the need to store 10 years of transaction data for data analysis, forecasting and products tracking (Lin et al., 2007). As a result, the establishment of a data warehouse system is essential for the success of such a significant project.

In order to select the most suitable data warehouse system for the Bar Code Implementation Project for Agricultural Products, a committee consisting of six experts with IS and business background is formed. This committee has identified several data warehouse system alternatives and the evaluation and selection criteria through a comprehensive investigation. Three alternative data warehouse systems and eight selection criteria are identified for evaluating the most suitable data warehouse system for development and implementation. These selection criteria include (a) Infrastructure Integration \((C_1)\), (b) Financial Cost \((C_2)\), (c) System Functionality \((C_3)\), (d) User friendly Interface \((C_4)\), (e) System Flexibility \((C_5)\), (f) Vendor Reputation \((C_6)\), (g) Technical Capability \((C_7)\), and (h) Vendor Support \((C_8)\) (Lin et al., 2007). Figure 7.1 shows the hierarchical structure of the data warehouse system project evaluation and selection problem. The selection criteria are described below to facilitate the
understanding of these criteria in the data warehouse systems project evaluation and selection problem.

Infrastructure Integration criteria ($C_1$) refer to the subjective assessment of the decision maker in regards to the integration capabilities of the data warehouse system with other systems in the organization. This is measured by the integration ability of the data warehouse system with other software systems, and the integration ability of the data warehouse system with different hardware platforms.

Financial Cost criteria ($C_2$) concern with the subjective assessment of the decision maker on the economical and financial feasibility of the organization to support the development and implementation of a data warehouse system (Earl, 1989; Jiang and Klein, 1999). It is measured by the initial purchasing cost of the system, and the post implementation cost to maintain the system.

The System Functionality criteria ($C_3$) reflect the perception of the decision maker on the capabilities of the data warehouse system to provide necessary IS functions in order to support the organization. This is measured by the variety of access means, query functionality, database support, data quality check, ease of source data transformation, and ease of system administration.

User-friendly Interface criteria ($C_4$) reflect on the subjective assessment of the decision maker on the easiness of the data warehouse system to learn and use. The system must also be capable in supporting users from various departments in the organization (Jiang and Klein,
1999; Lin et al., 2007). This is assessed by the ease of operation, the variety of interfaces, and the ease of learning.

The System Flexibility criteria \((C_5)\) of an alternative data warehouse system concern with the data warehouse system capabilities in terms of its responsiveness to change and adaptability to accommodate different organization’s requirements and needs (Lin et al., 2007). This is measured by the upgrade capability, the ease of integration, and the ease of in-house development.

The Vendor Reputation criteria \((C_6)\) concern with the subjective assessment of the decision maker on the commitments and continuous improvements of vendors to their data warehouse products in delivering their service and products to the organization (Lin et al., 2007). This is measured by the market share, the warranty provided by vendors, and the level of internationalization.

Technical Capability criteria \((C_7)\) of an alternative data warehouse system concern with the expectation of the management of an organization towards the technical specification of a data warehouse system with respect to its function and architecture. This includes research and development capability, technical support capability, experience in related products, and experience in related industries.

The Vendor Support criteria \((C_8)\) involve the subjective assessment of the decision maker on the ongoing technical assistance and service support provided by the data warehouse vendor to the organization after system implementation (Lin et al., 2007). This is measured by technical support, consultant service, training, quality of service, and delivery time for service.
7.3 Data Collection

The data warehouse system evaluation and selection process begins with assessing the performance of each data warehouse system with respect to each criterion, and with assessing the importance of these criteria. The actual experience in evaluating and selecting the most suitable data warehouse system shows that

(a) Assessments on each of the data warehouse system performance with respect to each criterion are presented subjectively by the decision maker as it is difficult to give in a precise and yet consistent manner. The use of crisp numbers between 1 and 9 to representing the decision maker’s performance assessments is cognitively very demanding and difficult to handle (Chen and Hwang, 1992; Deng, 1999).

(b) The criteria importance used for the data warehouse system evaluation and selection process is subject to the preference of the decision maker, and is hard to determine accurately. The process of assigning equal weights to all criteria under consideration is undesirable as it leads to an inconsistent decision outcome (Deng, 1999).

It is therefore necessary to apply the linguistic approach developed in Chapter 4 for solving the data warehouse system evaluation and selection problem. The linguistic approach is capable for effectively solving the data warehouse system evaluation and selection process in which both the criteria importance and alternative performance are presented subjectively. As a result, effective decisions can be made based on the proper consideration of the decision maker’s subjective assessments.
Figure 7.1 The hierarchical structure of the data warehouse system project evaluation and selection problem
Based on the interviews conducted by the organization, the assessment results with respect to each criterion are obtained. To facilitate the making of subjective performance assessments, linguistic variables of the criteria and sub-criteria variables shown in Table 4.1 are used effectively to handle and subjectiveness and imprecision. Subjective assessments of the data warehouse systems’ performance with respect to each evaluation criterion can therefore be made in an efficient manner. Table 7.1 to Table 7.8 show the performance assessments results of alternatives data warehouse systems.

