IT INVESTMENT DECISION-MAKING: PRACTICAL USABILITY OF A NORMATIVE MODEL

Master Thesis

Poot, V., University of Twente, Enschede, Netherlands, v.m.poot@student.utwente.nl

Thesis Supervisors:

Dr. Wijnhoven, A.B.J.M., University of Twente, Enschede, Netherlands,

a.b.j.m.wijnhoven@utwente.nl

Dr. Heerkens, J.M.G., University of Twente, Enschede, Netherlands, j.m.g.heerkens@utwente.nl

Abstract

This study researches the practical usability of a multi-criteria decision analysis (MCDA) method for making IT-investment decisions. The practical usability of the ROAHP model is studied by presenting ROAHP to CIO's and using a survey to collect their opinion on prerequisites for practical usability, strengths and weaknesses, and current routines of their organization that could benefit from ROAHP. To understand these opinions they are put in organizational context by profiling their organization's strategic decision making process based on dominant paradigms in strategic decision making research. The study concludes that CIO's recognize the potential of ROAHP but that it lacks usability. Furthermore, this study recommends future research to focus on the practical usability rather than validity of the method.

Keywords: IT-investments, Strategic Decision Making, MCDA, ROAHP, IT-investment decision making, Practical Usability

Acknowledgements

This thesis concludes my master's programme at the University of Twente and I would therefore like to take this opportunity to express my appreciation for all the help I received along the way. First and foremost, I would like thank my thesis supervisors: Fons Wijnhoven and Hans Heerkens. Thank you for your help in writing this thesis, your constructive feedback and ability to motivate have helped me a lot and I could not have done it without your help. Second, I would like to thank Norbert Derickx and the members of CIO Platform for helping me in collecting my data and welcoming me into their offices.

Special thanks go out to my parents, Anne Canisius and Ron Poot, and my girlfriend Aimée Bakker. You have been very supporting and encouraging throughout the process.

1 Introduction

Information technology (IT) is becoming more and more important in businesses everywhere. Despite the importance of IT for businesses, there are a lot of problems determining the value of an IT investment. This lies in the fact that the relationship between IT and organizational benefits remains unclear. The question whether IT adds value has been addressed in multiple studies, whether it be financial (e.g., return on investment), intermediate (e.g., process-related) or affective (e.g., perception related) (Kohli & Grover, 2008). There are still questions that remain: how does IT influence certain aspects of a business? Who should be involved in the decision making progress? What information is required by the management to make proper and grounded IT-investment decisions? How should these IT-investment decisions be made for optimal results?

One could argue that an investment decision should be made with a rationalistic approach. For example: the problem can be stated, different solutions can be presented and requirements of these solutions can be quantified into selection criteria and the best solution can be mathematically calculated. This approach would surely give the best option of the selected solutions. Such an approach, however, does pose certain problems. It requires the decision maker to be able to quantify requirements of a solution for the investment problem. The decision maker also has to assess how important these criteria (relatively to each other) are for their solution. The process of determining the criteria and their weights pose an information and value problem. How does one determine these criteria and their weights? What information does the decision-maker require for this?

For example, a study by Angelou and Economides (2008) presents a method for prioritizing a portfolio of ICT infrastructure projects. They present a multi-criteria decision analysis model called ROAHP (Real Options Analytical Hierarchy Process). This model uses a mathematical technique by combining AHP and RO into a combined model. This model uses real options to value projects within a portfolio of projects, taking into account possible subsequent projects that the initial projects can enable, which

might add value in the future. AHP is used to value intangible factors and by combining this with RO, Angelou & Economides (2008) argue that this model achieves a higher accuracy than models that only use RO. An important limitation of such a model is a reliability problem: the model assumes that the relative weights of the criteria are known *ex-ante*, while this is not (always) the case in real-life scenarios. Therefore the reliability can be a problem when the relative weights of the criteria are not known and cannot be properly determined. Another limitation is the validity problem, it does not take into account the organizational reality of decision making. In real-life scenarios of IT-investment decision making the process is often influenced by politics (Eisenhardt & Bourgeois, 1988), uncertainty, limited time and limited information. The real life process of decision making is far from a pure rational process and therefore a rationalistic approach, such as the ROAHP model, might not be fully usable in practice, but I argue that IT-investment decision making could benefit from a more rationalistic approach such as a multi-criteria decision analysis (MCDA), while keeping into account the politics, limited time frame and limited information available. While normative models are extensively discussed in the literature, it has a clear focus on finding adequate methods for valuating IT investments and their validity. I argue that they lack a focus on the usability for the end-users: IT-investment decision makers. What do IT investment decision makers think of normative models, and do they think they are usable in practice? Therefore, the key research question in this paper is:

- ***What is the practical usability of a normative decision making method for IT-investment decision makers?***

Furthermore, to further study the opinion of the end-users on normative models for IT-investment decision making, specifically ROAHP, I will address the following research questions:

- ***What do IT-investment decision makers think of ROAHP's potential to increase the quality of IT-investment decision making?***

- ***How do IT-investment decision makers think the IT-investment decision making process in their organization can benefit from ROAHP?***

The goal of this paper is to study the practical usability, strengths and weaknesses of a MCDA approach for making IT investment decisions, and in particular the ROAHP model presented by Angelou & Economides (2008), according to IT-investment decision makers. Practical usability in this context can be defined as to what extent the method is actually usable in practice.

In order to answer these questions, an explanation of ROAHP will be presented to CIO's for collecting their opinion on this RO method. To understand these opinions they are brought in organizational context by measuring the presence of characteristics of paradigms found in strategic decision making research. The results of both their opinions, and their strategic decision making process within their organization, can be examined and compared in order to find missed opportunities within these organizations (e.g., where a rationalistic approach such as MCDA could be used to improve the IT-investment decision making process). The result of this study will also provide valuable information for further research on increasing the real-life usability of MCDA models as decision support tool for IT-investment decisions.

This paper is structured as follows: the next chapter will start with a literature study on behavioural and normative models for strategic decision making. Through a literature search, paradigms in strategic decision making research are identified and are reviewed and criticized. In order to profile an organization's strategic decision making process these models are operationalized through multiple choice (MC) survey questions. Each paradigm will serve as a dimension for the strategic decision making profile. The profile will enable comparison between organizations on their strategic decision making process. Next, the ROAHP model by Angelou and Economides (2008) is explained in detail, reviewed and improved where necessary. In order to develop a quantitative survey for CIO's, a preliminary interview is developed first. The goal of this preliminary interview is to collect qualitative

data about the decision making process in organizations and their opinions on ROAHP. This preliminary interview consists of survey questions about the organization's strategic decision making process, an explanation of ROAHP is presented and the participants are asked about their opinion on ROAHP, and how it compares to their decision making process. This qualitative data is used to formulate a quantitative MC survey. The final survey uses the same multiple choice survey questions about the organization's decision making process, an introduction to ROAHP and MC questions about the usability, strengths and weaknesses of ROAHP and how ROAHP could potentially benefit their current decision making routines. Next, the results are presented and discussed, the conclusions and limitations summarized and recommendations for further research are given.

2 Behavioural and normative models of strategic decision making

In order to study how an IT-investment decision making process could benefit from normative models a literature study is conducted on both behavioural and normative models of strategic decision making. I review and criticize the normative models on practical usability. The models will be compared to behavioural models in order to see how they differ. In order to find literature I have used the article by Eisenhardt and Zbaracki (1992) as starting point. Their paper presents a review of dominant paradigms in strategic decision making. Using a forward reference search function 355 papers were found. Filtering these results on publication date (only papers since 2006) yields a result of 225 papers. This filter is chosen in order to get more up-to-date research on the subject, while the article by Eisenhardt and Zbaracki (1992) serves as an overview earlier research on the subject. The top 40 papers, based on "cited by" (highest to lowest), were selected. Of these 40 papers, all abstracts were read. While most papers were relevant to the subject of strategic decision making, most of them are not relevant for this research. One paper that shows that the ideas in the paper by Eisenhardt and Zbaracki (1992) are still relevant in current strategic decision making research is a paper by Elbanna (2006). This paper reviews a debate in strategic decision making process literature. They refer to this debate as the "synoptic formalism/political incrementalism debate" (Elbanna, 2006). "Synoptic formalism is considered an extension of the traditional rational model; and analysis is its basic feature" (Elbanna, 2006). Normative models for decision making fall under this category, as they use the traditional rational model as basis and have analysis as a basic feature. Contrasting to this is incrementalism, which explains what the strategic decision making process empirically looks like in organizations. Elbanna (2006) mentions three types of incrementalism: Lindblom (1959)'s incrementalism, Quinn (1980)'s logical incrementalism and Mueller, Mone, and Barker (2000)'s political incrementalism. Although there are some differences between those three types of incrementalism "they are often offered as the antithesis to synoptic formalism"(Elbanna, 2006). Eisenhardt and Zbaracki (1992) conclude that political incrementalism

provides a compelling description of how strategic decisions are made in reality. For this reason, political incrementalism is used as the antithesis to the synoptic formalism. Furthermore Elbanna (2006) gives a more up to date overview of literature on strategic decision making than the article by Eisenhardt and Zbaracki (1992) and is therefore used to further address the paradigms explained in the next section. So in summary, for the dominant paradigms (rationality and bounded rationality, politics and power and the garbage can model) I use the paper of Eisenhardt and Zbaracki (1992) and the discussed papers, complemented by the paper of Elbanna (2006) and the literature reviewed in that paper.

In order to find a normative model the following query has been formulated: *Information technology investment valuation.* Using this query in Web of Science (November 2015) yields 152 results. These results are then sorted by "cited by". The first paper that presents a usable method for prioritizing IT projects in a portfolio of projects is the paper by Bardhan, Sougstad, and Sougstad (2004). Using a forward reference search function 54 papers were found. The paper by Angelou and Economides (2008) is the only article found that presents a RO model similar to Bardhan et al. (2004)'s model. The authors extend on this model by adding AHP, enabling the comparison of tangible and intangible factors. The authors present a MCDA approach as a decision-support tool for making strategic decisions within organizations and demonstrate their methodology with a descriptive case. The ROAHP model presented by Angelou and Economides (2008) is discussed and explained in more detail, as this is the normative model of choice in this research.

