Master Thesis for Business Administration

Making rational decisions about IT projects using Enterprise Architecture

A case study conducted at ASML Netherlands N.V.

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Title page

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"If you can't measure it, you can't manage it"

-- William Edwards Deming (1900-1993),

American statistician, professor, author, lecturer and consultant

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Eindhoven, February 2016

Nick Laarhuis

Management summary

IT has transformed from supporting single activities to providing landscapes in which multiple information systems support multiple activities and processes. A result is that IT has become increasingly interwoven with organizations. Many organizations still see IT as a cost center driven on efficiency instead of using the capabilities it offers to position themselves as business enablers.

One of the critical topics linked to this is IT valuation; *how exactly can organizations create business value from their IT investments?* Most organizations struggle with the complexity associated with IT investment decisions. Choices based on as many alternatives and criteria as possible would probably lead to the most convenient outcome. Such a pure rational approach is hardly possible in practice given that alternatives and criteria are not always available or clear to the decision-maker. In addition, people do not have the capacity to process the vast amount of information related to IT investments. A consequence is that decision-makers rely on less rational ways of decision-making and do not base their choices on complete information. This is mostly the moment when political processes pre-dominate the decision-making process. [redacted].

The literature research revealed that in order to create IT-based value from an IT investment, enterprise architecture is an important part of the solution. For the most part, IT investments do not create business value directly; they instead do so indirectly by enhancing processes. Enterprise architecture, and more specifically the modeling language of ArchiMate, offers organizations an opportunity to create a holistic overview of their organization and make the relations between the organizational goals, business processes and the supporting IT transparent.

While political processes are considered to have bad influences on organizational performance, it is necessary to achieve a better balance between rationality and political processes. Increasing rationality in the decision-making process can establish a better balance, but political processes can never be fully erased. As stated before, people are not purely rational given that they are limited by their reasoning capacity. This limitation does not preclude the enhancement of rationality by so-called “rationality carriers.” It is known that the complexity surrounding IT investments makes it eventually difficult to make well-informed and founded investment decisions.

We could thus try to eliminate parts of the complexity and simplify the process; alternatively we could also follow the approach of this thesis and keep the process as rational as possible by increasing the reasoning capacity of the decision-maker. Different methods to prioritize an IT investment portfolio are presented in this thesis. However, none of them fully meets all of the requirements. They provide us with a good direction to work in, but a new multi-criteria approach based on enterprise architecture is proposed.

In order to determine if the proposed method fulfills the expectations, it is tested in at ASML. The case study is two folded: it includes both semi-structured interviews and a practical application of the method. The interviews are split into two groups: people who should work with the method (prepare the decision) and people who should base their investment decisions on more comprehensive information provided through the proposed method. To add value to the practical application component of the study, a workshop with the participants of the former group was arranged.

The ASML case study revealed that the proposed method in this thesis has the ability to increase rationality in the decision-making process and thereby decrease the less rational parts (e.g. political processes). Following such a procedural rational approach has the ability to increase the quality of IT investment decisions. However, to maintain objectivity strict guidelines are necessary using the proposed method. The case reveals also that the proposed method requires a certain maturity level to be able to make decisions.

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1. Introduction

This chapter introduces the topic of this thesis, namely: prioritizing a portfolio of IT projects using enterprise architecture. The problem statement is first placed into a theoretical context (1.1); thereafter the *research goal* of this thesis and how it can be achieved by answering the *research questions* are presented (1.2). Then main theories and concepts from the *scientific literature* and the extent to which this research contributes to the literature base are also described. As this research is conducted with a *case study at ASML Netherlands N.V.*, an explanation of the *relevance* for this company is also provided (1.3). The *research method* used for this research is explained next (1.4), followed by the *scope* (1.5) and general structure of this thesis (1.6).

1.1 Problem statement

In the 1990s, IT started to become increasingly important for organizations. The serious expansion of IT from those early days until now has provided organizations with great potential to increase their performance. One of the critical issues over time has been: exactly how organizations can create business value from their IT investments (Mukhopadhyay, Kekre, & Kalathur, 1995).

In general, deciding what investments an organization should make can be a difficult task. When it comes to IT investments, it is even more difficult. This is related to the fact that the costs and benefits corresponding to IT investments are hard to both identify and quantify. In addition to the tangible factors, there are also significant intangible factors that influence these investments (Powell, 1992).

Kohli and Grover (2008) provide us with the term “IT Valuation” to describe the research stream dealing with the relation between IT and organizational performance. Their research started with the thesis that “IT with its complementary resources can create value manifested at different levels and, while causality is elusive, we can understand how to create differential value by extending our knowledge of complementary and mediating factors in the value creation process” (Kohli & Grover, 2008, p. 27). This relationship is illustrated in the simple flow chart below (see figure 1). In order to create different types of value and at different organizational levels, we need a better understanding of how IT investments interact with these mediating factors (e.g. organizational changes, complementary resources, alignment, capabilities) (Kohli & Grover, 2008).

Figure 1 - Translating IT investment into IT based value using mediating factors (Kohli & Grover, 2008)

Buschle and Quartel (2011) complement this by saying that IT usually does not directly contribute to a company's goals and requirements, but rather indirectly to accomplishing them. A holistic overview of the organization is necessary for achieving the right evaluation of IT project proposals (Buschle & Quartel, 2011).

During the last decade, most large organizations spent up to almost 90% of their IT budgets on maintaining their current IT infrastructure (Quartel, Steen, & Lankhorst, 2010). This resulted in only a small piece of the financial pie remaining for innovative IT projects. The underlying trend was that most organizations saw (and still see) their IT as a *cost-center* instead of a *value-center* (Venkatraman, 1997). This view results in IT budget allocation being based mainly on the efficiency and cost criteria of the accompanying IT artifact.

If organizations look at IT value instead of IT costs it should be possible to determine the extent to which IT investments contribute to their organizational goals (Quartel, Steen, & Lankhorst, 2010). Powell (1992) already mentioned a significant presence of intangible benefits that makes IT project valuation more challenging. In addition to these intangible benefits, the current interconnectedness of all different kinds of IT within an organization makes it difficult to assign certain value to an IT artifact. This was easier in the past, as information systems typically supported only one single process. These days, IT applications and services support various business activities that in turn contribute to different business goals (Powell, 1992) (Quartel, Steen, & Lankhorst, 2010). Judging from the fact that IT is continuing to become increasingly important for organizations, an improvement in IT will almost certainly result in an improvement of the organization.

Since IT often plays supporting role, it generates few to no direct revenue streams. As a result, the value of IT should be derived from the processes it supports. The valuation of IT can be complex given that IT can be used by several processes and in different activities and that this complexity can become greater when an organization's dependency on IT increases.

Because it is very difficult to value IT investments, rational multi-criteria analysis (MCA) approaches are often ignored and replaced with more political processes. Eisenhardt and Bourgeois (1988) define politics as: "the observable, but often covert, actions by which executives enhance their power to influence a decision. These actions include behind-the-scenes coalition formation, offline lobbying and cooptation attempts, withholding information, and controlling agendas" (Eisenhardt & Bourgeois, 1988, p. 737). This definition is appropriate within the context of ASML. The Operational Structural Improvements (OSI) department of ASML is responsible for executing all (not product related) structural improvement projects Operations & Order Fulfillment activities. Final decisions concerning which projects will be included in the OSI portfolio are not based purely on rational grounds and might be influenced by political processes. These decisions are made by vice-presidents of the company's operational areas for which OSI executes projects and programs (i.e. Planning, Logistics, Productions, Customer Support, Quality and Process Improvements and Facility Management) (ASML Information Manager Customer Support, September 9, 2015). These individuals all have their own views on *"what is best for ASML,"* but they cannot be expected to have the overview or expertise required to place IT investments in their full context. Technical details related to IT investments are difficult to interpret for many people, which make it difficult for the IT side to make a case. The eventual decision-makers' lack of expertise could negatively influence the quality of their decisions. In addition to the earlier mentioned political processes, the IT side also has difficulties placing investment options in a proper context, which makes it difficult for them to express their full value (Mukhopadhyay, Kekre, & Kalathur, 1995).

Current decision support tools are usually not sufficient to provide a complete picture of a certain IT investment's contribution to the organization. Traditional cost-benefit analyses are mostly insufficient given that they do not take the managerial flexibility that is inherent in IT investment options into account. Managerial flexibility is defined as "responding to a change or new situation in business conditions" (Angelou & Economides, 2008, p. 479). In addition, some prioritization methods which I will discuss in the literature part of this thesis do not account for intangible benefits, risks or other factors related to IT investments (Angelou & Economides, 2008). Other research in this field reveals several methods, but none of them provides an accurate overview of these investments' mutual dependencies and interaction with the current IT landscape (Bardhan, Bagchi, & Sougstad, 2004) (Buschle & Quartel, 2011).

This brings us back to the earlier mentioned thesis of Kohli and Grover (2008), which stated that companies will be better capable of understanding the way an IT investment eventually generates business value. In this research the mediating factors will be clarified using another current IT topic namely enterprise architecture (EA) (Quartel, Steen, & Lankhorst, 2010). Figure 2 shows how the mediating factors are expressed in EA and how IT investments could result in IT based value.

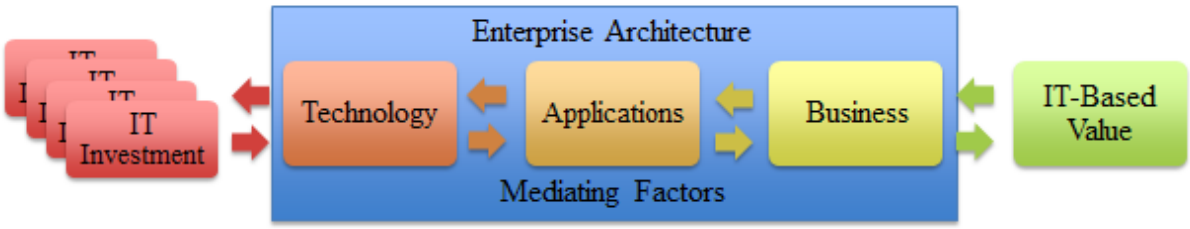

Figure 2 - IT investment translated into IT based value and reverse by EA

Using the modeling framework of EA enables us to determine the extra value IT investment can create on the business side. It gives us the possibility to retrieve the contribution of such an investment on the organization's goals. When EA is used to represent the complementary and mediating factors in the value creation process, causality no longer needs to be elusive.

The aim of the literature review is to provide us with an EA-based MCA method that enables a more rationalist evaluation of investment options. The purpose of this approach is to increase rationality in the decision-making process and thereby to decrease the influence of political processes, which should eventually lead to a higher quality decision. Providing better insight into how IT investments contribute to organizational goals will improve the cognitive ability of decision-makers and thus increase rationality within the process.