Table 7.1 Performance assessments of alternative data warehouse systems for Infrastructure Integration (C₁)

<table>
<thead>
<tr>
<th>Infrastructure Integration (C₁)</th>
<th>A₁</th>
<th>A₂</th>
<th>A₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration with software systems (C₁₁)</td>
<td>VG</td>
<td>VG</td>
<td>G</td>
</tr>
<tr>
<td>Integration with hardware platforms (C₁₂)</td>
<td>G</td>
<td>F</td>
<td>G</td>
</tr>
</tbody>
</table>

Table 7.2 Performance assessments of alternative data warehouse systems for Financial Cost (C₂)

<table>
<thead>
<tr>
<th>Financial Cost (C₂)</th>
<th>A₁</th>
<th>A₂</th>
<th>A₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial purchasing cost (C₂₁)</td>
<td>G</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Post implementation cost (C₂₂)</td>
<td>VG</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>
Table 7.3 Performance assessments of alternative data warehouse systems for System Functionality ($C_3$)

<table>
<thead>
<tr>
<th>System Functionality ($C_3$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety of access means ($C_{31}$)</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Query functionality ($C_{32}$)</td>
<td>G</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>Database support ($C_{33}$)</td>
<td>VG</td>
<td>VG</td>
<td>G</td>
</tr>
<tr>
<td>Data quality check ($C_{34}$)</td>
<td>G</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Ease of source data transformation ($C_{35}$)</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
<tr>
<td>Ease of system administration ($C_{36}$)</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>

Table 7.4 Performance assessments of alternative data warehouse systems for User-friendly Interface ($C_4$)

<table>
<thead>
<tr>
<th>User-friendly Interface ($C_4$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of operation ($C_{41}$)</td>
<td>F</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Variety of interfaces ($C_{42}$)</td>
<td>VG</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>Ease of learning ($C_{43}$)</td>
<td>F</td>
<td>VG</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 7.5 Performance assessments of alternative data warehouse systems for System Flexibility ($C_5$)

<table>
<thead>
<tr>
<th>System Flexibility ($C_5$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrade ability ($C_{51}$)</td>
<td>G</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Ease of integration ($C_{52}$)</td>
<td>G</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Ease of in-house development ($C_{53}$)</td>
<td>F</td>
<td>G</td>
<td>F</td>
</tr>
</tbody>
</table>
Table 7.6  Performance assessments of alternative data warehouse systems for Vendor Reputation ($C_6$)

<table>
<thead>
<tr>
<th>Vendor Reputation ($C_6$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market share ($C_{61}$)</td>
<td>F</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>Warranty ($C_{62}$)</td>
<td>VG</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Level of internationalization ($C_{63}$)</td>
<td>G</td>
<td>G</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 7.7  Performance assessments of alternative data warehouse systems for Technical Capability ($C_7$)

<table>
<thead>
<tr>
<th>Technical capability ($C_7$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and development capability ($C_{71}$)</td>
<td>F</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Technical support capability ($C_{72}$)</td>
<td>F</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Experience in related products ($C_{73}$)</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Experience in related industries ($C_{74}$)</td>
<td>G</td>
<td>VG</td>
<td>G</td>
</tr>
</tbody>
</table>

Table 7.8  Performance assessments of alternative data warehouse systems for Vendor Support ($C_8$)

<table>
<thead>
<tr>
<th>Vendor Support ($C_8$)</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical support ($C_{81}$)</td>
<td>VG</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Consultant service ($C_{82}$)</td>
<td>F</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Training ($C_{83}$)</td>
<td>F</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>Quality of service ($C_{84}$)</td>
<td>G</td>
<td>G</td>
<td>VG</td>
</tr>
<tr>
<td>Delivery time for service ($C_{85}$)</td>
<td>G</td>
<td>G</td>
<td>F</td>
</tr>
</tbody>
</table>
Based on the linguistics variables used by the weighting vectors as defined in Table 4.2, the criteria and sub-criteria weights for selecting the data warehouse system can be obtained directly from the decision maker. Table 7.9 shows the criteria weights for the criteria and sub-criteria. Based on the obtained fuzzy criteria weights and fuzzy performance ratings, the overall objective of the selection problem is to apply the linguistic approach developed in Chapter 4 to aggregate the fuzzy criteria weights and fuzzy performance ratings in order to produce the overall performance index for each data warehouse system.

Table 7.9  Weighting vectors for the criteria and sub-criteria

<table>
<thead>
<tr>
<th>( W )</th>
<th>Fuzzy criteria weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_{1} )</td>
<td>(7, 9, 9), (7, 9, 9)</td>
</tr>
<tr>
<td>( W_{2} )</td>
<td>(7, 9, 9), (7, 9, 9)</td>
</tr>
<tr>
<td>( W_{3} )</td>
<td>(7, 9, 9), (7, 9, 9)</td>
</tr>
<tr>
<td>( W_{4} )</td>
<td>(5, 7, 9), (5, 7, 9)</td>
</tr>
<tr>
<td>( W_{5} )</td>
<td>(5, 7, 9), (5, 7, 9)</td>
</tr>
<tr>
<td>( W_{6} )</td>
<td>(5, 7, 9), (5, 7, 9)</td>
</tr>
<tr>
<td>( W_{7} )</td>
<td>(5, 7, 9), (5, 7, 9)</td>
</tr>
<tr>
<td>( W_{8} )</td>
<td>(5, 7, 9), (5, 7, 9)</td>
</tr>
</tbody>
</table>

7.4  Results and Discussion

An analysis of the requirements of the data warehouse system evaluation and selection problem described as above reveals that (a) all the decision maker’s assessments on criteria weights and performance ratings are linguistic terms represented by fuzzy numbers, and (b)
the size of the problem is quite large. Existing approaches for dealing with this class of
decision situations often require either (a) comparison of the fuzzy utilities for all alternatives
involved or (b) transformation of the fuzzy data into a crisp format. The problem with these
approaches is that the ranking of fuzzy utilities is not satisfactory and the transformation of
fuzzy data into crisp format may lead to unreliable decision outcomes due to the loss or
incomplete use of all the information provided by original fuzzy data (Deng, 2005).