2.1 Theory of strategic decision making

In order to understand IT-investment decision making we first look at research on strategic decision making. Strategic decisions can be defined as a decision that is "important, in terms of the actions taken, the resources committed, or the precedents set" (Mintzberg, Raisinghani, & Théorêt, 1976).

Eisenhardt and Zbaracki (1992) present a review of three dominant paradigms in strategic decision making. These three paradigms are rationality and bounded rationality, politics and power, and the

garbage can model. I discuss these paradigms and review their empirical support in the following paragraphs.

2.1.1 Rationality and bounded rationality

The rational model of choice in its most basic form assumes that an actor enters a decision-making situation with known objectives. The actor defines the value of those objectives, gathers information and develops a set of alternative actions. Then the optimal alternative is selected based on that information. Take for example the scenario of purchasing a car. The buyer gathers the specifications of all cars available for purchase, these specifications can then be used for creating decision criteria. The buyer determines the relative importance of all these specifications and can then mathematically calculate the best option according to their own preferences. While this might give the best results, this approach is not realistic. It assumes that the goal is completely known, all information about the cars are known (information problem) and that all the relative weights are known *ex-ante* (reliability problem). Several empirical studies show that there are limitations on this model. For example the work by Cyert and March (1963) presented theory and case studies that show "that goals can be inconsistent across people and time, search behaviour is often local and standard operating procedures guide much organizational behaviour" (Eisenhardt & Zbaracki, 1992). A more recent adaptation of the model by Mintzberg et al. (1976) poses that decisions have unique patterns of solutions. They present a structured model of strategic decisions that they claim are unstructured. The model consists of three basis phases: the identification phase, the development phase and the selection phase. Theirs differs from the classic rational model in that the phases do not have a sequential relationship. In each phase decisions follow different routines (see table 1). These phases and routines can occur in any order and can repeat.

Phase	**Routines**
Identification phase	Decision recognition and diagnosis
Development phase	Search and design
Selection phase	Screen, evaluation-choice and authorization

Table 1. Mintzberg et al. structured decision making model

The identification phase consist of two routines: decision recognition and diagnosis. First the opportunity or problem has to be recognized by the management. In the diagnosis phase the management tries to gain understanding about the problem or opportunity; what are possible causes and effects of this decision making situation. The development phase consists of two routines: search and design. The search routine represents the activity of searching for ready-made alternatives for the decision problem. The design phase is used to modify or create a new solution for the decision problem. The selection phase consists of three different routines: the screen routine, evaluation choice routine and the authorization routine. In the screen routine management tries to reduce the amount of alternatives to a minimum, in order to allow for a more intense evaluation. This routine is more concerned with eliminating infeasible alternatives rather than selecting the appropriate ones (Mintzberg et al., 1976). The next routine is the evaluation-choice, which consists of selecting the best alternative based on the selection criteria. It is used to examine the different feasible alternatives and select the best one. "The evaluation-choice routine may be considered to use three modes: judgment, bargaining and analysis. In judgment, one individual makes a choice in his own mind with procedures that he does not, perhaps cannot, explain; in bargaining, selection is made by a group of decision makers with conflicting goal systems, each exercising judgment; and in analysis, as described above, factual evaluation is carried out, generally by technocrats, followed by managerial choice by judgment or bargaining."(Mintzberg et al., 1976). Mintzberg et al. (1976) find that judgement is favourable mode of selection, most likely due to the fact that it is fastest, most convenient and least stressful. The analytic mode clearly distinguishes fact and value in the selection phase. "It postulates that alternatives are carefully and objectively evaluated, their factual consequences explicitly determined along various goal, or value, dimensions and then combined according to some predetermined utility function – a choice finally made to maximize utility."(Mintzberg et al., 1976). The authorization routine occurs when the individual making the

decision does not have the authority to make it on his own. He needs to gather approval of all parties that have that authority or have the power to block the decision (e.g. environmental parties).

Another variation of the model presents rationality and bounded rationality as a dichotomy or continuum. This model acknowledges that decision processes are often boundedly rational and improve the rationality by increasing the amount of information and creating conflict by using more diverse standpoints. A study by Janis (1982) shows that in strategic decision situations a pattern can be found, which he calls 'groupthink'. This is the tendency to seek concurrence. In order to tackle this tendency he poses several antidotes like encouraging arguments, introducing a devil's advocate or hiring outside experts. This produced better results than consensus groups but came at the expense of group satisfaction and acceptance of the decision. More recent research breaks from the assumption that rationality and bounded rationality are a continuum but poses that rationality is multidimensional. This means that decision makers are, rather than rational or boundedly rational, rational in some ways, but not others. This research suggests "a set of decision making tactics or heuristics which are rational in some ways, but not others and which are effective in fast-paced, uncertain settings" (Eisenhardt & Zbaracki, 1992). The review of this paradigm by Eisenhardt and Zbaracki (1992) shows that there is sufficient empirical evidence that 1) cognitive limits to the rational model exist, decision makers do not always optimize but rather satisfice, 2) decisions follow the basic phases of problem identification, development and selection, but do not follow each other sequentially but rather cycle through and repeat these phases, and 3) the decision path is influenced by the complexity of the situation and the conflict that exists among the decision makers. The article by Elbanna (2006) shows that the presumption that rational behaviour in strategic decision making has a positive influence on the quality of the decision itself is backed up substantially within literature (J. W. Dean, Jr. & Sharfman, 1996; Eisenhardt & Bourgeois, 1988; Jones, Jacobs, & van't Spijker, 1992; Khatri & Hunt, 1994; Papadakis, 1998).

Within this research, as suggested by Elbanna (2006), as representative of the synoptic formalism perspective procedural rationality is used, specifically the definition of (procedural) rationality of J. W.

Dean, Jr. and Sharfman (1996). In their definition, one could conclude that an organization would be "more rationalistic" when using a normative model, such as a MCDA approach, for decision making. Their study on 52 strategic decisions shows a positive relation between procedural rationality and decision effectiveness. They define procedural rationality as follows: "the extent to which the decision process involves the collection of information relevant to the decision and the reliance upon analysis of this information in making the choice."(Elbanna, 2006). J. W. Dean, Jr. and Sharfman (1996) have developed a scale for measuring procedural rationality in strategic decision making processes. They use a 5 item ($\alpha = .80$) 7-point Likert scale in order to measure procedural rational behaviour in decision making (see table 2 for an overview).

In summary, there is substantial evidence found within literature that a positive relation between procedural rationality and decision effectiveness exists, thus supporting the presupposition mentioned at the beginning of this paper: an increase of rationality in a decision making process has a positive influence on the quality of the decision. Furthermore, J. W. Dean, Jr. and Sharfman (1996)'s definition and scale for measuring procedural rationality is chosen as representative of rationality within this research, as it is well suited for multiple reasons: 1) their definition of rationality corresponds with the definition of rationality in this paper, 2) their scale is made specifically for the purpose of measuring the extent of rationality involved in a decision making process and 3) has proven to be an accurate and valid measure of procedural rationality.

Procedural rationality item	**Response**
How extensively did the group look for information in making this decision?	(1= not at all, 7 = extensively)
How extensively did the group analyse relevant information before making a decision?	(1= not at all, 7 = extensively)

How important were quantitative analytic techniques in making the decision?	(1 = not at all important, 7 = very important)
How would you describe the process that had the most influence on the group's decision?	(1 = mostly analytical, 7 = mostly intuitive)
In general how effective was the group at focusing its attention on crucial information and ignoring irrelevant information?	(1 = not at all effective, 7 = very effective)

Table 2. Procedural rationality scale as formulated by J. W. Dean, Jr. and Sharfman (1996)

2.1.2 Politics and power

Another view on strategic decision making holds its roots in political science. In this view decisions are the result of a process where the "decision makers have different goals, they come together through coalitions, and the preferences of the most powerful triumph" (Eisenhardt & Zbaracki, 1992). The key assumption is that in organizations there are groups of people with different interests and while they may share goals they also have conflicting interests. The notion that organizations can be seen as political systems is supported by empirical evidence. For example the case study by Baldridge (1971). In this case New York University (NYU) shifted from an open enrolment school to a research-oriented university. This was in line with the general view of the university but different stakeholders (such as the students, faculties, alumni etc.), while sharing the common interest of the wellbeing of the university, had different interests. The proposition for increasing the tuition fee obviously co-aligned groups of students against the university. The notion that the most powerful triumph also holds empirical evidence. The study by Pfeffer and Salancik (1974) found that the share of the budget of each department was not determined by a rational criterion such as student units taught but by the power of the department. The act of engaging in politics is another important feature of the political model. Eisenhardt and Zbaracki (1992) define this as follows: "By politics, we mean those observable but often covert, actions by which people enhance their power to influence a decision. Examples of politics include coalition formation, lobbying, co-optation, withholding agendas, and control of agendas." Most scholars therefore accept the following ideas of the political model: 1) people in organizations have (partially) conflicting preferences,

2) strategic decision making is political due to powerful people getting what they want, and 3) people engage in politics to enhance their decision-making power. The summary of empirical research on political behaviour within organizations provided by Elbanna (2006) shows that political behaviour is mostly negatively related to organizational performance (Gandz & Murray, 1980) and decision effectiveness (J. W. Dean, Jr. & Sharfman, 1996; Eisenhardt & Bourgeois, 1988). This negative relation can be explained by the following reasons. J. W. Dean, Jr. and Sharfman (1996) state that political behaviour can lead to decision makers making decisions on incomplete information, this due to political behaviour distorting information (Pfeffer, 1992) and often restricting the information flow (Pettigrew, 1973). Another reason could be that political behaviour is often time-consuming and therefore cause a delay in the decision, possibly causing loss of opportunities (Pfeffer, 1992). J. W. Dean, Jr. and Sharfman (1996) also argue that "political behaviour may lead to incomplete understanding of the environmental constraints, resulting in the undermining of strategic decision effectiveness in two ways. First, political tactics are directed towards the interests, power bases and positions inside the organization rather than towards what is feasible, given the present environmental forces. Hence, decisions which result from such processes are less likely to consider environmental constraints. Second, political processes may exclude some feasible alternatives because they are in conflict with powerful individuals' interests, undermining the likely success of strategic decisions" (Elbanna, 2006). J. W. Dean, Jr. and Sharfman (1996) have also developed a scale for measuring the extend of political behaviour in a decision making process, similar to their scale for measuring the extent of procedural rationality (see table 3).