In theory, this seems very logical and feasible. However, will the method proposed in this thesis be as straightforward in the real world? The underlying questions are as follows: What obstacles do we face when using the proposed method in a real life setting? How can we make the proposed method applicable in practice? And last but not least, does using the proposed method eventually lead to better quality decisions? These questions lead to the following research goal:

1.1.1 Objective

The aim of this research is to develop an MCA method for prioritizing a portfolio of IT investments using EA. The research will evaluate the proposed method's practicality and impact on decision-making.

1.2 Central research question

What is the contribution of an MCA approach that uses EA to prioritize IT projects?

1.2.1 Research questions

Sub-question 1: What is the current state of research on prioritizing a portfolio of IT investments using MCA and EA?

Sub-question 2: How could current MCA methods, used in IT investment prioritization decisions, be improved based on previously researched strengths and weaknesses?

Sub-question 3: Is the method developed using MCA and EA feasible for decision-makers?

Sub-question 4: What are the limits of a rational approach for IT investment decisions?

1.3 Motivation

1.3.1 Relevance for the scientific community

From a scientific point of view, this research contributes in three ways. First, it provides a detailed case study of the difficulties with generating business value from IT investments. Next, it provides practical approaches on how these difficulties could be overcome by using MCA and EA. Finally, it answers the question: *What is the contribution of an MCA approach that uses EA to prioritize IT projects?*

1.3.2 Relevance for ASML Netherlands N.V.

At ASML the OSI department is responsible for all of the (non-product-driven) structural improvement projects within Operations and Order Fulfillment. Operations comprise six different domains, each with its own objectives and interests. Currently, decisions regarding what projects or programs to incorporate into the OSI portfolio are not based on full knowledge. By using an EA-based approach, ASML will be better able to show why certain investment options contribute more to organizational goals, thereby making the eventual decision more obvious for all stakeholders involved in the decision-making process.

1.4 Research method

The general structure of this research is based on information system design theory (ISDT). In a paper published in 1992, Walls, Widmeyer and El Sawy advocate the use of design science concepts for research in areas such as engineering, architecture, arts and information systems. According to these researchers, the goal of a theory based on the design concept is "to prescribe both the properties an artifact should have if it is to achieve certain goals and method(s) of artifact construction" (Walls, Widmeyer, & El Sawy, 1992, p. 41).

Design theories show how explanatory, predictive or normative theories can be put to practical use. If an artifact that embodies the laws of interaction of an explanatory or predictive theory is designed and constructed, and that artifact then satisfies its design requirements, then it provides a measure of empirical support for theory (Walls, Widmeyer, & El Sawy, 1992). Figure 3 gives the relation between the aforementioned concepts.

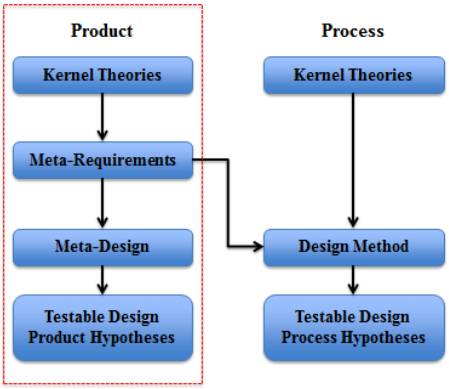

Figure 3 - Relationships among ISDT components

Walls et al. define design as both a product and a process. As a product, design is "a plan of something to be done or produced," whereas as a process it is a way to conceive a particular artifact that satisfies all requirements (Walls, Widmeyer, & El Sawy, 1992, p. 42). This thesis elaborates on prioritization methods for IT investments using a **product oriented design theory** constituting of kernel theories, meta-requirements and meta-designs. Finally, the evaluation of the key design propositions is done using a case study at ASML.

The following descriptions are used in the **product oriented design theory** approach:

Kernel theories: Theories that are well established and recognized by the natural and social sciences and that will influence the meta-requirements. The literature review provides us with different approaches to prioritize a portfolio of IT projects. These approaches are used as kernel theories to identify the meta-requirements in the subsequent step. This should provide an answer to the first research question: *what is the current state of research on prioritizing a portfolio of IT investments using MCA and EA?*

Meta-requirements: Meta-requirements describe the class of problems addressed in the research. Kernel theories are used to establish the prioritization requirements, which are in turn used to develop a method that is based on MCA and uses EA.

Meta-design: Meta-design involves the construction of design science-based theories that describe possible artifacts or classes of artifacts that satisfy the meta-requirements. Design components are established from the earlier identified requirements. This answers the second question: *how could current MCA methods, used in IT investment prioritization decisions, be improved based on previously researched strengths and weaknesses?*

Testable design product propositions: Elements that can be tested to determine if what was defined in the meta-design stage satisfies the set of meta-requirements that were established to construct theories in the second step of the research. In order to evaluate the key design propositions, the proposed method will be integrated into an Excel tool (i.e. artifact) and tested in a case study at ASML. The case contains two components. The first part consists of a practical application of the method. In the second part, stakeholders are confronted with the proposed approach (i.e. semi-structured interviews). The case study can be used to answer the third and fourth questions, namely: *is the method developed using MCA and EA feasible for decision-makers?* And *what are the limits of a rational approach for IT investment decisions?*

A convenience sample (i.e. a sample that is easy to attain) is used for the case study. In this instance, the sample contains stakeholders ASML's Customer Support (CS) process and a simplified version of that process. I chose this particular process because my ASML supervisor's network made it easy for me to make CS contacts in the company, while time constraints led me to select convenience sampling. In the sample I defined two different groups:

Content group: These individuals should be able to work with the proposed method (i.e. they prepare the decisions).

Decision group: These individuals should be able to make prioritization decisions based on the information provided using the method ('i.e. they are involved in the eventual decision').

1.5 Scope

The practical application at ASML is done using a simplified version of the *unscheduled down process (USD)*, which is a sub-process within CS. Conducting semi-structured interviews with content and decisions groups within CS should make it clear if this approach is feasible and what its impact will be on the quality of decisions. It should be noted that this is the first time that the method is tested in practice. This case can therefore be seen as a first attempt to evaluate its feasibility and impact on decision quality.

1.6 Document structure

Chapter 2 – Literature review

As mentioned earlier, the literature review is used to demonstrate the current knowledge base available on decision-making surrounding IT investments. This chapter is constructed as follows. It starts by describing decision-making in general as well a framework for decision quality that is commonly used at ASML. It then describes two ways in which complexity surrounding IT investments can be addressed (one that follows the rational approach and another that focuses on less rational possibilities). These two options are then described using current prioritization methods that are found in the literature.

The chapter ends with a summary of the requirements for the proposed method. This chapter answers the first research question: *what is the current state of research on prioritizing a portfolio of IT investments using MCA and EA?*

Chapter 3 – Proposed method

This chapter describes the MCA method that is based on EA and should meet the requirements outlined within the literature review. It contains both a general description and concrete process steps that are to be followed when using this approach. This chapter also elaborates on the Excel tool (i.e. artifact) that incorporates the proposed method and supports the calculations that it requires. This chapter provides an answer for research questions two: *how could current MCA methods, used in IT investment prioritization decisions, be improved based on previously researched strengths and weaknesses?*

Chapter 4 – Evaluation of the investment decision method

Chapter 4 starts with a clear description of the case study at ASML, including information of the specific business process that is chosen to demonstrate the proposed method in a real world example. It also provides information about the people who are incorporated into the case and the reason why they are selected. The chapter ends with an operationalization of the proposed method and summaries of the semi-structured interviews. The case study answers the third and fourth question, namely: *is the method developed using MCA and EA feasible for decision-makers?* And *what are the limits of a rational approach for IT investment decisions?*

Chapter 5 – Conclusions and recommendations

This chapter provides the answers to the general research question and sub-questions and offers recommendations for other organizations that are searching for a rational method for decision-making. For ASML, it describes the next steps the company is advised to follow if it decides to embrace this method. The chapter ends with directions for future research in this field and suggestions as to how it could build upon the foundation of this study.

2. Literature review

This literature review provides an overview of a common decision-making process and demonstrates how the way that decision-makers pass through this process determines the eventual outcome. Given that the focus of this thesis is on the decision-making process surrounding IT investments, the chapter also elaborates on the complexity that is inherent in these particular investment decisions (which should clarify the impact this complexity has on the decision-making process). The literature discusses two approaches that an organization could use to deal with the complexity surrounding IT investments, namely: complexity reduction or increasing ones information processing capacity. This separation is used to frame the current prioritization methods available in the literature.

2.1 Decision-making process

As stated in the introduction, the focus of this thesis is on the decision-making process surrounding IT investments. However, in order to better clarify exactly what this thesis is trying to improve, I begin with a short introduction to the decision-making process and I show that how we pass through this process determines the outcome.

Everyone has to make choices in their daily lives. What should I eat for dinner tonight? What will be the best next step in my career? What is the best business strategy to follow? Every decision represents a choice between alternative solutions (Dessler & Phillips, 2007). Saaty (2008) agrees with this and states that everyone is a fundamental decision-maker. Whether consciously or unconsciously, everything we do is the result of some decision.

Many people believe that problem-solving and decision-making are interchangeable given that most decisions are prompted by a problem (although this is not always the case; for instance, we may have two job offers to choose from) (Dessler & Phillips, 2007). As stated by Tversky and Kahneman (1981): “A decision problem is defined by the acts or options among which one must choose, the possible outcomes or consequences of these acts, and the contingencies or conditional probabilities that relate outcomes to acts” (Tversky & Kahneman, 1981, p. 453).

Developing and analyzing alternatives and eventually making a choice is recognized as the decision-making process. Dean and Sharfman (1993) complement on this and define **procedural rationality** as *"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"* (Dean & Sharfman, 1993, p. 589). From the aforementioned information, we should be able to define the following process steps that are necessary to arrive at a decision:

Procedural Rationality

1. **Define the problem;**
2. **Clarify the objectives (i.e. criteria and weights);**
3. **Identify alternatives;**
4. **Analyze the consequences; and**
5. **Make a choice (i.e. decide).**

Enterprise Architecture

Figure 4 gives a graphical representation of the five steps mentioned above.