To effectively handle the data warehouse system evaluation and selection problem, a
linguistic approach capable of handling fuzzy data in a simple and straightforward manner is
desirable. The linguistic approach is appropriate in dealing with the fuzzy data as the
approach can satisfy the requirements of this specific problem based on its simplicity and
efficient computation.

By applying the linguistic approach, the overall performance index for each data warehouse
system alternative across all the criteria and sub-criteria can be calculated in an efficient
manner. Table 7.10 shows the overall index values of the alternative data warehouse systems
and their corresponding rankings with respect to various attitudes: (a) pessimistic, (b)
moderate, or (c) optimistic view of the decision maker involved towards risk.

Table 7.10 shows that alternative data warehouse system $A_3$ is the obvious choice for
selection whether the attitude of the decision maker towards risks is pessimistic, moderate or
optimistic. It is observed that the ranking outcome of the alternative project is consistent
whether it is a pessimistic, moderate or optimistic attitude. It is also noticed that there is only
slight difference between the performance index values of the alternatives and their ranking
orders under the decision maker’s attitude towards risk.
Table 7.10  The performance index of alternative data warehouse systems and their rankings

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>$\lambda = 0.0$</th>
<th>$\lambda = 0.5$</th>
<th>$\lambda = 1.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index Ranking</td>
<td>Index Ranking</td>
<td>Index Ranking</td>
</tr>
<tr>
<td>$A_1$</td>
<td>0.74 2</td>
<td>0.76 2</td>
<td>0.79 2</td>
</tr>
<tr>
<td>$A_2$</td>
<td>0.58 3</td>
<td>0.61 3</td>
<td>0.68 3</td>
</tr>
<tr>
<td>$A_3$</td>
<td>0.89 1</td>
<td>0.91 1</td>
<td>0.93 1</td>
</tr>
</tbody>
</table>

Sensitivity analysis can also be conducted through changing the subjective assessments of the decision maker with respect to the decision variables when no clear-cut decisions are present. With the simplicity in concept underlying the approach, this approach can be incorporated into a DSS in which the decision maker can interactively explore the problem in different manners in order to have a better understanding of the problem and the relationships between the decision and its parameters can be obtained.

The study suggests that the linguistic approach is simple and effective in dealing with the subjective and imprecise nature of the evaluation process faced in the data warehouse systems project evaluation and selection problem. The linguistic approach provides an effective mechanism whereby the final decision outcome is directly linked to the decision maker’s degree of confidence towards risk.
7.5 Concluding Remarks

The data warehouse systems project evaluation and selection process is challenging due to the presence of subjectiveness and imprecision inherent in the human decision making process. The existence of subjectiveness and imprecision is because it is common for the decision maker to make subjective assessments with respect to the criteria importance and the project’s performance with respect to each criterion in the problem solving process. To effectively solve this problem, this chapter has formulated the data warehouse systems evaluation and selection problem as a multi-criteria analysis problem and applied the linguistic approach developed in Chapter 4 to address the evaluation and selection problem.

The result shows that the linguistic approach applied to solve the data warehouse system evaluation and selection problem is capable of adequately handling the subjectiveness and imprecision inherent in the data warehouse systems evaluation and selection process. The linguistic approach is found to be effective and efficient, due to the comprehensibility of its underlying concepts and the straightforward computation process.
Chapter 8

Pairwise Comparison for Evaluating and Selecting

Human Resource Management Information Systems

Projects

8.1 Introduction

Organizations are facing tremendous pressure to compete against their competitors in order for them to survive in this dynamic environment. To effectively deal with this competitive nature of the business environment, organizations are focusing their attention on improving their human resource management function as part of their business strategy in order to achieve competitive advantage (Stone et al., 2006; Hussain et al., 2007).

Human resource management emphasizes on the development of the organization’s capacity to respond to the external environment through a better deployment of human resources. There are increasing numbers of empirical studies on the effect of human resource management in increasing organizational performance by matching unique internal processes with environmental opportunities and needs (Bowen and Ostroff, 2004; Chan et al., 2004; Bhattacharya and Wright, 2005). As a result, organizations are able to achieve competitive advantage over their competitors and human resource management is now seen as an important factor in improving organizational performance and effectiveness.
In order for organizations to support their human resource management effectively and efficiently, the use of IS to support human resource management in organizations has increased dramatically in the past few years (Hawking et al., 2004; Stanton and Coover, 2004; Bhattacharya and Wright, 2005; Stone et al., 2006; Hussain et al., 2007). Human resource management IS facilitates the provision of quality information to management for informed decision making (Mayfield et al., 2003) and supports the provision of executive reports and summaries for senior management (Stone et al., 2006).

The development and implementation of human resource management IS projects has become a crucial activity for organizations nowadays. These IS projects have been considered to be the solution for organizations to improve productivity, increase employee satisfaction, and reduce costs (DeLone and McLean, 1992; Callon, 1996). By adopting the appropriate human resource management IS project, modern organizations can gain competitive advantages that are vital to the organization’s future growth.