In summary, literature shows substantial evidence that political behaviour has a negative influence on the decision making process, in contrast to rationality. J. W. Dean and Sharfman (1993) found that political behaviour and rationality are not mutually exclusive: an organization's decision making process can both be rational and political in nature. It is, however, reasonable to assume that political behaviour does limit the extent of rationality in an organization's decision making process, as it can lead to

decision-makers making decisions based on incomplete information, loss of opportunities as a result of delay in the decision making and the exclusion of feasible alternatives, which are all effects that decrease the extent of rationality in the decision making process. In order to measure the extent of political behaviour present in an organization's decision making process, the scale developed by is used.

Political behaviour item	**Response**
Were group members primarily concerned with their own goals, or with the goals of the organization?	(1 = own goals completely, 7 = organizational goals completely)
To what extent were people open with each other about their interests and preferences in the decision?	(1 = not at all, 7 = completely)
To what extent was the decision affected by the use of power and influence among group members?	(1 = not at all, 7 = completely)
To what extent was the decision affected by negotiation among group members?	(1 = not at all, 7 = completely)

Table 3. Political behaviour scale as formulated by J. W. Dean, Jr. and Sharfman (1996)

2.1.3 Garbage can model

The garbage can model was introduced by Cohen, March, and Olsen (1972). The model was a reaction to the rational and political decision models. It describes decision making in ambiguous settings called organized anarchies. These organized anarchies are organizations plagued by extreme ambiguity (Cohen et al., 1972). This ambiguity shows in three different manners:

- Problematic preferences (inconsistent and ill-defined preferences of decision makers)
- Unclear technology (decision makers have loose understanding of means and ends of technology)
- Fluid participation (decision makers come and go from the process)

The garbage can model describes four streams that come together randomly or accidentally: "(1) choice

opportunities-occasions which call for a decision, (2) solutions-answers looking for problems, (3) participants-people with busy schedules who might pay attention, and (4) problems-concerns of people within and outside the organization." (Eisenhardt & Zbaracki, 1992). These four streams come together and flow in and out of the garbage can and solutions occur largely due to chance. Empirical evidence supports that some organizations can be defined as organized anarchies. A study by (Olsen, 1976) gives a good example. The study examines the selection of a new dean at a university. The preferences of the decision makers were characterized as "multiple, inconsistent, ill-defined, and changing". The decision makers were looking for a young candidate who was a serious academic and preferably educated in mathematics. When these requirements could not be met by candidates their preferences changes to more realistic ones. The key decision makers also changed over time when problems in selecting a candidate arose. Pinfield (1986), in his study comparing structured models and the garbage can model, suggests that participation was not as random as the garbage can model claims. It was rather a "consequence of institutional roles, politics, and the phase of the decision process" (Eisenhardt & Zbaracki, 1992). Therefore the participation was predictable to some extent. He also found that the four streams were linked by the issue at hand, and individuals tried to manage the people involved in the decision process and manage the choice opportunities in the process. This observation criticizes the assumption of stochastic occurrence of the four streams. Another critique comes from Magjuka (1988). He studied participation in a curriculum reform of a public school over several years and several hundred teachers. While participation was random at the individual level, overall patterns were predictable from demographic and psychological variables, as well as the position of the teacher in the social network. Magjuka (1988) concludes that that the results suggest an interpretation "that does not support the Garbage Can or is in any sense congenial to the underlying thrust of the Garbage Can theory. The results indicate that patterns of participation are purposive, rational, and predictable."(Magjuka, 1988).

The empirical evidence for the garbage can model only modestly supports the existence of organization anarchies and the stochastic confluence of the four streams. Due to this empirical evidence and as the

other two paradigms have more empirical evidence, the garbage man model is not used in this paper. The strategic decision making process of organizations will be described and profiled using only the rational and the political perspectives. In order to increase the (procedural) rationality in the decision making process, organizations can use a MCDA method to support their decisions. In the next section a normative model is described and explained.

2.2 Description and Adaptation of ROAHP

The valuation of information technology investments is very challenging due to multiple reasons. IT investments are characterized by uncertainty, long pay-back times and the changing nature of a business (Bardhan et al., 2004). In finance, in order to evaluate an investment decision a discounted cash flow (DCF) approach is used. This means an investment decision is based on the calculated present value of expected cash flows by using a discount rate based on the corresponding risk involved. This approach, however, does not take into account the flexibility of most IT-investment decisions (Bardhan et al., 2004). An IT-investment can have a negative net present value (NPV) but provide a foundation for other services that might increase profitability in the future. Another reason why a DCF approach to IT investment decisions is not sufficient is the fact that an IT investment can hold qualitative factors that cannot be quantified easily. Benaroch and Kauffman (1999) present a MCDA model for valuating IT-investment using a real options (RO) approach. A real option can be seen as an option to purchase a (non-financial) asset in the future. When uncertainty is reduced a decision can be made to either expand, downsize or abandon other future projects, therefore taking into account the flexibility of most IT-investment decisions. This RO approach fits the nature of IT-investment decision making, which is characterized by flexibility and the capability to expand or launch other applications (Angelou & Economides, 2008) which might add value. Bardhan et al. (2004) present a RO approach for valuating a portfolio of IT-investment decisions. They argue that, because IT projects are characterized by interdependencies and sequencing constraints, previous RO approaches for valuating IT investment

decisions ignore project interdependencies because they only look at one project at a time. Their model of nested RO improves understanding of project interdependencies on project valuation decisions because it considers positive and negative dependencies of projects within a portfolio. The research by Angelou and Economides (2008) extends on the idea of using a nested RO model by adding analytical hierarchy process (AHP) to the existing RO model. Angelou and Economides (2008) present a MCDA method for prioritizing a portfolio of IT projects. The nested real options helps to include the interdependencies between projects during the valuation of the projects and will allow the ENPV to be calculated for each project. They argue that their model enables valuating IT projects with higher accuracy by combining RO with AHP in order to combine tangible and intangible factors. The tangible and intangible factors are made compatible and the project priority ranking is calculated using the Expert Choice tool (Expert Choice is a commercial AHP tool).

Angelou and Economides (2008)'s method's end goal is to calculate the overall benefit factor of each project. It combines tangible (one-time costs and ENPV) and intangible factors from each project and allows the user to calculate the overall benefit factor, according to the user's preferences. The method starts by calculating the extended net present value (ENPV). This differs from the NPV value of a project due to the fact that it adds the value of future options by using the RO method. It takes into account the managerial flexibility companies have. Companies can choose to, e.g., pause or abandon projects in case of a negative development or to extend it in case of a positive development. This flexibility is also called active management (Angelou & Economides, 2008).

Initial projects k are defined as (P1,k). Where (P1,*k*) is the initial "infrastructure project" *k* (*k* = 1,2,…,K) in phase 1 with K being the total amount of initial infrastructure projects. Angelou and Economides (2008) define subsequent projects as (P*i*,*j*), where *i* = 1, . . ., n phases and *j* = K+1, K,+2, …,M. M is the total number of ICT projects.

Notation	***Definition***
M	Total number of ICT projects
K	Number of initial infrastructure projects.
N	Number of phases considered.
$P_{1,k}$	Infrastructure project k in phase 1, k = 1,2,…,K
$P_{2,j}$	Project j in phase 2, j = K+1, K+2, ….,M
$NPV_{1,k}$	Net Present Value of project $P_{1,k}$, k=1,2,…K.
$ENPV'_{1,k}$	Potential Expanded NPV of project $P_{1,k}$ that contains the option(s) value(s) of future interdependent investment opportunities
$V_{2,j}$	Present value of operating revenues of project $P_{2,j}$
$C_{2,j}$	One time cost of implementing project $P_{2,j}$. Investment expenditure required to exercise the option (cost of converting the investment opportunity into the option's underlying asset, i.e., the operational project)
$OV_{2,j,k}$ ($OVA_{2,j,k}$)	Option value contribution (attribute) of project $P_{2,j}$ if project $P_{1,k}$, which is prerequisite for project $P_{2,j}$ is implemented– Hard dependency
$OV'_{2,j,k}$	Option value of project $P_{2,j}$ if project $P_{1,k}$, which enhances positively the performance of project $P_{2,j}$, is implemented
$OV'_{2,j}$	Option value of project $P_{2,j}$ if project $P_{1,k}$, which enhances positively performance of project $P_{2,j}$, is not implemented
$OVA'_{2,j,k}$	Option value contribution (attribute) of project $P_{2,j}$ to project $P_{1,k}$, which enhances the performance of project $P_{2,j}$ if it is implemented – Soft positive dependency
$-OV'_{2,j,k}$	Option value of project $P_{2,j}$ if project $P_{1,k}$, which influences negatively the performance of project $P_{2,j}$, is implemented.
$-OV'_{2,j}$	Option value of project $P_{2,j}$ if project $P_{1,k}$, which influences negatively the performance of project $P_{2,j}$, is not implemented.
$-OVA'_{2,j,k}$	Option value contribution (attribute) of project $P_{2,j}$ to project $P_{1,k}$, which influences negatively the performance of project $P_{2,j}$ if it is implemented – Soft negative dependency
$s_{k,j}$	Soft positive dependency of project $P_{2,j}$ on project $P_{1,k}$ (the percentage of reduction of operating revenues of project $P_{2,j}$ if it is not preceded by project $P_{1,k}$).
$-s_{k,j}$	Soft negative dependency of project $P_{2,j}$ on project $P_{1,k}$ (the percentage of reduction of operating revenues of project $P_{2,j}$ if it is preceded by project $P_{1,k}$).
TF_{lk}	Value of tangible factor l (l=1,…L) in project k, (in our model L=2: One time cost and ENPV)
tf_{lk}	Normalized of TF_{lk}

Figure 1. Modified notations used in the real options model of Angelou and Economides (2008)

The ENPV can be formulated as follows (see figure 1 for an overview of the definitions of the notations used):

Expanded Net Present Value = Static NPV + Value of Future Options Active management

Consider P1,1 implemented in phase 1 that holds one future investment opportunity P2,2 in phase 2, the total value of the cluster of projects can be calculated by the following formula:

$$ENPV(P1,1) = NPV(P1,1) + OV[P2, 2]$$

This formula can easily be extended to a more complex situation with more phases by adding more phases and the options that each project embeds. Angelou and Economides (2008) make a distinction between hard and soft interdependencies. Hard dependencies between projects exist if project P[2,2] cannot exist when project P[1,1] is not implemented. Because without project P[1,1], project P[2,2] cannot exist the overall option value should be the contribution of P[2,2] to P[1,1], defined as $OV[P_{i,j,k}] = \max (V[P_{i,j}] - C[P_{i,j}] , 0)$. V = present value of operating revenues of the project and C the one time implementing costs.