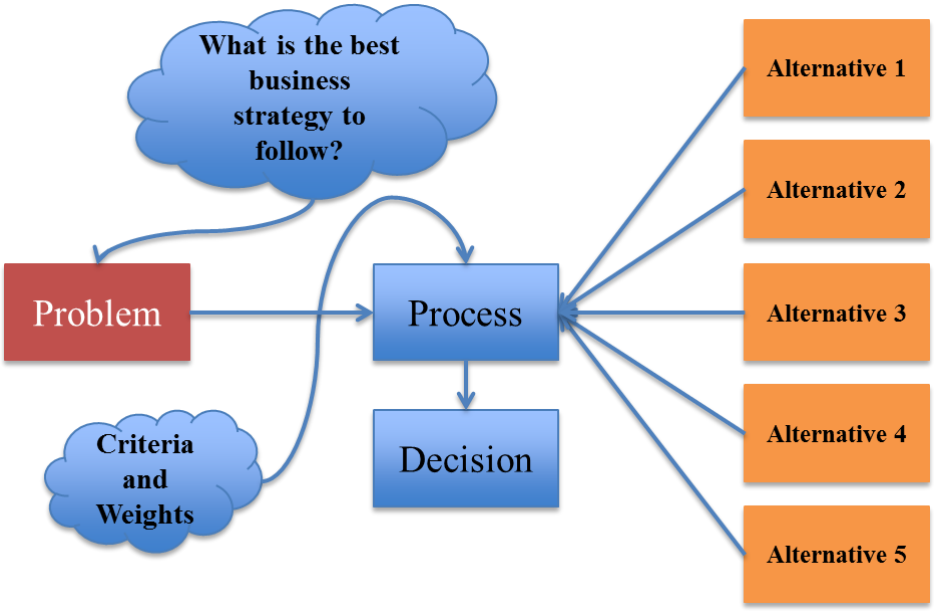

Figure 4 - Example of a decision-making process (procedural rationality)

Not every decision-maker approaches the process in the same way. However, the way in which one passes through the process will eventually determine the outcome. The example of someone looking for a new job can be used to illustrate this. During a job search someone could choose to collect criteria related to all of the available jobs, rank those criteria on importance and use logic and calculations to determine what job will best suits him or her.

While doing so would probably identify the job that suits best the needs of the job seeker, almost no one uses such an approach. To make the decision easier, most job seekers limit the number of jobs (i.e. alternatives) and criteria (e.g. will only consider flexibility, opportunities, security, reputation and salary). Although this will still result in the "best" job within the limited set of alternatives being identified, not restricting the set of alternatives would probably yield a job that even better matches the preferences. Another job seeker could ignore this optimizing process and just pick a job because it gives him or her best feeling or offers the highest salary. The same process is still being followed, but it is only based on one single or two criteria and probably just a few alternatives.

Following the classical models of **choice rationality** means that the decision-maker has knowledge of all the available alternatives and is able to compute the consequences of following each of these alternatives. It also calls for certainty in the evaluation (both present and future) of the consequences and the ability to compare these consequences no matter how diverse and heterogeneous they may be (Simon, 1979). Rationality (i.e. choice rationality) is discussed more in-depth in later parts of this chapter. However, in order to see how the rational method proposed in this thesis will alter the decision-making process, it is helpful to keep this description of rationality in mind.

Given that decision-making is a research field in itself; I believe it is necessary to explain what is within the scope of this thesis (i.e. what parts of the decision-making process I want to improve) and what is beyond it. The research will not offer guidelines for determining which alternatives (i.e. IT investments) organizations should consider. Furthermore, although it is also not within the scope of this research to prescribe protocols for determining criteria and weights, I do briefly discuss them below seeing as I need them in order to properly apply the proposed method during the case study.

The theme throughout this research concerns the rationalistic and political processes and the desirability of both. I now elaborate on the parts of the decision process that this research is attempting to improve. Structuring the decision-making process along the lines of EA will alter the decision-making process as follows:

- ***It gives the decision-maker the obligation to consider more alternatives; and***
- ***It clarifies and structures the criteria and weights used in the decision-making process.***

Later chapters clarify how this is reflected in the proposed method and provide sufficient information to place this research into a proper context.

2.2 Decision-making

I mentioned in the previous part that the way in which decision-makers navigate the decision-making process determines the eventual outcome of that process. The literature provides us with various ways in which decision-makers run through the decision-making process. Before going deeper into rational decision-making, I start with an overview of the most well-known approaches to the decision-making process.

Several papers discuss the different ways in which people approach the decision-making process (Eisenhardt & Zbaracki, 1992) (Ranganathan & Sethi, 2002). Simon (1955) explains at one end the more rational process, using a linear three-stage model of intelligence, design and choice (Simon, 1955). On the other end is the garbage can model provided by Cohen, March and Olsen (1972), which could be best described as organized anarchies. In this model, decision-making processes are chance events that happen due to the confluence of opportunities, problems and solutions, and people (Cohen, March, & Olsen, 1972). Alternatively, Pettigrew (1973) and Eisenhardt and Bourgeois (1988) suggest that the decision-making process is a political process of bargaining and negotiating between the decision-makers. In this view organizations could be recognized as collections of individuals with different goals (Pettigrew, 1973) (Eisenhardt & Bourgeois, 1988). Generally speaking, decision-making processes have two distinct dimensions, namely rationality and politics (Dean & Sharfman, 1993) (Ranganathan & Sethi, 2000).

The decision-making processes surrounding IT-investments have been investigated by many researchers in recent years. In relation to making complex decisions, managers often do not rely on rationality when reaching certain outcomes (Bannister & Remenyi, 2000). Despite the fact that both rational and political elements are found in practice, non-rational practices still dominate IT investment decisions; this might also be the case at ASML. Although decisions makers are intentionally rational, they are constrained by their reasoning capacity and incomplete information, which result in less completely rational decisions (Ranganathan & Sethi, 2002). Figure 5 provides a graphical representation of this division. I will discuss both issues in next parts of this chapter.

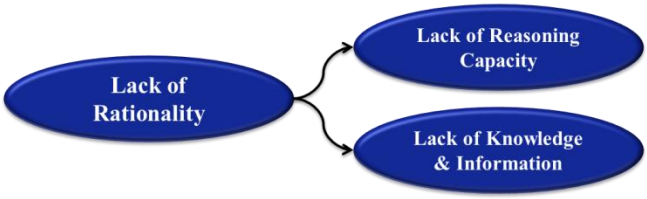

Figure 5 - Lack of rationality in decision-making

The study by Dean and Sharfman (1996) focused mainly on the influence process of making a decision has on decision-making effectiveness, and they found significant evidence that the process influences the outcome. Different processes lead to different choices, which is to say that decision-making processes influence the choices an organization make. And while different choices lead to different outcomes, not all outcomes are equally good (Dean & Sharfman, 1996).

Before going into the process of *"good decisions"*, it is necessary to understand the difference between decisions and outcomes. Good decisions can have both good and bad outcomes, as can bad decisions. It is logical that we expect our good decisions to yield more good outcomes than bad outcomes (and vice versa when we make bad decisions). Figure 6 gives a good representation of these differences. As the common saying goes, "a good decision never turns into a bad decision, and a bad decision never turns into a good decision". A decision has a quality at the time it is made, which clarifies why decisions are not judged on their outcomes but rather on the process used to make them (Matheson & Matheson, 1998). This is exactly what **procedural rationality** is about.

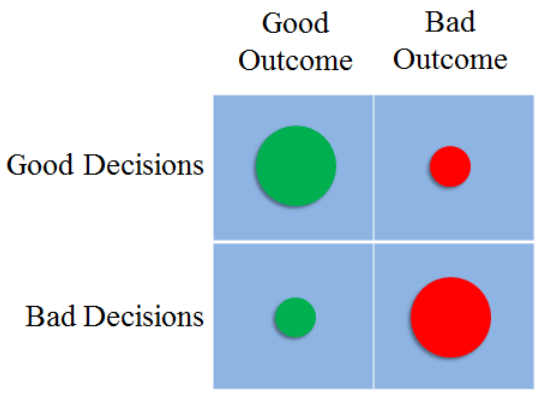

Figure 6 - Decisions vs. outcomes (Matheson & Matheson, 1998)

In order to demonstrate exactly what I try to improve with the proposed method, the decision quality framework is used. This framework developed by practitioners associated with *Stanford University and the Strategic Decisions Group* is a commonly used practice at ASML (ASML Senior Decision Support Expert, October 23, 2015). According to this approach, the following six elements ultimately determine the quality of decisions: *framing, alternatives, information, values, logic and implementation.* These elements are depicted in figure 7. The eventual quality of the decision is as high as the quality of the weakest of these six elements. Within each element, a quality level of 100% is defined as the point at which marginal effort is not justified by the benefit it would produce (Keisler, 2011).

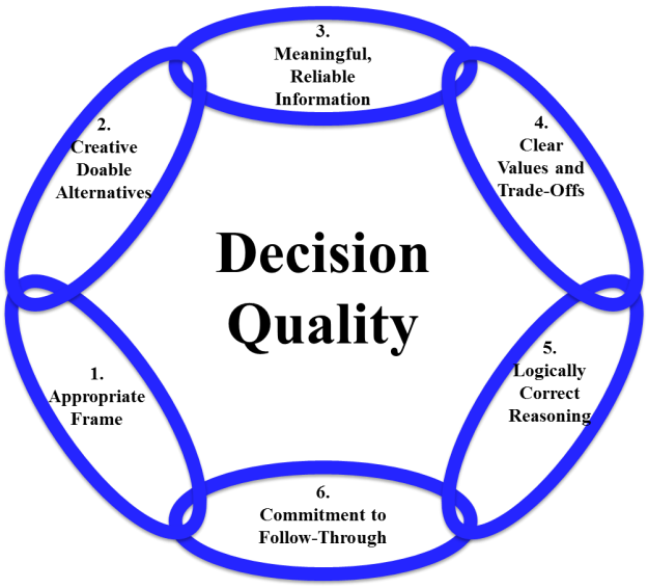

Figure 7 - The decision quality chain (Matheson & Matheson, 1998)

Decision-makers enhance the quality of decisions by executing their six decision rights (Matheson & Matheson, 1998). These six elements may be described as follows:

1. **Appropriate frame:** A decision frame that structures a decision in the context most relevant to its needs. The appropriate frame is the correct background, setting, and context for a decision.

2. **Creative, doable alternatives:** Creative alternatives that give a decision-maker the obligation to select from viable and distinct choices. Creative, doable alternatives are preconditions for any decision. If there are no alternatives, there is no decision.

3. **Meaningful, reliable information:** Relevant and reliable information upon which decision-makers can base their decisions. It requires that the right information is brought to bear on the decision.

4. **Clear values and trade-offs:** Clear values and trade-offs are found by establishing criteria for measuring the value of alternatives and how the company will make rational trade-offs among them.

5. **Logically correct reasoning:** Requires bringing together the inputs of the previous dimensions to determine which alternatives will create the most value.