The decision to evaluate and select an appropriate human resource management IS project in an organization is complicated due to (a) the availability of numerous alternative IS projects, (b) the cognitively demanding nature of the evaluation and selection process on the decision maker, (c) the presence of inherent subjectiveness and imprecision of the human decision making process, and (d) the pressure to consider all multiple evaluation criteria simultaneously in a timely manner (Deng and Wibowo, 2004). Effective decision making requires a balanced consideration of all these issues in the IS project evaluation and selection process (Deng and Yeh, 1998).
This purpose of this chapter is to formulate the human resource management IS project evaluation and selection problem as a multi-criteria analysis problem and to apply the pairwise comparison approach developed in Chapter 5 for solving the problem. By doing so, the chapter aims to demonstrate the applicability of the pairwise comparison approach developed for helping reduce the cognitively demanding nature of the evaluation and selection process on the decision maker and adequately modeling the inherent subjectiveness and imprecision in the decision making process.

8.2 The Human Resource Management Information Systems Project Evaluation and Selection

The Lion Travel Service Corporation is a very well known travel agency at Taiwan. It has the biggest share of the travel agency market in Taiwan (Chou et al., 2006). The company is fully computerized and many of the business processes and operations are already integrated with the use of information technology. This includes a web site with all kinds of information about personal and group travel where customers can make on-line booking. The problem that the company is currently facing is with its human resource management IS which can only provide basic management functions. This is not appropriate as the human resource department staff must sometimes work overtime to provide reports that the manager requests. As a result, the company is planning to implement a new human resource management IS project for development for better addressing this issue.

Based on a thorough investigation by the management of the company, four potential human resource management IS project alternatives are identified. The company has to decide on
whether it should (a) develop a new IS project by themselves \( A_1 \), (b) buy an IS package from a provider \( A_2 \), (c) buy an IS package from a provider and customize it by themselves \( A_3 \), or (d) buy an IS package from a provider and have it customized by the supplier \( A_4 \).

A Delphi approach is used to determine the evaluation and selection criteria which would be appropriate for the evaluation and selection process. Eight experts are chosen for this purpose. They helped prioritize the criteria and reached a consensus about the important criteria for evaluating and selecting the human resource management IS projects. The experts are chosen according to their experience with IS evaluation. Based on their thorough discussion, five selection criteria are identified including the External criterion \( C_1 \), the Internal criterion \( C_2 \), the Risk criterion \( C_3 \), the Cost criterion \( C_4 \), and the Benefits criterion \( C_5 \) (Chou et al., 2006). The hierarchical structure of human resource management IS project evaluation and selection problem is shown in Figure 8.1.

The External criterion \( C_1 \) concern with the subjective assessment of the decision maker on the expectation of the management of an organization on the use of IS to react to the external environment. This is measured by the ability of IS to ally with partner, its commitment to government requirements, its commitment to societal needs, and its ability to compete with other competitions.

The Internal criterion \( C_2 \) refer to the subjective assessment of the decision maker in regards to the expected contribution of the IS project alternative towards the internal environment of the organization. This is measured by the improvement on organizational learning; the capability of meeting user’s requirements, the compatibility with the existing IS portfolio, and the ability to restructure the organization.
The Risk criterion \( (C_3) \) involve the subjective assessment of the decision maker on the potential negative impact of the IS project including the failure in the development and the implementation of the IS project (Jiang and Klein, 1999). This is often assessed from the technical risk, the development risk, risk of cost overruns, and the size risk of individual projects involved for selection.

The Cost criterion \( (C_4) \) concern with the subjective assessment of the decision maker on the economical and financial feasibility of the IS project with respect to the resource limitation of an organization and its business strategy (Earl, 1989, Jiang and Klein, 1999). This is measured by hardware costs, software costs, implementation costs, and maintenance costs involved.

The Benefits criterion \( (C_5) \) reflect the perception of the decision maker on how individual IS projects serve the business strategy and organizational objectives in the long term (Earl, 1989; Callon, 1996). Issues such as the contribution to organizational goals, the importance to the organizational competitiveness, the aid to improve information quality, and the relevancy to critical success factors are taken into account.
Human Resource Management IS Project Evaluation and Selection

Level 2
Criteria

Level 3
Sub-criteria

Level 4
Alternatives

Legend:
C_1 : External criteria
C_2 : Internal criteria
C_3 : Risk criteria
C_4 : Cost criteria
C_5 : Benefits criteria

C_{11} : Ability to ally with partner
C_{12} : Commitment to government requirements
C_{13} : Commitment to societal needs
C_{14} : Ability to compete with other competitions
C_{21} : Improvement on organizational learning
C_{22} : Capability of meeting user’s requirements
C_{23} : Compatibility with existing IS portfolio
C_{24} : Ability to restructure the organization
C_{31} : Technical risk
C_{32} : Development risk
C_{33} : Risk of cost overruns
C_{34} : Size risk of individual projects
C_{41} : Hardware costs
C_{42} : Software costs
C_{43} : Implementation costs
C_{44} : Maintenance costs
C_{51} : Contribution to organizational goals
C_{52} : Importance to the organizational competitiveness
C_{53} : Aid to improve information quality
C_{54} : Relevancy to critical success factors

A_i (i = 1, 2, ..., n): Alternative IS Projects

Figure 8.1 The hierarchical structure of human resource management IS project evaluation and selection problem
8.3 Data Collection

A comprehensive investigation has been carried out to collect the required data for the evaluation process. Subjective assessments are usually involved in evaluating the performance of alternative human resource management IS projects and the importance of the selection criteria. To facilitate the subjective evaluation process, linguistic variables are used for representing the subjective assessments of the decision maker. To ensure the efficiency of the computation process for making the selection decision, fuzzy numbers are used to approximate the linguistic variables in the evaluation process.