The maximum potential ENPV can be calculated by the following formula:

$$ENPV(P1,1) = NPV(P1,1) + OV[P2,2,1]$$

The hard dependant project P[2,1] can be calculated by:

$$OV[P2,2,1] = \max (V[P2,2] - C[P2,2] ,0)$$

Soft dependencies can exist in both negative and positive form. A positive soft dependency exists when project A is not a prerequisite for project B but enhances the benefits of the latter. The same goes for a negative soft dependency but instead of project A enhancing project B's value it decreases its value. So in this case, rather than P1,1 being a prerequisite for P2,2, it enhances its benefits. The maximum potential ENPV can be calculated as follows:

$$ENPV'(P1,1) = NPV(P1,1) + OVA'[P2,2,1]$$

In order to estimate how much P[2,2] enhances P[1,1] you have to calculate OVA'[P2,2,1]. This is given by the following formula:

$$OVA'[P2,2,1] = OV'[P2,2,1] - OV'[P2,2]$$

OV'[P2,2,1] is the option value for P[2,2] when P[1,1] is implemented and OV'[P2,2] is the option value for P[2,2] when P[1,1] is not implemented. S*k*,*j* = the percentage of reduction of operating revenues of project *j* if it is not preceded by project P1,k. They can be calculated by to following formulas:

$$OV'[P2,2,1] = \max([V2,2] - C[2,2],0)$$

$$OV'[P2,2] = \max(([S,1,2]) * ([V2,2] - C[2,2],0)$$

For negative soft dependencies the same formula can be used by negating [S2,2]:

$$-OV'[P2,2,1] = \max([V2,2] - C[2,2],0)$$

$$-OV'[P2,2] = \max((1-[S1,2]) * ([V2,2] - C[2,2],0)$$

After calculating the ENPV of each project, Analytical Hierarchy Process (AHP) is used in order to determine each factors' relative weight. AHP is a MCDA technique in order to choose from a given set of alternatives. It helps to tackle complex decisions and allows to structure the alternatives hierarchically. AHP allows for different criteria with different units of measure to be transformed into one compatible unit of measure. A nine-point scale (extreme, very strong, strong, moderate and equal,

and intermediate values) is used in order to score the projects on each factor. Using pairwise comparison matrices all relative weights can be determined and all criteria can be hierarchized.

The decision making method as formulated by Angelou and Economides (2008) follows 5 different steps:

- Recognize the overall portfolio's projects as well as the initial infrastructure projects as chains of investment opportunities.
- Identify all hard and soft dependencies between all combinations of projects P1,k and P2,j, where k = 1, 2, 3,. . ., K and j = K+1, K+2,. . .,M.
- Identify the option presence and type for all projects.
- Apply the AHP methodology for intangible factors while integrating the TFs as estimated by the aforementioned options model.
  A) Estimate the maximum or minimum potential ENPV values for the infrastructure projects P1,k including the options attributes of subsequent investment opportunities.
  B) According to the specific options presence, perform pairwise comparisons for the estimation of intangible factors mainly resulting from ROs thinking.
- Perform sensitivity analysis to understand the contribution of each factor.

In order to ultimately prioritize the portfolio, the projects have to be arranged based on their total ICT utility factor. While Angelou and Economides (2008) do not mention this as a separate step in the method, but perform the calculation of the overall ICT utility factor in the application of ROAHP, I added this as sixth step to the methodology to ensure all steps are present in the explanation of the method:

- Calculate overall ICT utility factor of each project

The structure of the decision analysis method therefore consists of 6 steps: 1) portfolio recognition, 2) project interdependencies identification, 3) options identification, 4) cost-benefit analysis, A) ENPV

calculation and B) intangible factors estimation, 5) factor sensitivity analysis and 6) ICT utility factor calculation (see figure 2). The idea is to prioritize the initial project *k* on which the other projects are based. Using tangible and intangible factors as criteria the best initial project can then be found. Angelou and Economides (2008) describe two tangible and six intangible factors in their article but any factor that the user might find relevant can be included.

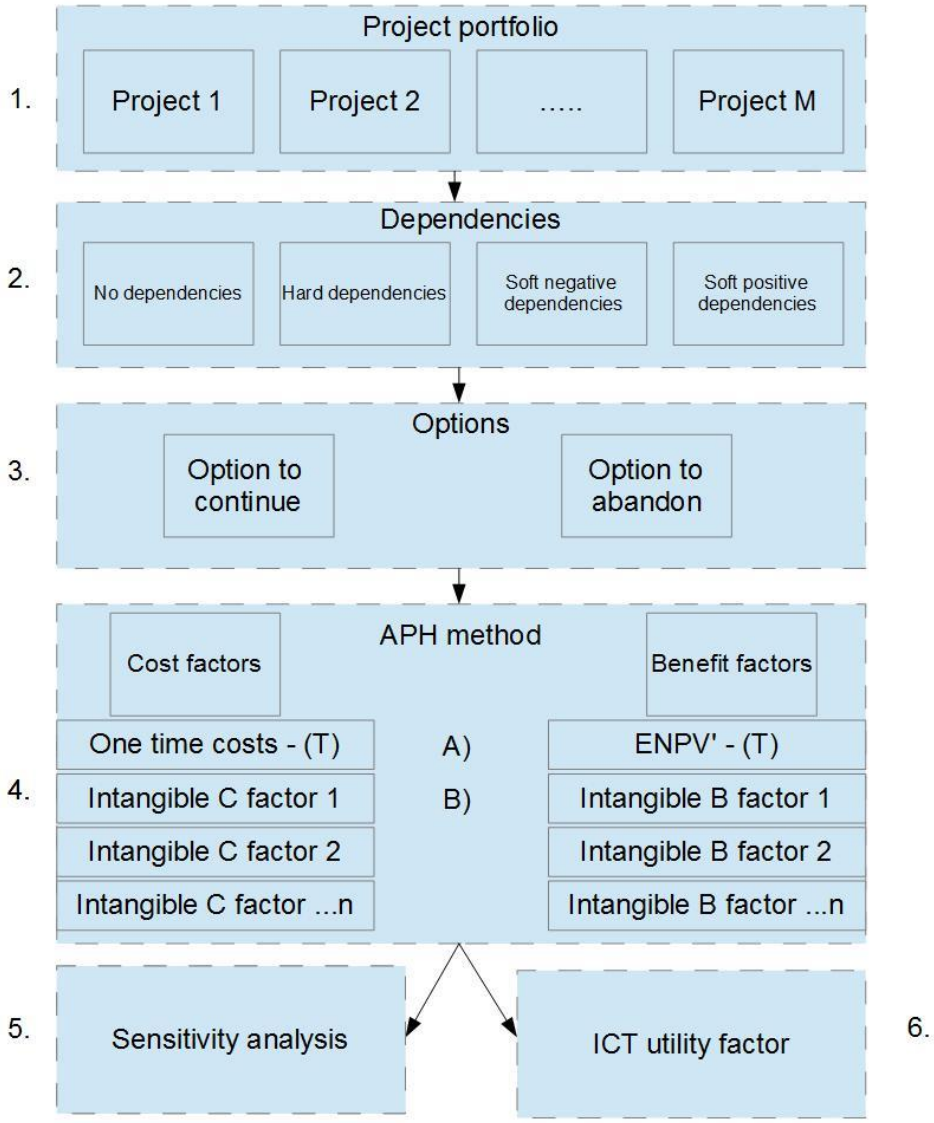


Figure 2. The 6 steps of the adapted ROAHP method

3 Methodology

The goal of this paper is to study the usability, strengths and weaknesses of a MCDA approach for making IT investment decisions, and in particular the ROAHP model presented by Angelou & Economides (2008), according to decision makers in real-life. For this goal the following research questions have been formulated:

- ***What is the usability of a normative decision making model for the IT-investment decision makers?***
- ***What do IT-investment decision makers think of ROAHP's strengths and weaknesses as a tool to increase the quality of IT-investment decision making?***
- ***How do IT-investment decision makers think the IT-investment decision making process in their organization can benefit from ROAHP***?

To answer these questions a preliminary interview was held to gather qualitative information about ROAHP's usability, strengths and weaknesses and how it could benefit the current decision making routines within the organization. This qualitative information is used to formulate statements about ROAHP, which will be used to conduct a survey to collect opinions of CIO's on ROAHP. In order to gather as much results as possible, and thus to minimize the amount of effort required to answer the survey, a quantitative approach was chosen to collect the CIO's opinions. This quantitative survey consists of the J. W. Dean, Jr. and Sharfman (1996) scales, an explanation of ROAHP and statements paired with a 7-point Likert-type scale to rate the agreement with these statements.

In the next section the preliminary interview is described and the results are shown. Next, the formulation of the survey based on this preliminary interview is presented.

3.1 Preliminary Interview

The goal of the preliminary interview is gather opinions of IT-investment decision makers in a qualitative manner, in order to formulate statements about ROAHP's usability, strengths and weaknesses and how it could benefit the current decision making routines within the organization. These statements will be used in the survey to quantitatively gather opinions of CIO's on ROAHP.