6. **Commitment to follow-through:** An effective decision leader who will gain alignment and be committed to action. The best decision is useless if the organization will not implement it.

According to a decision support expert at ASML, the method proposed in this thesis will contribute to three of these six dimensions: "the decision support tool developed in your research primarily focuses on *information (input for the tool), reasoning (calculations in the tool)* and *values (performance indicators in the tool)*. Be aware that the eventual quality of the decision will be as high as the weakest of all six elements, so don't lose the other dimension out of sight" (ASML Senior Decision Support Expert, November 12, 2015). As made clear earlier, the aim of this research is also to oblige the decision-maker to consider more alternatives. In order to place decisions in the right setting and context enterprise architecture serves as the appropriate frame. The proposed method therefore also contributes to the first element of the decisions quality framework.

To understand how the proposed method in this thesis helps to increase rationality in the decision-making process; the epistemological branch of philosophy must be considered. Epistemology is the study of knowledge and justified belief (Steup, 2005), and rationalism is the movement within epistemology that believes reason is the chief source of knowledge (Johnson & Christensen, 2014). Wijnhoven (2009) adds that "rationalism is any view appealing to reason as a source of knowledge or justification" (Wijnhoven, 2009, p. 4). In this thesis I adhere to this view and state that ***reason should be the primary source of judgment***.

Enterprise architecture is used to create insight in the IT landscape and lay the foundation for the causal model that helps to calculate the IT based value of certain IT investments. ArchiMate is the modelling language used in this thesis and is particularly suitable to create the causal model. The chain of reasoning made clear by ArchiMate provides the facts needed to prove that certain investment options are better than others. The choice for the ArchiMate language is rather self-explanatory by the fact that other frameworks such as TOGAF do not have a layered structure that can be used to install causal links. The basics of both EA and modelling language ArchiMate are described in *Appendix A*.

From the previous we know that ArchiMate provide us with a holistic overview of an organization and link IT to business and organizational goals. As proposed by Sarasvathy (2001), we can use the causal chains visualized in ArchiMate in two ways: causation and effectuation. Causation is the process through which an outcome is known and a mean is selected to create that outcome. The effectuation process works the other way around: it focuses on a fixed set of means and selects between outcomes that could be created by that set (Sarasvathy, 2001).

If we apply both causation and effectuation to the proposed method in this thesis, we could use the causality chains in ArchiMate to create a causal model. The business goals could be recognized as fixed outcomes that can be realized through supporting key performance indicators (KPI's), which in turn could be realized by the supporting application and infrastructure layer. For an effectuation process, the causality could be used to identify new business that could be realized with the current architecture. For the purpose of this thesis I focus on a causation process in which we prioritize certain (IT) investment options to achieve given organizational goals.

From a theoretical perspective, this paragraph should clarify the impact the proposed method will have on the quality of IT investment decisions. The following parts discuss the main reasons decisions-making processes lack rationality, namely: *lack of reasoning capacity* and *lack of knowledge and information*.

2.3 Lack of reasoning capacity

According to Eisenhardt and Zbaracki (1992), decision-making processes could be best recognized as an interweaving of both bounded rational and political processes. The decision-makers are bounded rationally in that they are limited by their reasoning capacity but engage in a cycle among rational decision-making steps.

March (1978) defines bounded rationality as "*a normative sensible adjustment to the costs and character of information gathering and processing by human beings"* (March J. , 1978, p. 589). However, this definition does not say anything about embedding rationality in technological artifacts or tools to support actors in the decision-making process and thereby make them more rational than they actually look. Cabantous and Grond (2011) talk about *"rational carriers"* that regulate and support decision-makers, which I discuss more in-depth later on (Cabantous & Gond, 2011).

Lindblom discussed two types of decision-making (root vs. branch) back in 1959. The root method is completely rational and involves decisions being made at the root of the problem. At that time Lindblom already recognized that this complete rational method does not work given that people are bounded rational and that organizational problems are too complex. On the other side he mentioned the branch method (a successive limited comparison). In this method, decisions are made in small steps and the results of each previous act are checked before the next step is taken.

As one must wade through the mud and large steps are not possible, Lindblom dubbed this the *"muddling though" method*. Decision-makers should make use of the root method, although they should also keep in mind that it may not be feasible in practice (Lindblom, 1959).

Researchers like March (1978) and Gigerenzer (2008) state that in general, people in complex situations do not have the reasoning capacity to make purely rational decisions and therefore looking for other options (March J. , 1978) (Gigerenzer, 2008). The fact that decision-makers lack reasoning capacity causes decision-makers to rely on other ways to approach the process, such as politics or heuristics. Researchers such as Gigerenzer (2008) have found evidence that supports heuristics; indeed Gigerenzer states that heuristics will even lead to higher decision outcomes then rational optimization.

"A heuristic is a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex method" (Gigerenzer & Gaissmaier, 2011, p. 454).

In later parts of this chapter I discuss a few generally accepted social heuristics that can be used as mental shortcuts easing the cognitive load of the decision-maker.

2.4 Lack of knowledge and information

In addition to the fact that decision-makers are constraint by their reasoning capacity, it is known that ratio is not evident in many decision-making processes. When decisions are made in fuzzy environments, the goals and/or constraints in the decision-making process are usually vague and the boundaries of decision alternatives are not defined sharply. In real-world decision-making, such an environment nearly always prevails. Decisions are based on alternatives whose goals, constraints and consequences are not precisely known (Bellman & Zadeh, 1970).

Gigerenzer and Gaissmaier (2011) add that there are two types of worlds: small and large. In the small world, all relevant alternatives, their corresponding consequences and probabilities are known; the future is certain. In contrast, the large world could be recognized as the aforementioned fuzzy environment of Bellman and Zadeh (1970).

In this latter situation, some relevant information is unknown (or must be estimated from samples) and the future is uncertain (Gigerenzer & Gaissmaier, 2011) (Bellman & Zadeh, 1970). Both Savage (1954) and Simon (1979) emphasize that in large world situations, we could no longer assume that rational models automatically provide the best solution (Simon, 1979) (Savage, 1954).

Decisions often follow the desires and subsequent choices of the most powerful people. People attempt to change the power structure by engaging in political tactics such as coalition formation, cooptation, the strategic use of information and the employment of outside experts (Eisenhardt & Zbaracki, 1992).

Within organizations a typical source of political behavior is the conflicting objectives stakeholders have. Business managers regularly use several tactics to influence IT appraisals (Berghout, Nijland, & Grant, 2005). According to Eisenhardt and Zbaracki (1992), people in the political model are rational on an individual level but not so collectively. Organizations could be recognized as coalitions of people with competing interests. Although they share the same overall goals (such as profitability), they also have conflicting interests. In nearly every group decision, it is ultimately the most powerful group member that determines the outcome (Eisenhardt & Zbaracki, 1992).

Berghout et al. argue that "*rationalism* or counter tactics may counteract influence techniques in an attempt to get behind the cloak and dagger side of organizations power and politics, but politics and power in decision-making cannot and should not be filtered out" (Berghout, Nijland, & Grant, 2005, p. 31).

There are several studies that provide support that decisions taken within organizations reflect the preferences of powerful people or groups (Hills & Mahoney, 1978) (Pfeffer & Moore, 1980) (Pfeffer & Salancik, 1974). Some studies state that politics are common in IT investment decisions and some even posit that power and politics could not be eliminated from these decisions completely (Ranganathan & Sethi, 2000) (Berghout, Nijland, & Grant, 2005). It has been shown that politics could have a negative influence on an organization's performance. Several case studies conducted by Einsenhardt and Bourgeois (1988) provide evidence that reducing politics could have positive effects on the efficiency and profitability of organizations (Eisenhardt & Bourgeois, 1988).

Dean and Sharfman (1996) complement Eisenhardt and Bourgeois (1988) by providing evidence that managers who collect information and use analytical techniques make more effective decisions than the managers who do not. In addition, managers who engage in politics and power or push hidden agendas are less effective than those who do not (Dean & Sharfman, 1996).

In some decision-making processes it is known that ratio is completely ignored. Janis (1972, 1982) mentioned *"groupthink" as* an example of a situation in which this is the case. Groupthink can be seen as the desperate drive to reach consensus on a decision within a group at any cost. When concurrence-seeking becomes dominant in a cohesive in-group, it tends to override realistic the appraisal of alternative courses of action. In such situations it is clear that most ratios are ignored in the eventual decision (Janis, 1972) (Janis, 1982).

2.5 Complexity of IT investment decisions

According to Ranganathan and Sethi (2002), taking as many alternatives and variables as possible into account would increase the rationality of the decision-making process (Ranganathan & Sethi, 2002). However, the problem with rationality and the reason why many organizations instead rely on politics emerges here.

In the introduction to this thesis the complexity surrounding IT investment focuses mostly on the difficulty of establishing and defining the different factors (both tangible and intangible) attached to such investments. Kohli and Grover (2008) note that it is also hard to find the relation between an IT investment on one end and business value on the other (Powell, 1992) (Kohli & Grover, 2008). Furthermore, IT investment decisions are often made by decision-makers who do not have any background in IT; for them it is even more difficult to gain insight in the effect that certain investments might have.

Additionally, causes the large number of variables, alternatives and relations between them needed for rational decision-making this "classic" complexity. The theory of bounded rationality tells us the same story: it states that an attempt to be rational is bounded (or limited) by the enormous complexity of these decision problems (Meijer, 1998).

We humans are not able to process the large amount of complex information needed for rational decisions, which Simon (1955) refers to as our limited reasoning capacity. On a similar note, March (1978) states that people are limited by their cognitive capabilities (Simon, 1955) (March J. , 1978).

As stated by Bannister and Remenyi (2000), there is currently a limit on the rationality employed in the decision-making process surrounding IT Investments. A few reasons have already been mentioned; however, the limitations of the existing valuation methods used in IT investment decisions also force decision-makers to rely on "gut feelings" (Bannister & Remenyi, 2000).

The literature provides two main movements in relation to dealing with complexity around decision-making. The first is in line with the bounded rationality theory. Meijer (1998) mentions that this first movement seeks to reduce complexity by decomposing the decision process, which means decreasing the number of criteria and alternatives (Meijer, 1998). A second movement is in line with the proposition of this thesis to keep the decision-making process as rationalistic as possible. In line with Cabantous and Grond (2011), this could be achieved by increasing the reasoning capacity of decision-makers using so called "rationality carriers" (Cabantous & Gond, 2011). March (2006) talks about technologies related to model-based rationality (March J. , 2006). The main idea is that these artifacts could embed rational models to support the decision-maker in the decision-making process. The result is two streams of thoughts about how to deal with the complexity surrounding IT investments (see figure 8).