It is observed that two common issues are involved in this human resource management IS project evaluation and selection process. The evaluation criteria are generally multi-dimensional in nature and a simultaneous consideration of those multiple criteria is required for making effective selection decisions. The evaluation process involves subjective assessments, resulting in qualitative and vague data being used.

Using the pairwise comparison technique based on the linguistic variables defined as in Table 5.1, the fuzzy reciprocal judgment matrices for the performance of alternative human resource management IS projects in regard to each criterion can be determined. Tables 8.1 to 8.5 show the results for the External criterion ($C_1$), the Internal criterion ($C_2$), the Risk criterion ($C_3$), the Cost criterion ($C_4$), and the Benefits criterion ($C_5$) respectively.
Table 8.1 A fuzzy reciprocal judgment matrix for the External criterion

\[
C_1 = \begin{bmatrix}
A_1 & \tilde{1} & \frac{3}{3} & \frac{7}{7} & \frac{5}{5} \\
A_2 & \frac{3}{3} & \tilde{1} & \frac{9}{9} & \frac{3}{3} \\
A_3 & \frac{7}{7} & \frac{9}{9} & \tilde{1} & 3 \\
A_4 & \frac{5}{5} & \frac{3}{3} & \frac{3}{3} & \tilde{1}
\end{bmatrix}
\]

Table 8.2 A fuzzy reciprocal judgment matrix for the Internal criterion

\[
C_2 = \begin{bmatrix}
A_1 & \tilde{1} & \frac{5}{5} & \frac{5}{5} & \frac{3}{3} \\
A_2 & \frac{5}{5} & \tilde{1} & \frac{9}{9} & \frac{3}{3} \\
A_3 & \frac{5}{5} & \frac{9}{9} & \tilde{1} & \frac{3}{3} \\
A_4 & \frac{3}{3} & \frac{3}{3} & \frac{3}{3} & \tilde{1}
\end{bmatrix}
\]

Table 8.3 A fuzzy reciprocal judgment matrix for the Risk criterion

\[
C_3 = \begin{bmatrix}
A_1 & \tilde{1} & \frac{9}{9} & \frac{3}{3} & \frac{5}{5} \\
A_2 & \frac{9}{9} & \tilde{1} & \frac{9}{9} & \frac{3}{3} \\
A_3 & \frac{3}{3} & \frac{9}{9} & \tilde{1} & \frac{3}{3} \\
A_4 & \frac{5}{5} & \frac{3}{3} & \frac{3}{3} & \tilde{1}
\end{bmatrix}
\]

Table 8.4 A fuzzy reciprocal judgment matrix for the Cost criterion

\[
C_4 = \begin{bmatrix}
A_1 & \frac{1}{1} & \frac{3}{3} & \frac{7}{7} & \frac{5}{5} \\
A_2 & \frac{3}{3} & \tilde{1} & \frac{9}{9} & \frac{3}{3} \\
A_3 & \frac{7}{7} & \frac{9}{9} & \tilde{1} & \frac{3}{3} \\
A_4 & \frac{5}{5} & \frac{3}{3} & \frac{3}{3} & \tilde{1}
\end{bmatrix}
\]
Table 8.5 A fuzzy reciprocal judgment matrix for the Benefits criterion

\[
\begin{bmatrix}
A_1 & A_2 & A_3 & A_4 \\
\tilde{1} & \tilde{5} & \tilde{5} & \tilde{3}^{-1} \\
\tilde{5}^{-1} & \tilde{1} & \tilde{9}^{-1} & \tilde{3}^{-1} \\
\tilde{5}^{-1} & \tilde{9} & \tilde{1} & \tilde{5} \\
\tilde{3} & \tilde{3} & \tilde{5}^{-1} & \tilde{1} \\
\end{bmatrix}
\]

In order to determine the relative importance of the selection criteria, pairwise comparison is used based on the linguistic variables defined as in Table 5.1, resulting in the determination of a fuzzy judgment matrix as shown in Table 8.6. Given the problem structure and the available data as above, the overall objective of the problem is to produce an overall performance index for each human resource management IS project alternative by effectively aggregating the obtained assessments for criteria weights and performance ratings.

Table 8.6 A fuzzy reciprocal judgment matrix for the relative importance of the selection criteria

\[
\begin{bmatrix}
C_1 & C_2 & C_3 & C_4 & C_5 \\
\tilde{1} & \tilde{7} & \tilde{9} & \tilde{5} & \tilde{3}^{-1} \\
\tilde{7}^{-1} & \tilde{1} & \tilde{9} & \tilde{3} & \tilde{3}^{-1} \\
\tilde{9}^{-1} & \tilde{9} & \tilde{1} & \tilde{3} & \tilde{7} \\
\tilde{5}^{-1} & \tilde{3}^{-1} & \tilde{3}^{-1} & \tilde{1} & \tilde{5}^{-1} \\
\tilde{3} & \tilde{3} & \tilde{7}^{-1} & \tilde{5} & \tilde{1} \\
\end{bmatrix}
\]
8.4 Results and Discussion

The discussion above shows that (a) fuzzy data are involved in assessing the performances of human resource management IS project alternatives with respect to each criterion, and (b) the criteria weights are represented by linguistic terms approximated by triangular fuzzy numbers. To deal with this kind of IS project evaluation and selection problem situation, the pairwise comparison approach developed in Chapter 5 is appropriate for effectively handling this problem.