3.1.1 Description

To let participants of the interview evaluate ROAHP as a solution for issues in their decision making process, an illustrative case of ROAHP is presented and an exploratory open interview structure is used to receive their opinions. This structure is useful as the relevant criteria for measuring decision makers' evaluation of a method such as ROAHP are not yet known (Creswell, 2013). Using a mix of a small survey and open interview questions, participants will at first be introduced to the topic and asked to answer the questions corresponding to the scales (for procedural rationality and political behaviour) of J. W. Dean, Jr. and Sharfman (1996). The answers to these questions will create a profile of the strategic decision making process in an organization. These scales (see Appendix A) were both developed specifically for their research: to measure procedural rationality and political behaviour in strategic decision making. All items that did not correlate well with the scale were dropped and the result was five items for procedural rationality ($\alpha = .80$) and four for political behaviour ($\alpha = .66$) (see table 4). In order to calculate the value of each construct for each organization, the item means are calculated and will then be summed. In order to compare both scales, the scale scores are divided by the total number of items per construct. All items have the same relative weight.

Political behaviour items	Procedural rationality items
Individual vs. organizational goals	Use of analysis
Open about preferences	Information search
Use of negotiation	Quantitative methods
Use of power	Intuitive vs. analytic
	Information focusing

Table 4: Items used in the scales as presented by J. W. Dean, Jr. and Sharfman (1996)

By comparing both scales, the strategic decision making process can be profiled as either mainly political or mainly rationalistic. This profile can then be used to identify possible missed opportunities within the organization. An organization with a profile that has political behaviour as dominating characteristic has the opportunity to become more rationalistic, and therefore has an opportunity to improve the quality of the decision making process. In order to examine the selection phase of the decision making process the participants are asked about their organization's selection routines (as described by Mintzberg et al. (1976)).

Using a mix of a small survey and open interview questions, participants will at first be introduced to the topic and asked to answer the MC questions corresponding to the scale of J. W. Dean, Jr. and Sharfman (1996). Next, they are asked to answer the following open questions about their decision making routines:

1. When given a situation in which a strategic decision should be made, how does your organization select possible feasible solutions? (screen routine)

2. How does your organization evaluate each solution? (evaluation-choice routine)

3. How is authority gained for ultimately making the decision? (authorization routine)

4. Do you recognize any problems with your current strategic decision making process? - Describe the problems per routine (screen, evaluation-choice and authorization).

Next, participants are given an introduction and explanation of ROAHP per step of the adapted method (see appendix B for the full description of the method as explained to the participants). Participants were then asked the following questions about the method:

1. What do you think is of importance in order to make the use of the described method feasible?
2. What are potential strengths and/or weaknesses of the described method?
3. Of the aforementioned routines, which (one) could benefit from the use of the presented model?

3.1.2 Results

In order to produce valid results, a prerequisite is that the people interviewed should possess enough knowledge about the strategic decision making process within their organization. Another prerequisite is that the organizations must be mature enough to engage in some form of portfolio management. The data was gathered by visiting three organizations and asking a mix of survey and open interview questions to IT-portfolio managers, closely involved in the IT-investment decision making process in their organization. A total of 5 organizations had agreed to participate, but only three could make time within the scheduled timeframe. All three organizations are commercial organizations with a yearly gross revenue of at least €500 million and/or an IT budget of at least €25 million. The names of the organizations have been changed for the sake of confidentiality. The first organization is a large brewing company founded in the Netherlands, which we will refer to as "Beer". The second organization is a Dutch airport company, named "Airplane" and the last organization is a manufacturer of confectionary and gum, which we will call "Candy". The questions and answers about ROAHP will now be discussed and the statements derived from the answers will be presented (see table 5 for an overview of the answers).

The first question about the method is:

"What do you think is of importance in order to make the use of the described method feasible?"

Both Beer and Airplane stressed the importance of the acceptation of the method by stakeholders. Candy mentioned that the benefits of the method must be clear, while Beer stated that there must be a proof of concept. This resulted in the following two statements:

Statement 1: *"In order for this method to work, the business stakeholders have to accept it"*

Statement 2: *"The benefits of this model must be clear"*

All three organizations agreed that the method must be not be too much effort and easy to perform. Beer and Airplane also mentioned that it should be easy to explain the method. This resulted in the next two statements:

Statement 3: *"The method must be easy to explain"*

Statement 4: *"The method must be easy to perform"*

Airplane explained that it was very important that the data needed for the method must already be available and no additional data has to be collected.

Statement 5: *"The data needed for this method must already be available"*

Furthermore, both Beer and Airplane said that the model, and especially the results must be presented in a visually attractive manner.

Statement 6*: "The results of the analysis must be presented in a visually attractive manner"*

Beer and Candy also mentioned organizational requirements that could be important in order to make the use of this method feasible. These answers are not used because these are requirements for the organization, not the method itself, and are therefore not within the scope of this research.

The second question about the method is:

"What are potential strengths and/or weaknesses of the described method?"

All three organizations mentioned several strengths and/or weaknesses and this resulted in 5 statements about the strengths of ROAHP and 4 about the weaknesses (see table 5 for an overview of the strengths and weaknesses mentioned):

Statement 7: *"A potential strength of this method is that it can quantify intangible factors"*

Statement 8: *"A potential strength of this method is that it helps to identify the interdependencies between projects within the portfolio"*

Statement 9: *"A potential strength of this method is that it can compare tangible and intangible factors and weigh their importance relative to each other"*

Statement 10: *"A potential strength of this method is that it provides a clear prioritization of projects"*

Statement 11: *"A potential strength of this method is that it can help improve the quality of decisions"*

Statement 12: "*The method is too theoretical, it will not work in real life decision making"*

Statement 13: "*The method is too much of an administrative burden"*

Statement 14: "*There is too much information to deal with to make use of this method"*

Statement 15: "*The benefits of the method are not clear"*

The last question is about how current decision making routines could benefit from ROAHP:

"Of the aforementioned routines, which (one) could benefit from the use of the presented model?"

Airplane and Candy both said that the screen routine could benefit from ROAHP, as it could help decrease the initial amount of potential projects.

Statement 16: *"The method can potentially help with decreasing the initial amount of potential projects"*

All three organiziations believed the evaluation choice routine could benefit from ROAHP. Beer added that only the highest management layer would benefit from this and Candy thought it would help increase the transparency of the portfolio. The evaluation choice routine consists of evaluating the selected alternatives and making a prioritization based on this evaluation. Therefore, the following two statements have been added:

Statement 17: *"The method can potentially help me with comparing the costs and benefits of different projects"*

Statement 18: *"The method can potentially help me prioritize projects within a portfolio of projects"*

These 18 statements about ROAHP are used to formulate a survey to quantitatively collect opinons of CIO's on ROAHP. In the next paragraph a description of this survey is presented.

	Beer	**Airplane**	**Candy**	**Statement**
Strength	It can quantify intangible factors	Ability to calculate intangible factors		A potential strength of this method is that it can quantify intangible factors
Strength		It shows the interdependencies between projects		A potential strength of this method is that it helps to identify the interdependencies between projects within the portfolio
Strength		Ability to calculate tangible factors and the weighting of the criteria		A potential strength of this method is that it can compare tangible and intangible factors and weigh their importance relative to each other
Strength			It provides a clear prioritization of projects	A potential strength of this method is that it provides a clear prioritization of projects
Strength				A potential strength of this method is that it can help improve the quality of decisions
Weakness			The benefit calculation is too theoretical, this is	The method is too theoretical, it will not

			not feasible in practice	work in real life decision making
	Beer	**Airplane**	**Candy**	**Statement**
Weakness		This method can be too much of an administrative burden		The method is too much of an administrative burden
Weakness	There is too much information to deal with			There is too much information to deal with to make use of this method
Weakness			Benefits must be clear, this is very hard and therefore a potential weakness	The benefits of the method are not clear

Table 5: Strengths and weaknesses of ROAHP

3.2 Survey

The goal of the survey is to study the practical usability of ROAHP, according to IT-investment decision makers. In the preliminary interview opinions on ROAHP were collected and 18 opinion statements were formulated. In order to check whether the CIO understood the explanation of the method a fifth category was added: 'understanding of the method'. This makes for a total of 20 statements (see table 7 for an overview): 2 statements about the understanding of ROAHP, 6 statements about prerequisites to make ROAHP usable, 5 statements about the strengths and 4 statements about the weaknesses of ROAHP, and 3 statements about how their current decision making routines could benefit from ROAHP (see table 6).

In order to put these opinions in organizational context, CIO's are first questioned about about the decision making process in their organization using the items from the scale of J. W. Dean, Jr. and Sharfman (1996)(see table 2 and 3 for the questions). Next, the CIO's were presented an explanation of ROAHP (see Appendix B for a full description) asked to rate the statements on a 7-point Likert-type scale (see table 5), ranging from 1 (strongly disagree) to 7 (strongly agree).