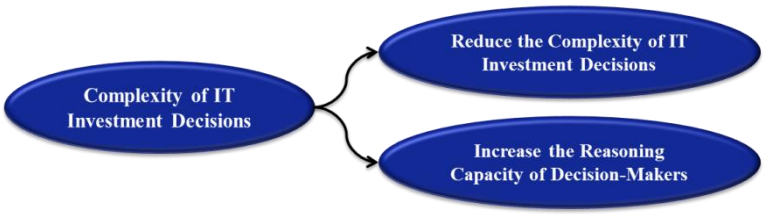

Figure 8 - Complexity of IT investment decisions

From the proposition of this thesis it is clear that my intention is not to reduce complexity. However, in order to make the process as rationalistic as possible, it is precisely the aim to increase the reasoning capacity by introducing an artifact to solve this problem. **Using a tool-based decision support model would enable us to extend the cognitive capabilities of decision-makers and therefore hold on to rationality**.

Available IT project valuation methods

A few valuation methods have already been mentioned in the introduction to this thesis. In order to find a way to determine the business value of the IT investment, a tool with practical applicability is needed. The current literature base provides us many means and methods, but most of them do not fulfill the needs of current (IT) organizations and only cover one or two requirements related to IT project valuation. I discuss each method and why I think it does not meet our preferences below. This eventually results in pros and cons that could be used as requirements for the proposed method. To do so I mainly focus on methods that increase rationality within the decisions-making process and consider in particular those that increase the information processing capacity. However, in order to paint a complete picture I also briefly elaborate the methods that try to reduce complexity.

2.5.1 Ways to reduce complexity

Although the focus of this thesis is on a method to improve the reasoning capacity of decision-makers, it is not argued that methods to reduce complexity could not be valuable for organizations; one approach does not preclude the other. It should be recognized, for example, that proper IT governance could be very valuable, if not necessary for applying, a certain decision-making method.

Social heuristics

As stated earlier, people are bounded rationally by their limited reasoning capabilities. Heuristics can be mental shortcuts that ease the cognitive load of making a decision. These heuristics (or mental shortcuts) are in place to fill the gap that originates from the cognitive limitations of decision-makers. Social heuristics could be used as bounded rationality tools to guide decisions in complex and uncertain environments. Below I discuss a few generally accepted social heuristics (Hertwig & Herzog, 2009) (Gigerenzer & Gaissmaier, 2011), namely

1. The recognition heuristic, which is based on recognition retrieved from memory. If only one or two options are available, then the option recognized has a higher value for certain criteria.
2. The fluency heuristic, which is also a mental heuristic. Here the option that is processed more fluently, faster or more smoothly than another has a higher value.
3. The take-the-best heuristic. In this case, the eventual decision is made on the first criterion that effectively discriminates between the options.

Business case

The business case is a traditional and much used approach for project proposal assessment. Indeed, it lies at the heart of every project that uses the PRINCE2 (projects in controlled environments, version 2) methodology. The business case format is not prescribed in the PRINCE2 methodology, although some guidelines are offered. Given that PRINCE2 does not provide companies with a predefined business case template, the format could vary from one company to another (Portman, 2009). "The business case presents the optimum mix of information used to judge whether the project is (and remains) desirable, viable an achievable and therefore worthwhile investing in" (Office of Government Commerce, 2009, p. 21). Lankhorst, Quartel and Steen (2012) state that IT is traditionally viewed from a cost-center perspective when conducting business case calculations, which usually results in more intangible factors being more or less neglected in the decision-making process (Lankhorst, Quartel, & Steen, 2012). The business case approach mostly relies on basic cost-benefit analysis which does not meet the requirements of rationality. The business case mainly focuses on the financial aspects of an investment proposal and is therefore recognized as a method for reducing complexity instead of enhancing peoples' reasoning capabilities. The following calculations can be seen as an attempt to *increase this reasoning capacity* (however, since they explicitly focus on financials and neglect the many non-financial factors related to IT investment proposals, they are classified as being complexity reducing within this thesis).

- **Net Present Value (NPV)**
- **Return on Investment (ROI)**
- **Discounted Cash Flow (DCF)**

As stated by Angelou and Economides (2008), traditional finance theory proposes analyzing budget allocation requests using the DCF methodology. The problem with this method is that it does not properly account for the flexibility needed in relation to IT investment decisions.

An investment proposal (Infrastructure project, e.g. new server) could for example have a negative NPV but provides the organization with an opportunity to set up a later business-value adding project. In such a case, other benefits than those provided in the stand-alone business case should be taken into account (Angelou & Economides, 2008).

Enterprise governance of IT

The enterprise governance of IT (EGIT), or the more commonly used term of governance of IT, is an integral part of overall enterprise governance. It gives business and IT people a direction for their responsibilities in the support of both business and IT alignment. It also addresses the definition and implementation of formal processes, structures and relational mechanisms in the organization to fulfill the responsibilities on both the business and IT sides. In the end, IT governance should be a first step in generating business value from the IT organization (Van Grembergen & De Haes, 2009). The mind-shift is best described by Weill and Ross (2009): "If senior managers do not accept accountability for IT, the company will inevitably throw its IT budget at a myriad of tactical initiatives with no significant impact on organizational capabilities" (Weill & Ross, 2009, p. 9). It is precisely this mind-shift that the Dutch airliner KLM experienced in 2001. Such a mind-shift formed the basis for the company to completely overhaul its IT governance, starting with appointing a new CIO. The rest of this section provides a short description of this case in which KLM transformed its governance, based on the work of De Haes, Gemke, Thorp and van Grembergen (2011) (De Haes, Gemke, Thorp, & Van Grembergen, 2011).

In this case, one of the first steps was to reconnect loosely coupled IT functions that were scattered throughout the organization. This was done by installing a CIO Office to support the CIO function. The primary task of the new CIO was then to re-establish the governance principles and practices of KLM, with the main goal of providing all stakeholders with a better understanding of both the cost and value of IT. The reason was that a better understanding would eventually lead to improved decisions on what and how to potentially outsource.

Table 1 - Governance principles and practices at KLM (De Haes, Gemke, Thorp, & Van Grembergen, 2011)

1.	The business should not experience a difference between working with an internal or external IT provider.
2.	The WHAT and HOW (and WHY) should be differentiated.
3.	The demand-function should be improved by creating a business demand office for each business domain.
4.	The supply-function should be improved by creating an innovation organizer and service manager for each business domain.
5.	Monthly decision meetings on WHAT and HOW should be convened (Management & IT).
6.	The focus should be on the costs that can be influenced either in full or in part, split between innovation and continuity.
7.	Each innovation (investment) should have one business owner to whom all costs are charged.
8.	Each service (continuity) should have one business owner to whom all costs are charged.
9.	There should be a top-down budget framework and simplified budget process.
10.	Activity-based costing should be applied to processing primary cost to product cost.

Governance principle six represents one of the most important changes, as a clear differentiation was made between continuity and innovation budget. The responsibilities and authorities are stressed along two dimensions, namely IT function and IT cost. By splitting the IT costs into two different areas, the investment decisions that come along with those areas are also split. A clear differentiation was also made between business and IT responsibilities. This resulted in four different areas, with each its own authority and responsibilities in IT investment decisions. As this framework provides clear boundaries for the four areas and the responsible managers, much of the complexity is reduced. Figure 9 gives a graphical representation of the organizational changes KLM made.

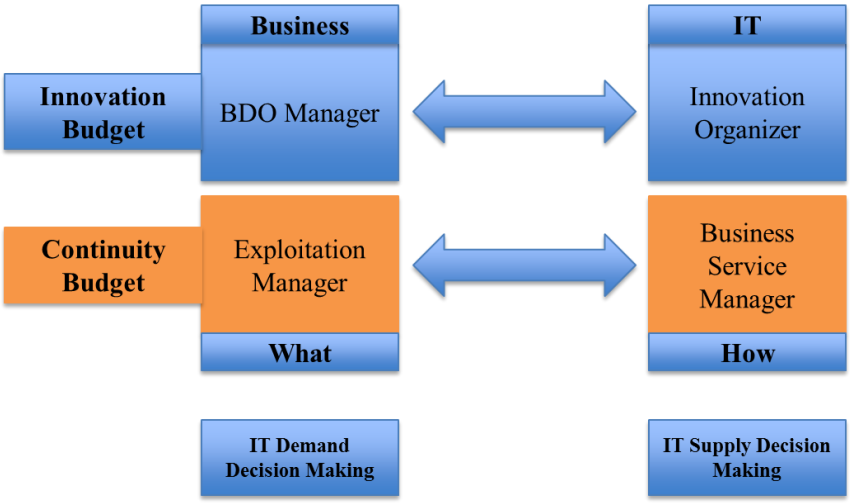

Figure 9 - Mirror roles between business and IT at KLM (De Haes, Gemke, Thorp, & Van Grembergen, 2011)

Restructuring IT governance certainly adds value to an organization. At KLM it took away much of the complexity faced by individual decision-makers by restricting their governance. Although such a restructuring does not provide us with guidelines about how investment decisions are later made, it could be of real value (and is likely a prerequisite) for implementing the eventual method for increasing decision-makers reasoning capacity.

2.5.2 Ways to increase reasoning capacity

In order to make the decision-making process more rational, the reasoning capacity must be increased. In accordance with Cabantous and Grond (2011), this could be effectuated by transferring the computations to so-called "rationality carriers" (Cabantous & Gond, 2011). The methods mentioned below try to cope with vast amounts of information. I also discuss why these approaches do not meet the requirements.

Nested real option valuation approach

Bardhan, Bagchi and Sougstad (2004) combine project interdependencies and a real option approach in an attempt to increase reasoning capacity. More explicitly, the nested real option approach models project interdependencies as real options. The real option approach provides managers with flexibility in their investment decisions. For example, an IT infrastructure project could have a negative NPV when considered on a stand-alone-basis, but it could provide a manager with the option to launch future value-added services for application development (Bardhan, Bagchi, & Sougstad, 2004).

The main contribution of Bardhan, Bagchi and Sougstad (2004) is that they develop a nested real option model that incorporates project interdependencies for project valuation. Other studies mostly use real options to make go no-go decisions concerning single projects and thereby ignore project interdependencies. It could be the case that projects are broken down into different phases that are funded separately. For example one phase might not be attractive on its own (e.g. an infrastructure project), but this phase might enable the execution of future phases and together complete the entire project. The idea is that phase one projects deserve partial credit for the future benefits they enables (Bardhan, Bagchi, & Sougstad, 2004).

A modern-day example is a good way to get a better sense of the real option. Company X is a 21st century biotechnology company that specializes in human genomics. It obtained two patents for a new technology that it developed, which it plans to use as the basis for developing a new product. Because the product's potential market is uncertain, management does not want to commit to fully investing in its development and chooses to create an option to sell the technology if at any time during the development effort it becomes clear that the product's future payoff would not be favorable (Kodukula & Papudesu, 2006).