By applying the pairwise comparison approach, an overall performance index for each human resource management IS project alternative and its corresponding ranking order can be obtained in a simple and efficient manner. Table 8.7 shows the overall performance index of all alternatives and their corresponding rankings. Alternative $A_2$ is the preferred choice since it has the highest index of 0.79.

<table>
<thead>
<tr>
<th>IS Projects</th>
<th>Index</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>0.28</td>
<td>4</td>
</tr>
<tr>
<td>$A_2$</td>
<td>0.79</td>
<td>1</td>
</tr>
<tr>
<td>$A_3$</td>
<td>0.44</td>
<td>3</td>
</tr>
<tr>
<td>$A_4$</td>
<td>0.61</td>
<td>2</td>
</tr>
</tbody>
</table>
The study suggests that the pairwise comparison approach developed in Chapter 5 is capable for reducing the cognitively demanding nature of the evaluation and selection process on the decision maker and effectively handling the multi-dimensional nature of the selection process, and the presence of subjectiveness and imprecision in IS evaluation and selection problem.

### 8.5 Concluding Remarks

Human resource management IS project evaluation and selection has become increasingly important for organizations in today’s competitive environment. The selection process, however, is made complex and challenging due to the multi-dimensional nature of the process and the presence of subjectiveness and imprecision inherent in the human decision making process. As a result, how to handle the multi-dimensional nature of the selection process and adequately model the subjectiveness and imprecision becomes a critical issue for effectively solving the human resource management IS project evaluation and selection problem in a real world setting.

This chapter has presented an empirical study on the Lion Travel Service Corporation to exemplify applicability of the pairwise comparison approach developed in Chapter 5 to effectively solve IS project evaluation and selection problem under uncertainty. It is shown that the pairwise comparison approach illustrated in this chapter is capable of adequately handle the cognitive demanding on the decision maker in the IS project evaluation and selection process, and the presence of subjectiveness and imprecision in IS evaluation and selection problem. The merit of this approach includes its simplicity in concept and the efficiency in computation.
Chapter 9

Conclusion

9.1 Introduction

Evaluating and selecting IS projects to develop and implement in modern organizations is an important task in every sector of human activities nowadays. This is because industrial production, service provision, and business administration are all heavily dependent on the smooth operations of IS which are expensive to develop, complex to use, and difficult to maintain (Santhanam and Kyparisis, 1995; Callon, 1996; Stamelos and Tsoukias, 2003). The availability of more alternative IS projects, the increasing complexities of these alternatives, and the pressure to make quick decisions in a dynamic environment, however, complicate the IS project evaluation and selection process (Badri et al., 2001; Lee and Kim, 2001).

This study has developed three novel approaches for effectively solving the problem of IS project evaluation and selection under uncertainty in an organization. Three common scenarios in IS project evaluation and selection have been identified that leads to the development of three novel approaches for facilitating the decision making process in evaluating and selecting the most appropriate IS project from available IS project alternatives in a given decision making situation. The results show that these approaches are capable to effectively deal with IS project evaluation and selection problem under uncertainty in a simple and straightforward manner.
This chapter presents a summary of the development of three novel approaches and their applications to facilitate the use of these approaches developed in solving practical IS project evaluation and selection problems. The characteristics of the approaches developed are illustrated, the implications of the empirical studies in relation to the application of the three developed approaches for addressing real IS project evaluation and selection problems are discussed to exemplify the applicability of these approaches for handling the IS project evaluation and selection problem in real situations. The specific contributions of this study and suggestions for future research are described.

9.2 Characteristics of the Approaches Developed

Evaluating and selecting appropriate IS project for development in an organization is complex and challenging (Deng and Wibowo, 2004; Deng, 2005). The complexity of the evaluation and selection process is due to the multi-dimensional nature of the decision making process, the conflicting nature of the multiple selection criteria, and the presence of subjectiveness and imprecision of the human decision making process (Chen and Gorla, 1998; Badri et al., 2001; Braglia et al., 2006). The challenging of the evaluation and selection comes from the need for making transparent and balanced selection decisions based on a comprehensive evaluation of all available IS projects in a timely manner while effectively considering the interest of various stakeholders in the IS project evaluation and selection process (Archer and Hasemzadeh, 2000).

This study has developed three novel approaches for solving the IS project evaluation and selection problem in a simple and effective manner. Linguistic terms approximated by fuzzy
numbers are used to formulate the IS project evaluation and selection problem in a cognitively less demanding manner for better handling the subjectiveness and imprecision inherent in the IS project evaluation and selection process. As a result, effective IS project evaluation and selection decisions can be made.