Likert-type item	Strongly disagree	Disagree	Mildly Disagree	Neutral	Mildly agree	Agree	Strongly agree
Score	1	2	3	4	5	6	7

Table 6: Likert-type scale

Question	Response	Category
Q1. The explanation of the method is clear to me	(1 = not at all, 7 = completely)	Understanding of method
Q2. I understand what problem the method is trying to solve	(1 = not at all, 7 = completely)	Understanding of method
Q3. In order for this method to work, the business stakeholders have to accept it	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q4. The benefits of this model must be clear	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q5. The method must be easy to explain	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q6. The method must be easy to perform	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q7. The data needed for this method must already be available	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q8. The results of the analysis must be presented in a visually attractive manner	(1 = strongly disagree, 7 = strongly agree)	Prerequisite to make the model usable
Q9. A potential strength of this method is that it can quantify intangible factors	(1 = strongly disagree, 7 = strongly agree)	Potential strength
Q10. A potential strength of this method is that it helps to identify the interdependencies between projects within the portfolio	(1 = strongly disagree, 7 = strongly agree)	Potential strength
Q11. A potential strength of this method is that it can compare tangible and intangible factors and weigh their importance relative to each other	(1 = strongly disagree, 7 = strongly agree)	Potential strength
Q12. A potential strength of this method is that it provides a clear prioritization of projects	(1 = strongly disagree, 7 = strongly agree)	Potential strength
Q13. A potential strength of this method is that it can help improve the quality of decisions	(1 = strongly disagree, 7 = strongly agree)	Potential strength

Q14. The method is too theoretical, it will not work in real life decision making	(1 = strongly disagree, 7 = strongly agree)	Potential weakness
Q15. The method is too much of an administrative burden	(1 = strongly disagree, 7 = strongly agree)	Potential weakness
Q16. There is too much information to deal with to make use of this method	(1 = strongly disagree, 7 = strongly agree)	Potential weakness
Q17. The benefits of the method are not clear	(1 = strongly disagree, 7 = strongly agree)	Potential weakness
Q18. The method can potentially help with decreasing the initial amount of potential projects	(1 = strongly disagree, 7 = strongly agree)	Benefit to current routines
Q19. The method can potentially help me with comparing the costs and benefits of different projects	(1 = strongly disagree, 7 = strongly agree)	Benefit to current routines
Q20. The method can potentially help me prioritize projects within a portfolio of projects	(1 = strongly disagree, 7 = strongly agree)	Benefit to current routines

Table 7: Questions about ROAHP

4 Results

This chapter presents the results and analysis of the gathered data. Survey data was gathered by sending out online surveys to 106 CIO's operating within the Netherlands. The survey was completed by 15 CIO's (N = 15), whose responses have been anonymized for the sake of confidentiality, resulting in a response rate of 14%. A total of 26 CIO's actually responded to the survey, however, only 15 surveys were answered and usable. The reason for this low response rate is unknown, but it can probably be partially explained by the fact that the role of CIO can be very time-consuming and, even though confidentiality was guaranteed, the fact that some organizations consider insight on their decision making process confidential and therefore do not wish to share this information.

4.1 Strategic decision making process

In order to calculate the value of each construct for each organization, the J. W. Dean, Jr. and Sharfman (1996) item means are calculated and are summed. In order to compare both scales, the scale scores are divided by the total number of items per construct, 5 and 4 for procedural rationality and political behaviour respectively (see table 8). The strategic decision making process in the majority of organizations (60%) is mainly driven by procedural rationality and, logically, in 40% of the organizations driven by political behaviour. In order to classify each decision making process, the Likert-type item scores have been divided in two categories: 1) low, a score between 1 and 4, and 2) high, a score between 4 and 7. This means there are four possible combinations of politics and procedural rationality (high politics/low rationality, high politics/high rationality, low politics/high rationality and low politics/low rationality). It is noteworthy that almost all (14 out of 15) strategic decision making processes of the organizations scored high in both procedural rationality and political behaviour.

Organization	Procedural rationality	Political behaviour	Type of strategic decision making process (rationality/politics)
1	4,4	2	high/low
2	5	5,5	high/high
3	5,4	4,75	high/high
4	4,4	4,75	high/high
5	4,4	4,75	high/high
6	6	4,75	high/high
7	4,8	5,5	high/high
8	4,6	4,5	high/high
9	4,8	5	high/high
10	5,6	4,75	high/high
11	5,6	4,25	high/high
12	5	4,75	high/high
13	5,4	4,5	high/high
14	4,8	5	high/high
15	4,8	4,5	high/high
Mean	5	4.62	high/high

Table 8: Results of the J. W. Dean, Jr. and Sharfman (1996) items

4.2 Results of ROAHP items

In this paragraph the results of the items about ROAHP are discussed per category of items (see Appendix D for a full overview of the results). The first two statements after the explanation of ROAHP are about the understanding of the method. While 12 CIO's (80%) either agree or mildly agree that the explanation was clear, two CIO's indicate that they thought the explanation of the method wasn't clear. Most CIO's did understand what problem the method was trying to solve and 80% either agreed or strongly agreed with this statement. It can be concluded that the explanation and intention of the method was understood by the majority of CIO's. This validates the assumption that CIO's understand the method and are able to answer the questions in the other four categories.

	The explanation of the method is clear to me	I understand what problem the method is trying to solve
Strongly disagree	0,0%	0,0%
Disagree	0,0%	0,0%
Mildly disagree	13,3%	6,7%
Neutral	6,7%	6,7%
Mildly agree	33,3%	6,7%
Agree	46,7%	46,7%
Strongly agree	0,0%	33,3%

Table 9: The understanding of ROAHP

The following statements are about prerequisites to make ROAHP usable. Almost all CIO's (93,3%) agreed that, in order to make ROAHP work, the business stakeholders have to accept it. One CIO mildly disagreed with this statement. This CIO also did not agree with the statement that the method must be easy to perform or that the results must be presented in a visually attractive manner. The other CIO's were in agreement about almost all statements (see table 10).

	In order for this method to work, the business stakeholders have to accept it	The benefits of this model must be clear	The method must be easy to explain	The method must be easy to perform	The data needed for this method must already be available	The results of the analysis must be presented in a visually attractive manner
Strongly disagree	0,0%	0,0%	0,0%	0,0%	0,0%	6,7%
Disagree	0,0%	0,0%	0,0%	6,7%	0,0%	0,0%
Mildly disagree	6,7%	0,0%	0,0%	0,0%	13,3%	0,0%
Neutral	0,0%	0,0%	6,7%	6,7%	13,3%	0,0%
Mildly agree	13,3%	13,3%	13,3%	20,0%	26,7%	0,0%
Agree	33,3%	40,0%	46,7%	40,0%	33,3%	53,3%
Strongly agree	46,7%	46,7%	33,3%	26,7%	13,3%	40,0%

Table 10: Prerequisites to make ROAHP usable

Multiple strengths of ROAHP were mentioned in the interview and received agreement by the majority of CIO's in the survey (see table 11), while the statements about the weaknesses received less

agreement. The opinions on the weaknesses of ROAHP are divided (see table 12). More CIO's disagreed than agreed with the statement about ROAHP being too much of an administrative burden (46,7% against 40%, respectively). The statement about whether there is too much information to deal with to make use of the method was agreed upon by 40% of the CIO's, while 33,3% have a neutral opinion on the matter.

	A potential strength of this method is that it can quantify intangible factors	A potential strength of this method is that it helps to identify the interdependencies between projects within the portfolio	A potential strength of this method is that it can compare tangible and intangible factors and weigh their importance relative to each other	A potential strength of this method is that it provides a clear prioritization of projects	A potential strength of this method is that it can help improve the quality of decisions
Strongly disagree	6,7%	6,7%	0,0%	0,0%	0,0%
Disagree	0,0%	0,0%	0,0%	6,7%	13,3%
Mildly disagree	0,0%	6,7%	0,0%	0,0%	0,0%
Neutral	20,0%	6,7%	13,3%	6,7%	13,3%
Mildly agree	20,0%	20,0%	26,7%	40,0%	26,7%
Agree	40,0%	40,0%	40,0%	46,7%	26,7%
Strongly agree	13,3%	20,0%	20,0%	0,0%	20,0%

Table 11: Strengths of ROAHP

The results show that 86,7% of the CIO's think that ROAHP can help them with comparing the costs and benefits of projects. The majority of CIO's (53,4%) also think that ROAHP can decrease the amount of initial amount of potential projects but 26,7% either disagrees or strongly disagrees with this statement. 73,3% indicate that ROAHP can potentially help to prioritize projects within a portfolio of projects.

	The method is too theoretical, it will not work in real life decision making	The method is too much of an administrative burden	There is too much information to deal with to make use of this method	The benefits of the method are not clear
Strongly disagree	0,0%	0,0%	0,0%	13,3%
Disagree	6,7%	20,0%	13,3%	46,7%
Mildly disagree	20,0%	26,7%	13,3%	13,3%
Neutral	26,7%	13,3%	33,3%	13,3%
Mildly agree	33,3%	40,0%	26,7%	6,7%
Agree	6,7%	0,0%	13,3%	6,7%
Strongly agree	6,7%	0,0%	0,0%	0,0%

Table 12: Weaknesses of ROAHP

	The method can potentially help with decreasing the initial amount of potential projects	The method can potentially help me with comparing the costs and benefits of different projects	The method can potentially help me prioritize projects within a portfolio of projects
Strongly disagree	6,7%	0,0%	0,0%
Disagree	20,0%	13,3%	13,3%
Mildly disagree	0,0%	0,0%	6,7%
Neutral	20,0%	0,0%	6,7%
Mildly agree	20,0%	46,7%	40,0%
Agree	26,7%	40,0%	13,3%
Strongly agree	6,7%	0,0%	20,0%

Table 13: Benefit to current decision making routines

In the next chapter, these results will be discussed and interpreted.

5 Discussion

This chapter presents a discussion of the results in order to interpret and describe the significance and implications of the findings in this research. In the beginning of this paper I argue that current research on normative models for IT-investment decision making lacks a focus on the usability for the end-users: IT-investment decision makers.

The results indicate that political behaviour is almost equally apparent as rationality in the decision making process of almost all large organizations. Literature shows substantial evidence that, within a strategic decision making process, political behaviour is negatively related and rationality is positive related to organizational performance. This shows a potential for organizations to improve their decision making process by finding a better balance between their political behaviour and rationality in their IT-investment decision making process.

Results of this study show that IT-investment decision makers are open to new ways, such as an MCDA approach, for valuating IT-investments. CIO's recognize the potential of ROAHP to increase the quality of their current routines of their decision making process by decreasing the amount of potential projects, comparing the costs and benefits of individual projects and prioritizing projects within a portfolio of projects. Furthermore, IT-investment decision makers recognize the benefits of ROAHP. In fact, CIO's were quite positive about ROAHP. The method's potential to quantify intangible factors and the ability to compare these with tangible factors, the ability to identify interdependencies between projects within a portfolio of projects and the potential to provide a clear prioritization of projects are seen as strengths of ROAHP. While this shows that CIO's are not concerned about the validity of ROAHP, results from the preliminary interviews and the survey show that there is agreement among CIO's about prerequisites that are essential to make ROAHP usable in practice. All CIO's agreed with the prerequisite that the benefits of the method must be clear. Furthermore, the business stakeholders have to accept the method and therefore the method must be easy to explain, easy to perform, the data required for the method should be available and the results should be presented in a visually attractive manner. Opinions on the

potential weaknesses of ROAHP are less strong, but a considerable amount of CIO's agreed that ROAHP is too theoretical and that it will not work in practice. This shows that, even though CIO's believe that the method has the potential to increase the quality of decision making in their organization, they are still concerned about it being too theoretical to use in practice. Angelou and Economides (2008) state that ROAHP "provides a better understanding of interdependencies and various intangible factors of projects extracted by the ROs analysis, enabling these projects to be valued and prioritized with higher accuracy". The results of this research reveal a gap between theory and practice. CIO's, the end-users of ROAHP, do not doubt the potential benefits of the method, given it meets the prerequisites mentioned earlier.