A value net is used to take into consideration all of the stakeholders that could benefit from a certain IT investment. A value net is defined as "a map that links a firm to various player segments: customer, competitors, suppliers and complementary/partners who increase the value of a company's services to its customers" (Bardhan, Bagchi, & Sougstad, 2004, p. 36). It serves as a starting point for the real option calculations to make sure that all of the added value is taken into account.

Two types of dependencies between projects are recognized: *soft decencies and hard dependencies*. Soft dependencies occur when the capabilities created for one project enhance the capabilities required by another project, whereas hard dependencies occur when the capabilities realized for one project are also required by one or more of the other projects. The figure below provides an example of a project portfolio that consists of three phases. Hard dependencies are indicated by solid lines and soft dependencies by dashed lines (Bardhan, Bagchi, & Sougstad, 2004).

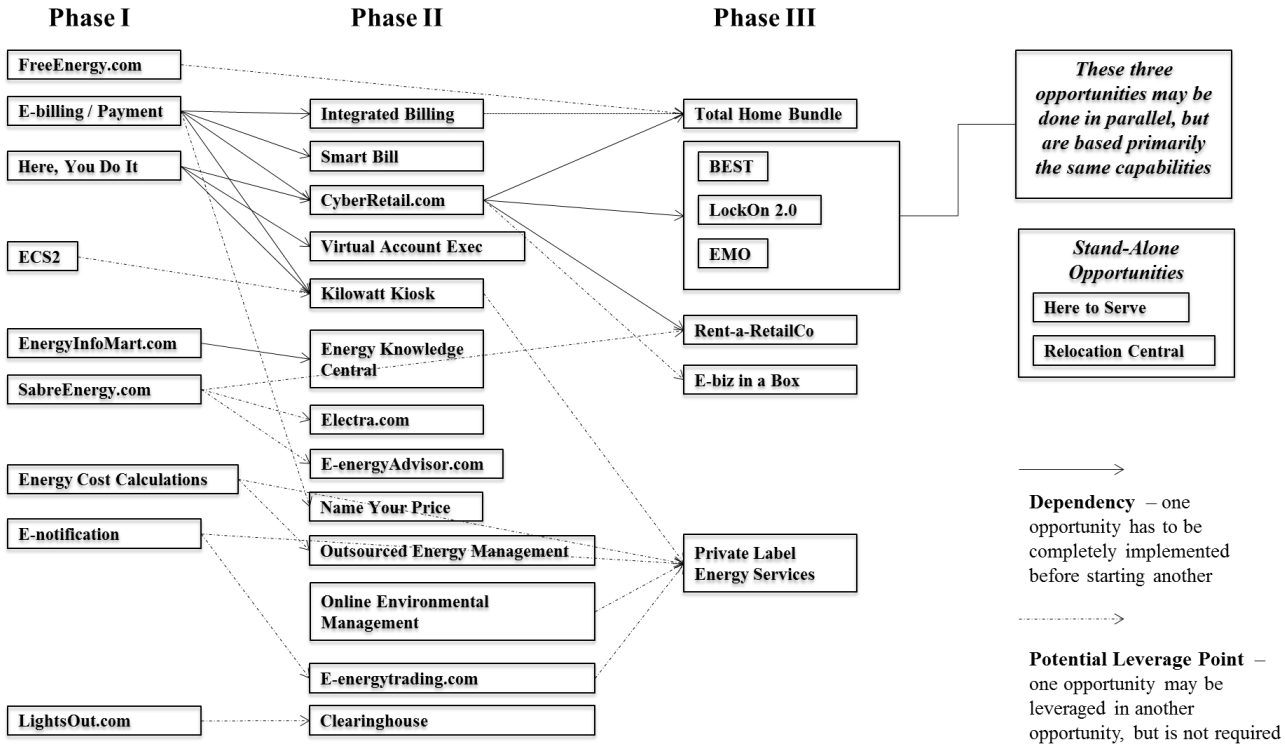

Figure 10 - Example of project dependencies (Bardhan, Bagchi, & Sougstad, 2004)

These dependencies are incorporated into the option value calculation of a certain project (V_j). The formula is constructed as follows:

$$V_j = B_j N(d_{1j}) - C_j e^{-r_f t} N(d_{2j}), \text{ where}$$
$$d_{1j} = [\ln(B_j/C_j) + (r_f t + \sigma_j^2 t/2)]/\sigma_j\sqrt{t}, \text{ and}$$
$$d_{2j} = d_{1j} - \sigma_j\sqrt{t}, \text{ and}$$
$$B_j = PV(cf_j * (1 - \Sigma_k s_{kj}))$$

The table below explains the variables used in the option value calculation above.

Table 2 - Notations used in the real option model (Bardhan, Bagchi, & Sougstad, 2004)

$\mathbf{V_j}$	Option value of project *j*.
$\mathbf{B_j}$	Present value (PV) of the expected benefits (returns) of project *j*.
$\mathbf{C_j}$	PV of the expected costs of project *j*.
N(˙)	Cumulative standard normal probability density function.
$\boldsymbol{\sigma_j^2}$	Variance of expected project return of project *j*.
T	Time to option expiration.
$\mathbf{r_t}$	Risk-free interest rate.
$\mathbf{r_d}$	Risk-adjusted discount rate.
$\mathbf{S_{kj}}$	Dependency of project *j* on project *k* (expressed in terms of the percentage of the benefit of project *j* that depends on project *k*.
$\mathbf{cf_j}$	Net cash flows associated with project *j*.

There are a few disadvantages related to the nested real option method. In addition to the fact that it uses advanced mathematical calculations that could harm its adoptability, it also entails some other inconveniences. As mentioned earlier, IT investments deal with qualitative and quantitative benefits; however, this method lacks non-financial (qualitative) criteria and thereby restricts the decision-maker. Another important issue is that this method requires all future options and their values to be known, and it does not provide instructions for calculating them.

The real option-analytic hierarchy process method

The real options-analytic hierarchy process (ROAHP) method combines real options (RO) approach with the analytic hierarchy process (AHP). The work of Angelou and Economides (2008) in this area is strongly related to the work of Bardhan, Bagchi and Sougstad (2004).

Combining the RO approach with AHP makes it possible to not only consider the financial (quantitative) criteria related to projects, but also the non-financial (qualitative) criteria. The RO approach used by Angelou and Economides (2008) is comparable to the approach mentioned in the nested RO section. It follows the same rule by incorporating the option value of future projects into the NPV of a current project and thereby calculating the extended net present value (ENPV). Just like the nested RO approach, it is necessary to calculate the ENPVs of both all possible investments and all possible combinations (Angelou & Economides, 2008).

The AHP method is proposed for also incorporating the qualitative criteria related to projects. Saaty developed this approach in the 1970's in order to organize and analyze complex decisions. Just like other MCA methods, AHP scores the alternatives on certain weighted criteria. It evaluates each alternative with respect to each criterion and then multiples that evaluation by that criterion's importance. This can be expressed by the following formula: (Bhushan & Rai, 2007)

$$R_i = \sum_{j=1}^{N} a_{ij} w_j$$

where R_i = Total score of the *i*th alternative

a_{ij} = the actual value of the *i*th alternative on the *j*th criteria

w_j = the weight or importance of the *j*th criteria

The AHP method differs from conventional MCA methods in the way it determines the weight of the different criteria. Saaty (2008) states: "To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criteria or property with respect to which they are compared" (Saaty, 2008, p. 85). A pairwise comparison is made to determine the weights and show how much more important one criterion is than another. Figure 11 gives an example of how such a pairwise comparison looks like.

	Flexibility	*Opportunities*	*Security*	*Reputation*	*Salary*	*Weights*	*X*	*Score*
Flexibility	*1*	*1/4*	*1/6*	*1/4*	*1/8*	*0.038*	*1*	*Equal*
Opportunities	*4*	*1*	*1/3*	*3*	*1/7*	*0.124*	*3*	*Slightly More Important*
Security	*6*	*3*	*1*	*4*	*1/2*	*0.262*	*5*	*More Important*
Reputation	*4*	*1/3*	*1/4*	*1*	*1/7*	*0.082*	*7*	*Far More Important*
Salary	*8*	*7*	*2*	*7*	*1*	*0.494*	*9*	*Extremely More Important*

Figure 11 – Example of a pairwise comparison matrix (Saaty, 2008)

In the figure above we can see that for example that the opportunities criterion is four times as important as the flexibility criterion. This integer means in between *slightly more important* and *more important*. The weights are calculated by dividing each single entry by the sum of its column. The weight of each criterion is then determined by the average of each row. We can see that the salary criterion is most important in this example.

In ROAHP, the outcome of the ENPV is used as one of these criteria. In comparison with the above-mentioned example, we can say that the outcome of the ENPV is the financial (i.e. quantitative) criterion of *salary*, as financial criteria are often most important. It is therefore obvious that the monetary criterion yield the highest rates. Furthermore, the other criteria are qualitative.

This ROAHP method overcomes some flaws of the previously mentioned nested RO method by also incorporating qualitative criteria. However, this method also has some drawbacks. Angelou and Economides (2008) do not provide guidelines for scoring the alternatives. The RO model in this method still needs information on a certain investment's future options before the calculations can be made, but this information is not always available. Finally, the pairwise comparison is an additional step that might be undesirable and as these weights have to be determined by the decision-maker this step cannot be transferred to a computer system.

Bedell's method

The method stems from 1985, when IT was considered in a completely different manner than it is today. In the intervening years, IT has developed significantly and its use within organizations has been greatly enhanced. Although Bedell's method is fairly outdated, I mention it here to bolster the ultimate foundation of the method proposed in this thesis.

The main purpose of Bedell's method is to link information systems (IT) to business value in a systematic and transparent manner. Extensive prior research is not needed given that most of the analysis is done by management assessment. The method has been embraced in portfolio valuation literature and successfully applied in many organizations (Schuurman, Berghout, & Powell, 2008).

This method basically provides decision support at four different levels of an organization as illustrated in figure 12 below. The first (on top) level represents the organization in its entirety while the second consists of the business processes, the third describes the activities that shape those business processes and the fourth (or lowest) level is composed of the information systems that support these activities (Buschle & Quartel, 2011).