Chapter 4 has presented a linguistic approach for effectively solving the IS project evaluation and selection problem under uncertainty. This approach uses linguistic variables approximated by fuzzy numbers to express the decision maker’s subjective assessments in evaluating criteria importance and alternative performance in the decision making process. It applies the utility theory (Chen and Hwang, 1992; Olson, 1996) to aggregate the fuzzy assessments of each alternative with respect to the sub-criteria of each criterion in order to constitute the fuzzy assessments regarding their corresponding higher level criteria. The concept of the degree of optimality (Zeleny, 1998; Yeh et al., 2000) is applied to defuzzify the weighted fuzzy performance matrix so that the complex and unreliable process of comparing fuzzy utilities often required in fuzzy multi-criteria analysis (Chen and Hwang, 1992; Deng, 1999; Yeh et al., 2000) is avoided. The concept of the positive ideal solution and the negative ideal solution is applied for calculating the overall performance index for each alternative IS project across all criteria. As a result, effective decisions can be made based on the proper consideration of the decision maker’s subjective assessments.

Chapter 5 has developed a pairwise comparison approach to help reduce the cognitive demanding on the decision maker in the IS project evaluation and selection process. The pairwise comparison technique is applied for evaluating the performance of alternative IS projects and the relative importance of the selection criteria. To effectively model the subjectiveness and imprecision of the decision making process, linguistic variables
approximated by triangular fuzzy numbers are used to represent the pairwise assessments. To avoid the complicated and unreliable process of comparing and ranking fuzzy utilities often required in multicriteria analysis, the concept of the degree of dominance between alternatives (Yeh and Deng, 2004) is introduced for calculating an overall performance index for every alternative IS project across all criteria.

Chapter 6 has presented an intelligent DSS approach for facilitating the selection of appropriate multi-criteria analysis approaches in solving IS project evaluation and selection problem. The development of such an approach recognizes the availability of numerous multi-criteria analysis approaches in the literature and the different requirements, expectation and skills of the decision maker on the use of these approaches for addressing the IS project evaluation and selection problem. A knowledge base consisting of IF-THEN production rules is developed for assisting the decision maker with a systematic selection of the most appropriate multi-criteria analysis approaches in a specific IS project evaluation and selection situation. As a result, effective decision support can be provided due to adequate consideration of the decision maker’s requirements for the use of specific approaches and the efficient use of the powerful reasoning and explanation capabilities of a computer-based system (Chu et al., 1996; Deng and Liu, 2001).

There are tremendous potential and benefits as recognized in the literature for applying intelligent DSS for addressing structured and semi-structured problems in the real world setting (Jelassi et al., 1983; Zionts et al., 1992; Eom et al., 1993; Turban and Aronson, 2000). With the use of an intelligent DSS for solving a real IS project evaluation and selection problem in Chapter 6, the study shows the advantages of such an approach in the real applications including (a) the flexibility to respond quickly to the decision maker’s questions,
(b) the ability to help the decision maker better understand the decision problem and the implications of their decision behaviors, and (c) the capability to accommodate various requirements of the IS project evaluation and selection problem and the decision maker.

### 9.3 Implications of the Empirical Studies

The empirical studies of three real IS project evaluation and selection problems have been presented in this research for demonstrating the applicability of the three novel approaches developed in solving practical IS project evaluation and selection problems. These studies show that the three novel approaches developed are effective and efficient for solving the IS project evaluation and selection problem in a simple and straightforward manner.

Chapter 6 has presented an empirical study of a SCM system evaluation and selection problem based on a steel mill in Taiwan to exemplify the applicability of an intelligent DSS for solving the real IS project evaluation and selection problem. The study reveals that effective decision support can be provided with the development of a flexile DSS framework capable of considering both the characteristics of the problem and the requirements of the decision maker and the provision of interactive user interfaces between the decision maker and the DSS. It also reveals that the use of this intelligent DSS helps the decision maker better understand the decision problem and the implications of their decision behaviors, and therefore improving their confidence in making better decisions.

In Chapter 7, the application of a linguistic approach for addressing a data warehouse system evaluation and selection problem is presented to exemplify the applicability of the linguistic...
approach for dealing with the subjective and imprecise nature of the evaluation process faced
in the IS project evaluation and selection process. This is a typical example of an IS project
evaluation and selection problem where all the assessments with respect to criteria
importance and alternative performance are fuzzy. A linguistic variables are used to
formulate the selection problem for adequately handling the subjectiveness and imprecision
inherent in the selection process. It shows that the linguistic approach can effectively solve
this kind of IS project evaluation and selection problems.

Chapter 8 has presented an empirical study on a new human resource management IS project
evaluation and selection problem on a well known travel agency to exemplify applicability of
the pairwise comparison approach developed for effectively solving the selection problem.
Two common issues are involved in this evaluation process. The evaluation criteria are
generally multi-dimensional in nature and a simultaneous consideration of those multiple
criteria is required for making effective selection decisions. The evaluation process involves
subjective assessments, resulting in qualitative and vague data being used.

To facilitate the subjective evaluation process, linguistic variables are used for representing
the subjective assessments of the decision maker. To ensure the efficiency of the computation
process for making the selection decision, fuzzy numbers are used to approximate the
linguistic variables in the evaluation process. The simplicity in concept and the efficiency in
computation of the pairwise comparison approach are illustrated by this study.
9.4 Contributions of the Research

This study has comprehensively reviewed existing literature on IS project evaluation and selection. Numerous approaches have been identified for solving the IS project evaluation and selection problem in general. These approaches can be divided into four categories including (a) utility based approaches, (b) mathematical programming approaches, (c) outranking approaches, and (d) pairwise comparison based approaches.