To answer the key research question of this paper: I argue that ROAHP does not meet these prerequisites and, while this is open for debate, is thus not easy enough to explain, to perform and the data required is often not available. ROAHP requires a significant amount of mathematical know-how and data about costs and benefits, and dependencies between projects that are often not known and this impedes the practical usability of a normative model such as ROAHP.

6 Conclusions and future research

The goal of this paper is to study the practical usability, strengths and weaknesses of an MCDA approach for making IT investment decisions, and in particular the ROAHP model presented by Angelou & Economides (2008), according to IT-investment decision makers. Based on the findings of this research, it can be concluded that there is consensus among IT-investment decision makers on the potential of an MCDA approach to increase the quality of IT-investment decisions. Most CIO's recognized ROAHP's ability to improve the quality of decisions by being able to quantify intangible factors, identify interdependencies between projects within a portfolio of projects, the ability to compare tangible and intangible factors, weigh their relative importance and to provide a clear prioritization of projects. But in order to make the method usable in practice, CIO's agree that certain prerequisites need to be met in order to make ROAHP usable in practice: the benefits of the method must be clear, stakeholders have to accept the method, it must be easy to explain, easy to perform, the data required for the method must be available and the results must be presented in a visually attractive manner. There is less consensus among CIO's about the weaknesses of ROAHP. Some CIO's agreed that ROAHP is too theoretical and that there is too much information to deal with in order to use the method in practice, while almost equal numbers disagreed.

The limitations of this study do present opportunities for further research. Results of this study show that CIO's agree on certain prerequisites for making ROAHP usable in practice, but do not give insight on the relative importance of these prerequisites. Another limitation is the explanation of the method presented to CIO's. While most of the CIO's answered that they understand ROAHP, a more detailed explanation and in-depth case study would make sure a CIO fully understands the theory of ROAHP and how to use it.

While current research on normative models for IT-investment focuses on the validity and accuracy of the model, this study shows the end-users are already convinced of the potential of these methods. However, the use of normative models is still not widespread because they are not found usable in

practice. This study shows a need for change in research on normative models for IT-investment decision making and, given these observations, IT-investment decision making research is ready to shift its attention to the end-users.

Appendix A

Rationality

1. How extensively did the group look for information in making this decision? (1= not at all, 7 = extensively)
2. How extensively did the group analyse relevant information before making a decision? (1= not at all, 7 = extensively)
3. How important were quantitative analytic techniques in making the decision? (1 = not at all important, 7 = very important)
4. How would you describe the process that had the most influence on the group's decision? (1 = mostly analytical, 7 = mostly intuitive)
5. In general how effective was the group at focussing its attention on crucial information and ignoring irrelevant information? (1 = not at all effective, 7 = very effective)

Political behaviour

1. Were group members primarily concerned with their own goals, or with the goals of the organization? (1 = own goals completely, 7 = organizational goals completely)
2. To what extent were people open with each other about their interests and preferences in the decision? (1 = not at all, 7 = completely)
3. To what extent was the decision affected by the use of power and influence among group members? (1 = not at all, 7 = completely)
4. To what extent was the decision affected by negotiation among group members? (1 = not at all, 7 = completely)

Appendix B

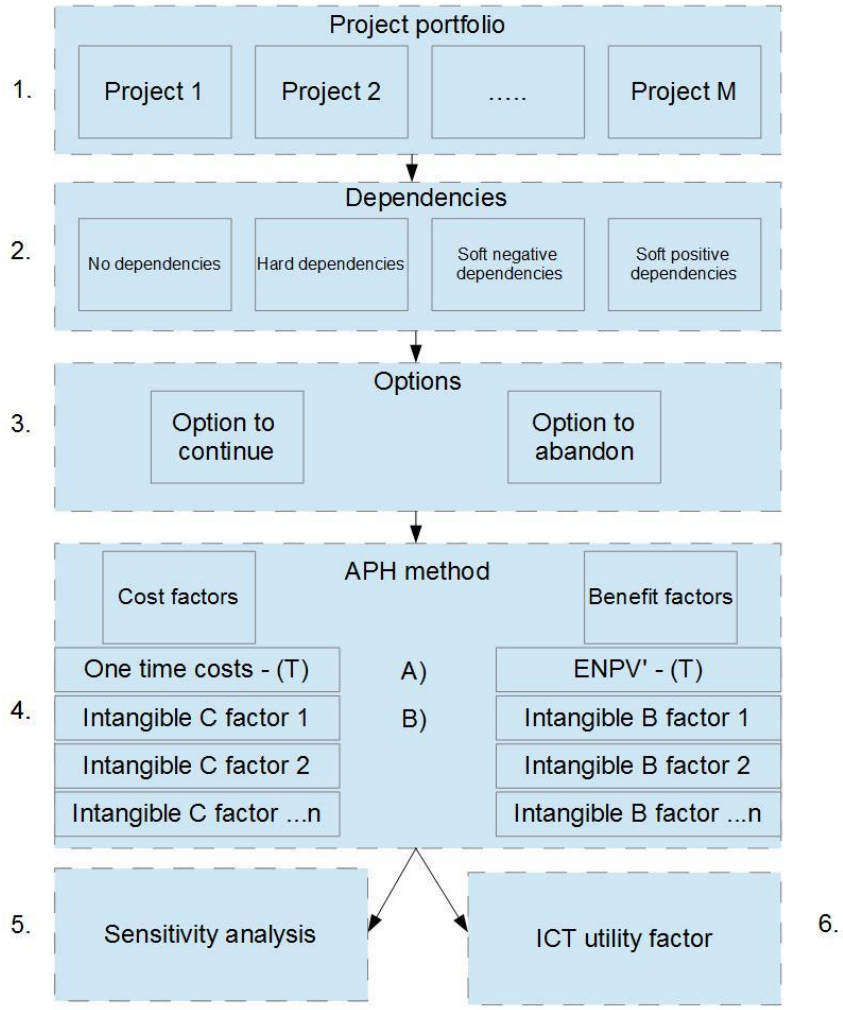
Description of the ROAHP method:

The inadequacy of traditional quantitative cost-benefit analysis for evaluating investment in business projects with an IT component have led researchers to suggest real options (RO) analysis for valuating ICT projects. However, RO models are strictly quantitative and often, ICT investments may contain qualitative factors that cannot be quantified in monetary terms. In addition, RO analysis results in some factors that can be treated more efficiently when taken qualitatively. Real Options Analytical Hierarchy Process is a suggested method that combines RO and the analytical hierarchy process into a combined multiobjective, multicriteria model for prioritizing a portfolio of interdependent ICT investments. If you follow this method for your portfolio of projects it will produce a ranking of all the projects according to the criteria you find important and how important you believe they are.

Next, a basic introduction to the method. The method follows the following steps for performing a prioritization of projects within a portfolio:

1. Define all (potential) projects in your portfolio
2. Define all dependencies between the projects (e.g. project A enables project B)
3. Define all options (e.g. option to continue the project or abandon)
4. Weigh all decision criteria that you find relevant for the decision, relative to each other. You can do this by following a method called Analytical Hierarchy Process (AHP). AHP software makes you rate the relative importance of each criterion compared to the other criteria. Do this for all criteria. Next, determine the value of all criteria per project.
5. Perform a sensitivity analysis of each criterion (the AHP software can do this for you). This is an indicator of how much each criterion influences the final ‘score’ of each project.

6. Calculate the ICT utility factor. This is done based on the dependencies, options and cost and benefit factors. All projects get an ICT utility factor and the ranking is based on this final 'score'.



Appendix C

Beer

Question	Answer	Notes
Strategic decision	Deciding on the year project portfolio	
MC. 1	3	
MC. 2	5	Only cost analysis
MC. 3	1	
MC. 4	6	
MC. 5	4	
MC. 6	5	Investing in common goals
MC. 7	3	
MC. 8	6	
MC. 9	5	
RQ. 1	-List of ideas that are gathered -A strategic direction is determined -Budget is determined, based on history and knowledge and intuition -These ideas are tested against the strategic direction and budget constraints (testing happens by consultation and analysis -Projects are improved and finalized -Overview of projects + advise about bottlenecks of each project is presented to the board	
RQ. 2	Evaluation consists of testing the project against the strategic	

	pillars, budget constraints (quantitative) and a qualitative benefits analysis	
RQ. 3	Department idea -> business owner -> board	
RQ. 4	**Screen:** No issues recognized here **Evaluation-choice:** -History, budgets and costs -Too much sub portfolios and budgets, no overall optimization -Not rational enough, relying too much on intuition and no qualitative analysis of benefits Authorization: No issues either	
MQ. 1	-The method must be easily explainable. It is important that it can be explained in Laymen's terms for the board. -It must not become too much of an administrative burden. -It should not be too much effort -It should provide better insights -The model and the results must be presented in a visually attractive manner -A proof of concept is very important in order to get the business stakeholders to accept this -The organization must be mature enough to make use of such a model	

MQ. 2	**Strength(s):** -A strength of this method is that it can quantify intangible factors **Weakness(es):** -Too much information to deal with -This is hard to keep simple	
MQ. 3	**Evaluation choice routine:** -Only the highest management layer will benefit.	