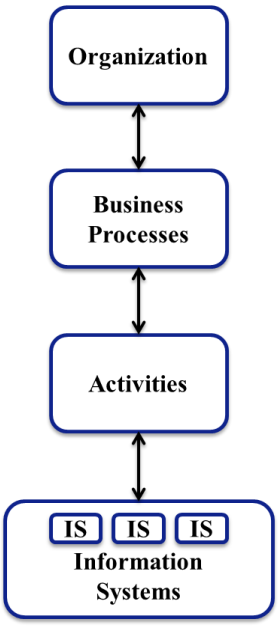

Figure 12 - Different levels mentioned in Bedell's method (1985) (Buschle & Quartel, 2011)

This is translated into three basic questions, and answering these questions is the method's main goal.

1. *Should the organization invest in IT in general?*
2. *For which business process should the investment be made?*
3. *Which concrete investments should be made, in terms of new IT or enhancements to existing information systems?*

The portfolios mentioned in this method build around two axes: *importance and effectiveness.* Furthermore, these portfolios will eventually help to answer the three basic questions cited above. Answers to these questions can be found by comparing the importance and effectiveness of IT for the tree highest levels. An example of such a comparison is given in figure 13.

(Strategic) importance: *The activities that are supported by the information systems are critically important if the business process or organization is to achieve the strategic objectives. (To-be situation)*

Effectiveness: *The information systems are effective when they have has high technical quality, are cost-effective and are functionally appropriate. (As-is situation)*

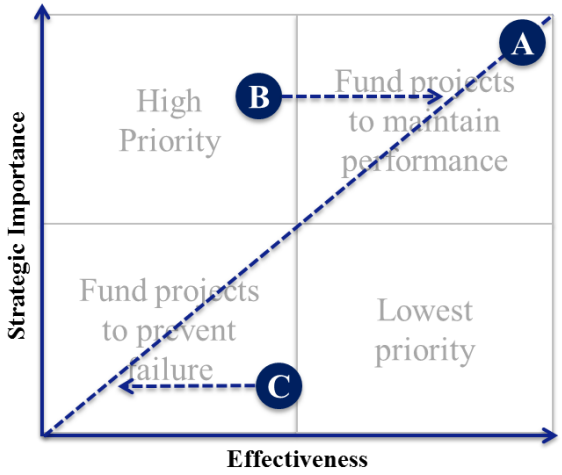

Figure 13 - Strategic importance vs. Effectiveness (Buschle & Quartel, 2011)

As mentioned earlier, using this method does not require extensive prior research. There are only four variables that need to be determined before the calculations can be made.

- *The current importance of each business process to the organization. (IBO)*
- *The current importance of each activity to the business process. (IAB)*
- *The general effectiveness of information systems in relation to the business processes.*
- *The potential general importance of information systems to the business processes*

The diagram in *Appendix B* is used to determine the required importance scores.

The calculations described in the figure below are then performed using a bottom-up approach (while the final analysis uses the reverse top-down approach). An extensive explanation of the different calculations made in this method can be found in *Appendix C*, while *Appendix D* contains a small valuation example that uses Bedell's method (Schuurman, Berghout, & Powell, 2008) (Buschle & Quartel, 2011).

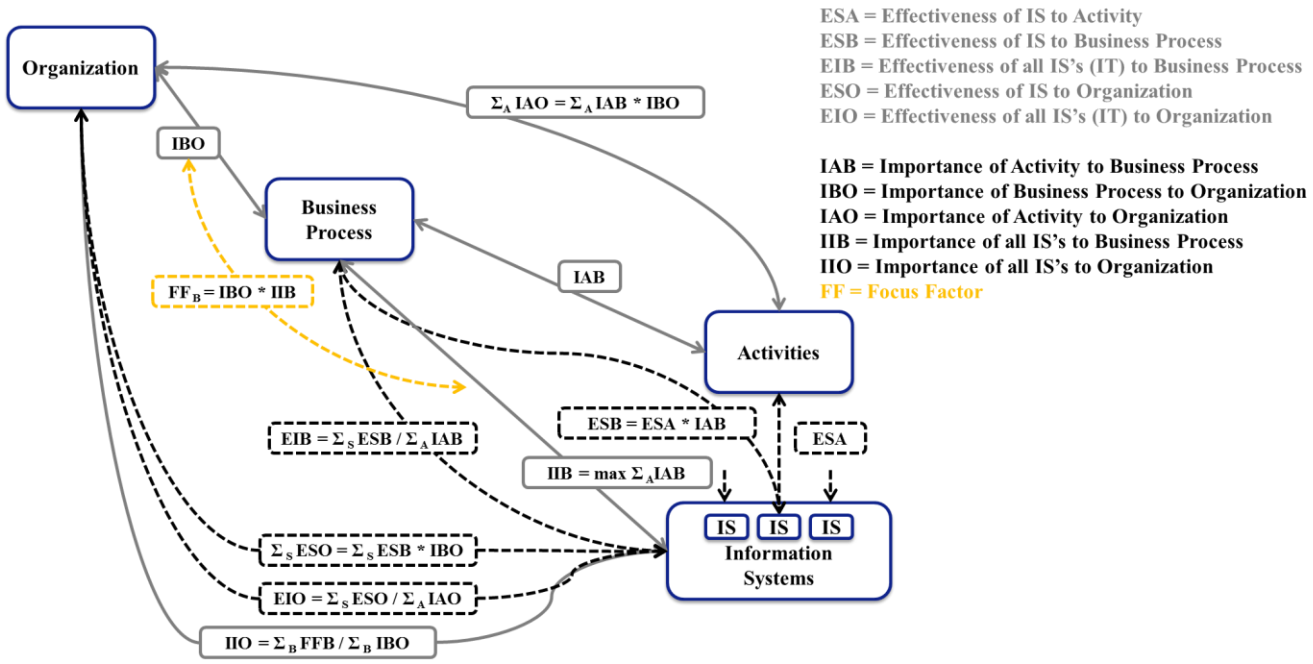

Figure 14 - Overview of Bedell's method. (Buschle & Quartel, 2011)

Extending Bedell's method to EA valuation

According to Buschle and Quartel (2011), a few limitations with Bedell's original model necessitate some adjustments. As made clear earlier, EA provides us with a holistic organizational overview that shows the causal links between IT and the organizational goals via the business processes/services. As mentioned above, Bedell's method was not developed for use in conjunction with EA. This relates to the fact that at the time when this method was developed, IT was organized in a slightly different manner: systems were used locally and not interconnected into a company-wide network of systems and applications (Buschle & Quartel, 2011).

After the extensions made here, Bedell's method should be suitable for use in today's IT world. The adaptations will also ensure that the method is capable of being used in conjunction with EA as well as with the ArchiMate modelling language (both of which are described in detail in *Appendix A*). Before I discuss the additions made by Buschle and Quartel, it is important to first briefly elaborate on the limitations associated with Bedell's method.

The first constraint is that as described by Bedell in 1985, the method has a fixed layer structure that does not allow business processes to be divided into sub-processes or an additional service layer (e.g. business services between the business and the organization) to be added. While it is currently common for companies to use certain activities in multiple business processes, Bedell's basic method does not allow network structures. The method also assumes a one-on-one relation between activities and information systems and does not support an application service or component level as structured in ArchiMate. Finally, it does not allow a layer to be crosscut. It is thus not possible to link an information system directly to a business process without the intervention of an activity (Buschle & Quartel, 2011).

The idea behind extending Bedell's method is that new methods are too often being developed without building on the existing knowledge base. Buschle and Quartel (2011) therefore tried to overcome the aforementioned limitation and thereby improve an existing method. These days IT systems and services are increasingly interwoven and both the business and business processes could be supported by multiple IT systems. The derivation rule should therefore be changed from a one-one-one rule to an N-to-N rule. In comparison with the fixed structure of Bedell's method, EA also recognizes some additional layers, e.g. organizational goals and the services provided by the different layers (namely business, application and infrastructure). These service layers are characteristics of service-oriented architecture (SOA), as described in more detail in the following section.

Following the SOA approach means that a business process is not supported directly by an application; the support is instead provided indirectly (via a service). The figure below represents an example in which the effectiveness (E) of some IT element (S) is calculated for some arbitrary architecture element X. The dashed lines indicate that the elements C[i] may contribute indirectly to X, while C [i] represents the element to which the IT element contributes directly. This should be taken as input for the calculation of E(S,X).

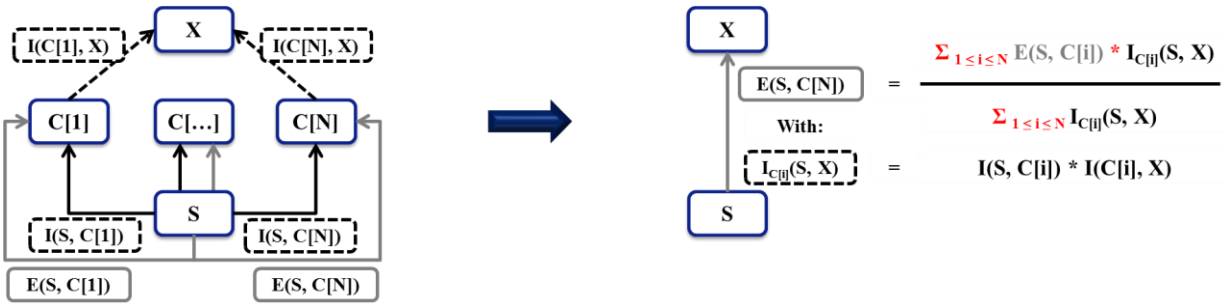

Figure 15 - Generalized rule for calculating effectiveness (Buschle & Quartel, 2011)

In order to calculate the effectiveness of S on X, the importance calculation (as represented in the figure below) should be taken into account. The importance calculations is required for each element C[i] for X, i.e. I(C[i],X) (Buschle & Quartel, 2011).

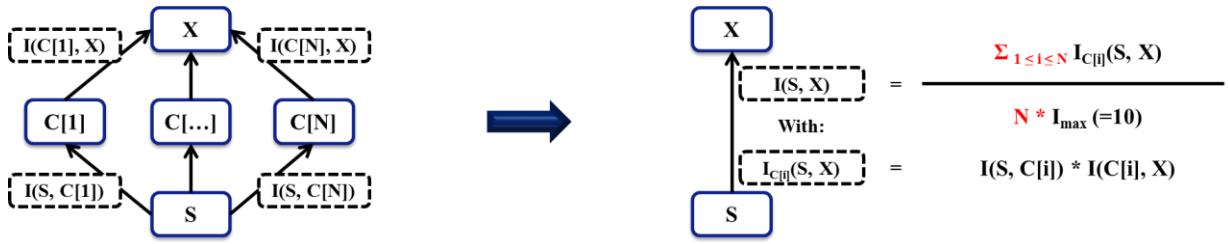

Figure 16 - Generalized rule for calculating importance (Buschle & Quartel, 2011)

It is possible in SOA that not only services from lower levels are used, but also services that are delivered at the same level. This is in contrast to Bedell's method, which uses a strict hierarchical structure. In order to prevent cyclic used-by/contribution dependencies, we should apply the architecture principle. This principle states that a service may not invoke a higher-level service. Another way to resolve cyclic dependencies is to decompose the involved elements (Buschle & Quartel, 2011). First, I discuss the concepts *ARMOR* and *SOA* before I demonstrate how the aforementioned calculations will work in the EA modelling language of ArchiMate.