A comparative analysis of existing approaches to IS project evaluation and selection demonstrates the merits of individual approaches for addressing real IS project evaluation and selection problems under various circumstances. Such an analysis also shows that existing approaches are not totally satisfactory for effectively solving the IS project evaluation and selection problem. Most existing IS project evaluation and selection approaches suffer from various shortcomings including (a) required complicated mathematical programming, (b) inability to handle the uncertainty and ambiguity present in the evaluation process, (c) unreliability and complexity of the ranking procedures in comparing the utility values, and (d) inconsistent ranking outcomes.

The contributions of this research are mainly from two perspectives. The first main contribution is the development of three novel approaches for solving the IS project evaluation and selection problem under uncertainty in modern organizations. The second main contribution is the presentation of three empirical studies for demonstrating the applicability of the three novel approaches developed in solving real IS project evaluation and selection problems.
The novel approach developed in Chapter 4 is capable of adequately handling the subjectiveness and imprecision of the human decision making process by calculating the overall performance index for each alternative. The overall performance index for each IS project alternative across all the criteria and sub-criteria with respect to various attitudes of the decision maker towards risks including (a) pessimistic, (b) moderate, or (c) optimistic is calculated in an efficient manner using the linguistic approach. This enables the decision maker to fully explore the relationships between the decision outcomes and their risk attitude. As a result, better decisions can be made due to the better understanding of the decision problem and the implications of the decision maker’s decision behaviors.

Recognizing the cognitively demanding nature of the IS project evaluation and selection process on the decision maker and the presence of inherent subjectiveness and imprecision of the human decision making process, Chapter 5 has developed a pairwise comparison based approach with the help of fuzzy set theory for evaluating the performance of alternative IS projects and the relative importance of the selection criteria. By applying this approach, an overall performance index for the IS project alternative and its corresponding ranking order can be obtained in a simple and efficient manner.

An intelligent DSS approach for facilitating the selection of appropriate multi-criteria analysis approaches in solving the IS project evaluation and selection problem is developed in Chapter 6. The development of such an approach recognizes the availability of numerous multi-criteria analysis approaches in the literature and the different requirements, expectation and skills of the decision maker on the use of these approaches for addressing the IS project evaluation and selection problem. A knowledge base consisting of IF-THEN production rules is developed for assisting a systematic selection of the most appropriate multi-criteria
analysis approaches in a specific IS project evaluation and selection situation. Effective
decision support can be provided with the development of a flexible multi-criteria analysis
approach selection procedure capable of considering both the characteristics of the problem
and the requirements of the decision maker with the provision of an interactive user interface
between the decision maker and the DSS.

The second main contribution of this research is the presentation of three empirical studies on
the application of the three novel approaches developed for solving three real IS project
evaluation and selection problems. Such empirical studies help illustrate the applicability of
the three novel approaches developed for solving the general IS project evaluation and
selection problem. Each of the IS project selection problem has different requirements and
characteristics, thus requiring a specific approach for dealing with each problem differently.
The studies show that the three novel approaches developed are capable of solving practical
IS project evaluation and selection problems efficiently and effectively.

9.5 Suggestions for Future Research

IS project evaluation and selection continues to be an important decision making problem in
modern organizations in today’s complex environment. The challenge of evaluating and
selecting the most appropriate IS project for development comes from the need to (a)
adequately handle the uncertainty and imprecision inherent in the decision making process,
and (b) make transparent and balanced selection decisions based on a comprehensive
evaluation of all available IS projects in a timely manner. The study conducted by this
research only covers part of the IS project evaluation and selection areas. There are a few other areas that can be explored further. These areas include:

(a) The knowledge base that is used for assisting the decision maker with a systematic selection of the most appropriate multi-criteria analysis approach in a specific IS project evaluation and selection situation for the decision maker can be further expanded to deal with the group decision making situation. This will further enhance the applicability of the DSS for dealing with the practical IS project evaluation and selection situations as real IS project evaluation and selection is often group based.

(b) The incorporation of other evolutionary computing approaches such as neural networks and genetic algorithms may be desirable to provide effective mechanisms in modeling the decision maker’s preference and to effectively handle the inherent subjectiveness and imprecision of the human decision making process in a practical environment.

(c) The growing popularity and the availability of the Internet nowadays make it possible to develop an effective DSS that are applicable to the Internet. This study can be further expanded to include the use of World Wide Web infrastructure and a client/server computing architecture to allow a web-based DSS application for solving the IS project evaluation and selection problem.
References


Conference on Web Information Systems Engineering, 12 December - 14 December, pp. 149-160.


## Appendix A

### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>Analytical hierarchy process</td>
</tr>
<tr>
<td>ANP</td>
<td>Analytical network process</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision support systems</td>
</tr>
<tr>
<td>ELECTRE</td>
<td>Elimination and et choice translation reality</td>
</tr>
<tr>
<td>IS</td>
<td>Information systems</td>
</tr>
<tr>
<td>MAUT</td>
<td>Multi-attribute utility theory</td>
</tr>
<tr>
<td>NGT</td>
<td>Nominal group technique</td>
</tr>
<tr>
<td>PROMETHEE</td>
<td>Preference ranking organization method for enrichment evaluation</td>
</tr>
<tr>
<td>SAW</td>
<td>Simple additive weighting</td>
</tr>
<tr>
<td>SCM</td>
<td>Supply chain management</td>
</tr>
<tr>
<td>SMART</td>
<td>Simple multi-attribute rating technique</td>
</tr>
<tr>
<td>TOPSIS</td>
<td>Technique for order preference by similarity to ideal solution</td>
</tr>
</tbody>
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