Airplane

Question	Answer	Notes
Strategic decision	Investing in a 'Digital Airport Program'	
MC. 1	5	Mainly the IT-Architects
MC. 2	5	Technical feasibility
MC. 3	1	Just budget constraints
MC. 4	6	
MC. 5	4	
MC. 6	3	
MC. 7	3	
MC. 8	4	
MC. 9	2	
RQ. 1	-Defining strategy -Every business domain has an information manager, requests information needs -Business information plan	

	-Sub portfolio is defined
RQ. 2	-Business information management defines a mandate -Costs, benefits and scope are defined -Architects tests projects on those -Delivery -Prince2 processes
RQ. 3	Subdomain -> domain director -> board
RQ. 4	**Evaluation choice routine:** -Stakeholder management -Missing information -No real benefit management -Politics interfering
MQ. 1	-It is important that business stakeholders accept this model. -It must be easy to explain -The data required for this model must already be available -It must be presented in a visually attractive manner -It must be easy to perform
MQ. 2	**Strength(s):** -Ability to calculate intangible factors -It shows the interdependencies between projects -It has the capacity to deal with a lot of information -The weighting of the criteria **Weakness(es):**

	-This method can be too much of an administrative effort -Resistance against models	
MQ 3	**Screen routine:** -It can help to reduce the initial amount of potential projects **Evaluation choice routine:** -Comparison of projects -Provides a high level selection method -The information provided by this model give something to discuss **Authorization:** -The information provided by this model give something to discuss	

Candy

Question	Answer	Notes
Strategic decision	Investing in a tool for a distance selling information system including food labels	
MC. 1	7	
MC. 2	3	Qualitative
MC. 3	1	'Gut feeling'
MC. 4	6	IT-project
MC. 5	3	
MC. 6	6	Clear
MC. 7	6	
MC. 8	6	Capacity constraint as determiner for priority
MC. 9	2	
RQ. 1	-Describing or designing the process -Requirements from IT and Business -Look for solutions that meet the requirements -Look for information at suppliers of a solution	
RQ. 2	-Must meet requirements -Feasibility study -Deliberation between the people involved -Costs are important and are analysed (must not exceed budget) -Benefits are not measured	

RQ. 3	-Depending on the size of the project (in money or importance) -Local (finance, general manager and IT manager) -> Business unit management (the VP and controller) -> Group Board -> (Owner)	
RQ. 4	**-Authorization** -Not clear who has authority about projects under €50.000 **-Evaluation-choice** -Benefit management hard to realise **-Screen** -More structured feasibility study, perhaps a template or guidelines	
MQ. 1	-The benefits of this model must be clear -It has to be practical to work with -Culture change: cancelling projects based on the option theory would cause loss of face, this is very unlikely in the culture of this organization.	
MQ. 2	**Strength(s):** -It increases awareness and transparency about the portfolio -Gives a clear prioritization of projects **Weakness(es):** -Benefit calculation is too theoretical, this is not feasible in practice	

	-Benefits must be clear, this is very hard and therefore a potential weakness	
MQ. 3	**Screen routine:** -It can help to reduce the initial 'pile' of projects by funnelling **Evaluation choice routine:** -It can help to increase the transparency **Authorization:** -Not a lot of effects found	

Appendix D

Organization	Mean	Std. Deviation	N
1	5,10	1,37267	20
2	5,35	1,46089	20
3	5,30	1,97617	20
4	5,20	0,69585	20
5	5,45	0,99868	20
6	5,80	1,73509	20
7	3,90	2,17401	20
8	5,00	2,12751	20
9	4,95	1,09904	20
10	4,75	1,37171	20
11	5,20	1,60918	20
12	5,10	0,85224	20
13	4,50	1,87785	20
14	5,50	1,14708	20
15	5,60	1,31389	20

Table X: Means of ROAHP questions per organization

Statement	Mean	Std. Deviation	N
1	5,13	1,060	15
2	5,93	1,163	15
3	6,13	1,125	15
4	6,33	0,724	15
5	6,07	0,884	15
6	5,67	1,345	15
7	5,20	1,265	15
8	6,07	1,486	15
9	5,20	1,521	15
10	5,33	1,633	15
11	5,67	0,976	15
12	5,20	1,082	15
13	5,13	1,598	15
14	4,33	1,291	15
15	3,73	1,223	15
16	4,13	1,246	15
17	2,73	1,438	15
18	4,33	1,839	15
19	5,00	1,309	15
20	4,93	1,624	15

Table X: Means of ROAHP questions per statement

Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Organization																				
1	5	6	6	6	6	6	6	7	5	6	6	5	4	5	3	5	2	2	6	5
2	6	6	7	6	5	6	6	7	6	6	6	6	6	4	3	2	2	5	6	6
3	6	6	7	7	7	7	5	6	1	7	7	5	6	3	3	2	2	6	6	7
4	5	5	5	6	6	6	6	6	6	5	6	5	5	5	5	4	4	4	5	5
5	6	6	6	6	6	6	7	6	6	6	5	6	6	5	5	3	3	5	5	5
6	5	7	7	7	7	7	3	7	7	7	7	5	7	5	4	4	1	7	5	7
7	3	7	3	7	4	2	3	1	4	1	6	6	2	7	5	6	1	2	6	2
8	5	7	7	7	7	5	5	7	7	6	7	6	7	4	3	3	2	1	2	2
9	6	6	5	5	6	4	7	7	4	3	4	4	4	5	5	6	4	5	5	4
10	3	3	7	7	5	7	5	6	4	4	4	5	5	4	2	4	6	4	5	5
11	6	7	6	6	6	6	6	6	6	6	6	6	6	3	2	4	2	2	6	6
12	6	6	6	5	6	5	4	6	5	5	5	6	5	4	4	5	3	6	5	5
13	4	4	7	7	7	7	6	6	6	5	5	2	2	2	2	4	5	4	2	3
14	6	6	7	7	7	5	5	7	5	6	5	5	5	6	5	5	2	6	5	5
15	5	7	6	6	6	6	4	6	6	7	6	6	7	3	5	5	2	6	6	7

Table X: Results of all ROAHP questions

References

Angelou, G. N., & Economides, A. A. (2008). A Decision Analysis Framework for Prioritizing a Portfolio of ICT Infrastructure Projects. *Engineering Management, IEEE Transactions on, 55*(3), 479-495. doi:10.1109/TEM.2008.922649

Baldridge, J. V. (1971). *Power and conflict in the university: Research in the sociology of complex organizations*. New York: John Wiley & Sons.

Bardhan, I., Sougstad, R., & Sougstad, R. (2004). Prioritizing a portfolio of information technology investment projects. *Journal of Management Information Systems, 21*(2), 33-60.

Benaroch, M., & Kauffman, R. J. (1999). A case for using real options pricing analysis to evaluate information technology project investments. *Information Systems Research, 10*(1), 70-86. doi:10.1287/isre.10.1.70

Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A Garbage Can Model of Organizational Choice. *Administrative Science Quarterly, 17*(1), 1-25. doi:10.2307/2392088

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, California: Sage publications.

Cyert, R. M., & March, J. G. (1963). A behavioral theory of the firm. *Englewood Cliffs, NJ, 2*.

Dean, J. W., Jr., & Sharfman, M. P. (1996). Does Decision Process Matter? A Study of Strategic Decision-Making Effectiveness. *The Academy of Management Journal, 39*(2), 368-396. doi:10.2307/256784

Dean, J. W., & Sharfman, M. P. (1993). The relationship between procedural rationality and political behavior in strategic decision making. *Decision Sciences, 24*(6), 1069-1083.

Eisenhardt, & Bourgeois. (1988). Politics of strategic decision making in high-velocity environments: Toward a midrange theory. *Academy of management journal, 31*(4), 737-770.

Eisenhardt, & Zbaracki. (1992). Strategic Decision-Making. *Strategic Management Journal, 13*, 17-37. doi:DOI 10.1002/smj.4250130904

Elbanna, S. (2006). Strategic decision-making: Process perspectives. *International Journal of Management Reviews, 8*(1), 1-20. doi:10.1111/j.1468-2370.2006.00118.x

Gandz, J., & Murray, V. V. (1980). The Experience of Workplace Politics. *The Academy of Management Journal, 23*(2), 237-251. Retrieved from http://www.jstor.org/stable/255429

Janis, I. L. (1982). *Groupthink: Psychological studies of policy decisions and fiascoes*: Houghton Mifflin Boston.

Jones, R. E., Jacobs, L. W., & van't Spijker, W. (1992). Strategic Decision Processes in International Firms. *MIR: Management International Review, 32*(3), 219-236. Retrieved from http://www.jstor.org/stable/40228105

Khatri, N., & Hunt, R. G. (1994). *Strategic decision processes and organisational performance*. Buffalo: State University of New York.

Kohli, R., & Grover, V. (2008). Business value of IT: an essay on expanding research directions to keep up with the times. *Journal of the association for information systems, 9*(1), 23-39.

Lindblom, C. E. (1959). The science of" muddling through". *Public administration review, 19*, 79-88.

Magjuka, R. (1988). Garbage can theory of decision making: A review. *Research in the Sociology of Organizations, 6*, 225-259.

Mintzberg, H., Raisinghani, D., & Théorêt, A. (1976). The Structure of "Unstructured" Decision Processes. *Administrative Science Quarterly, 21*(2), 246-275. doi:10.2307/2392045

Mueller, G. C., Mone, M. A., & Barker, V. L. (2000). *STRATEGIC DECISION MAKING AND PERFORMANCE: DECISION PROCESSES AND ENVIRONMENTAL EFFECTS*. Paper presented at the Academy of Management Proceedings.

Olsen, J. P. (1976). Choice in an organized anarchy. *Ambiguity and choice in organizations*, 82-139.

Papadakis, V. M. (1998). Strategic investment decision processes and organizational performance: an empirical examination. *British Journal of Management, 9*(2), 115-132.

Pettigrew, A. M. (1973). *The Politics of Organizational Decision-making*. London: Tavistock.

Pfeffer, J. (1992). *Managing with power: Politics and influence in organizations*. Boston, MA: Harvard Business Press.

Pfeffer, J., & Salancik, G. R. (1974). Organizational Decision Making as a Political Process: The Case of a University Budget. *Administrative Science Quarterly, 19*(2), 135-151. doi:10.2307/2393885

Pinfield, L. T. (1986). A field evaluation of perspectives on organizational decision making. *Administrative Science Quarterly*, 365-388.

Quinn, J. B. (1980). *Strategies for change: logical incrementalism*. Homewood, IL: R.D. Irwin.