ARMOR

ARMOR was established as language for modeling the business goals into a framework (Engelsman, Quartel, Jonkers, & Sinderen, 2010). A paper by Quartel, Engelsman, Jonkers and Sinderen (2009) eloquently explains why EA contributes to IT investment prioritization by visualizing the causal chains. The ARMOR language visualizes the further refinement of goals into sub-goals, which are then realized through business services and processes. This facilitates the forward tracing from stakeholder concerns to business services and processes (and possibly the supporting applications and technology) that provide a solution for these concerns, but also the backward tracing from business services and processes to the goals and concerns of the stakeholders. The next chapter clarifies how ArchiMate and ARMOR relate to the prioritization method mentioned in this thesis (Quartel, Engelsman, Jonkers, & Sinderen, 2009). Figure 17 shows the behavior aspect of ArchiMate for all the three layers in ArchiMate, extended with business goals.

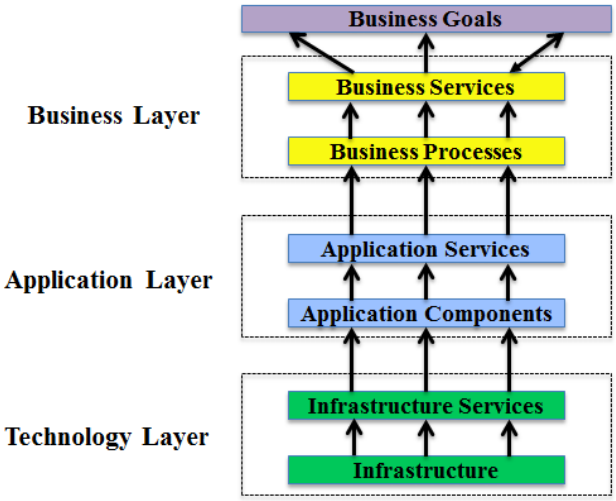

Figure 17 – The core ArchiMate framework extended with business goals

SOA

Service-oriented architecture represents a set of design principles that enable units of functionality to be provided and consumed as services. IT has made great strides in software engineering, but it is also receiving increasing attention in other disciplines. The interesting thing is that the service concept applies equally well to both the business and the software applications (Lankhorst M. , 2009).

Services provide the "units of business" that represent value propositions within a value chain or business process. In order to achieve the ultimate flexibility in business and IT design, this essentially simple concept can and should be used in all levels of the EA not just in software engineering (Lankhorst M. , 2009).

The Open Group defines SOA as: "*an architectural style that supports service-orientation. Service-orientation is a way of thinking in terms of services and service-based development and the outcomes of services*".

If SOA is related to the approach used in ArchiMate, we can see that a service is defined between all the three layers (i.e. business, applications and infrastructure). This is exactly the concept of SOA: multiple IT functions or transactions supporting a business process through a service (ASML Information Manager Customer Support, October 25, 2015).

Service level agreements provide the architect with a specification of the verifiable quality characteristics that the service will provide. *"An SLA cannot guarantee that you will get the service it describes, any more than a warranty can guarantee that your car will never break down"* (Bianco, Lewis, & Merson, 2008, p. 4)

If an SOA is set up properly, it will have a link with service level agreements (SLAs). When it is not, an SLA will mostly be constructed on just the requirements of an application. However, if an SOA has a properly layer design, an SLA can be defined between each of the layers (ASML Information Manager Customer Support, October 25, 2015). An SLA describes an arrangement between a service provider and a service consumer; examples include *availability*, *speed* or *accuracy* of a service. A service level report (SLR) defines whether an existing SLA is achieved (e.g. on a monthly basis). *Chapter 4* shows how this works out in our real-world ASML example.

Extending Bedell's method to EA valuation (continued)

To see how the calculations, mentioned in the first part, will work in the EA modeling language of ArchiMate, I use the same fictitious case as mentioned by Buschle and Quartel (2011); for a complete description, see *Appendix D*. Enterprise architecture models describe how IT artifacts (e.g. application components, functions and services) contribute to the business artifacts (e.g. business activities, functions, processes, services and products). This information, when extended with annotations about each contributing artifact's effectiveness on and importance to each directly related artifact, provides the necessary input for the extended version of Bedell's method (Buschle & Quartel, 2011).

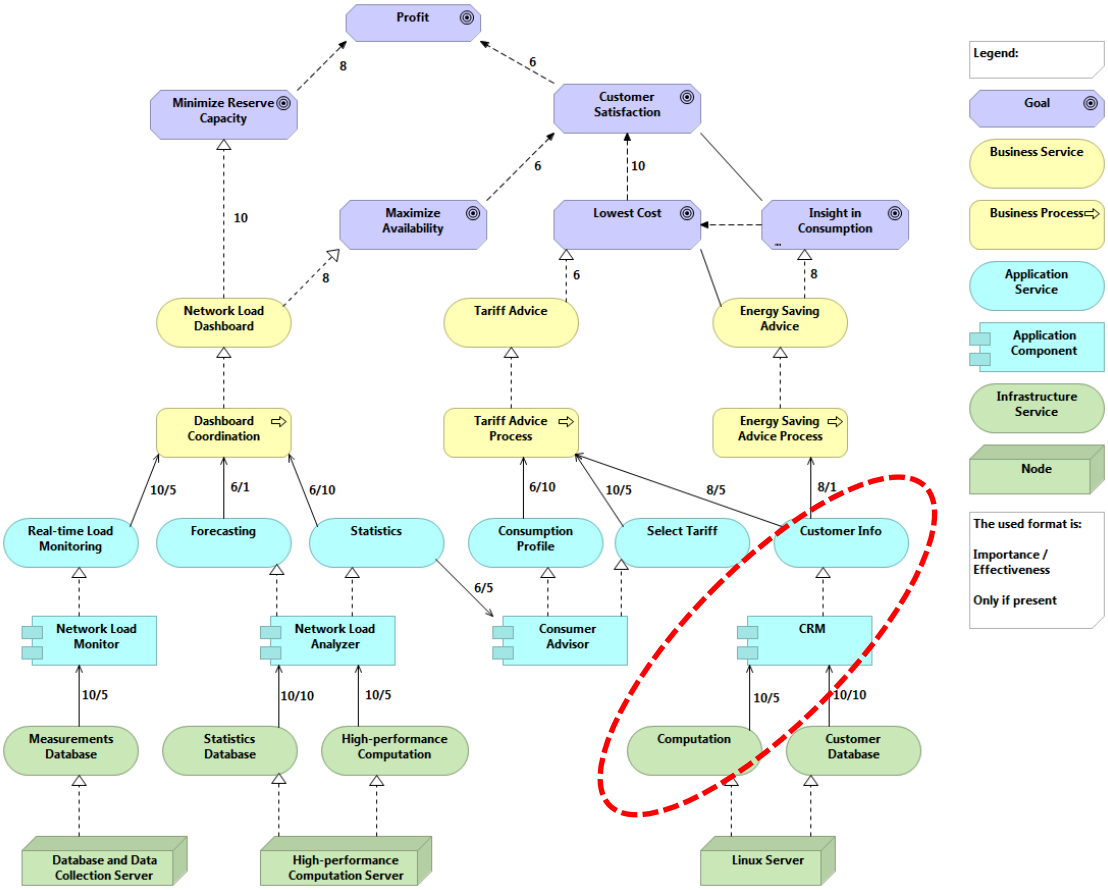

Figure 18 - Example of an extended version of Bedell's method (Fictitious case) (Buschle & Quartel, 2011)

**Effectiveness scores only applicable for the IT components in the ArchiMate model.*

Although the extensions made by Buschle and Quartel (2011) constitute a good step toward the method I propose in this thesis, the extended version still have some flaws. The problem is that projects usually do not improve complete IT components, but rather small parts thereof. The method proposed by Buschle and Quartel (2011) assumes that an improvement of the Computation Service improves the Customer Information Service and therefore decreases costs and increase insights in consumption (see figure 18) (Buschle & Quartel, 2011).

For instance, a project could be concerned with only increasing the capacity of the Linux server and thus improving the Computation Service's response time. According to the current method, such a project would lead to a decrease in cost, whereas an increase could result if the server now requires more maintenance. This shows that one sub-part of an IT component could have differing influences. The division of criteria that is made here is therefore not concrete enough. An extension of this method is needed in order to be able to assess project influences in greater detail.

2.6 Conclusion

This conclusion bridges chapters 2 and 3, which show different approaches for prioritizing a portfolio of IT investments. I have clarified why current approaches do not totally fulfill the requirements for the prioritization method and shown that EA is an essential component for demonstrating why certain investments contribute more to organizational goals than others. The paper by Buschle and Quartel (2011) can be seen as being core to this this research, and chapter 3 shows how it relates to the solution. It is also important that the SOA is set up correctly, which means that a service is defined between every layer in ArchiMate (i.e. organization, business, application and infrastructure). If this SOA is set up properly, the organization should be able to arrange an SLA for these services. This SLA incorporates performance indicators to which the service provider has to comply; whether the agreed levels are met can be determined using a service lever report (SLR).

Before I start describing the proposed method, this conclusion provides an overview of the methods discusses thus far and scores them against certain criteria (as shown in the figure below). The method proposed in chapter 3 aims to satisfying all of these criteria, which are as follows:

Qualitative element: Does the method generate benefits that cannot be expressed in financials?
Quantitative element: Does the method generate financial investment benefits?
Project interdependencies: Do the investment options have interdependencies (e.g. infrastructure and application projects)?
Causal model: Does the method use a causal model to show the effects of certain investments?
Ease of Use: Is the method easy to apply (bearing in mind that ease of use depends on the complexity of the calculations needed for the method and the number of steps that need to be taken)?

	Takes into account quantitative criteria	Takes into account qualitative criteria	Takes into account project interdependencies	Makes use of a causal model	Ease of Use*
Nested Real Option Approach	x	-	x	-	Low
ROAHP	x	x	x	-	Low
Method of Bedell	x	x	-	x	Medium
Extended Method of Bedell	x	x	x	x	Medium

Figure 19 - Comparison of current prioritization methods

- Ease of use (Low, Medium & High)
- Depending on complexity of the calculations needed
- Depending on number of steps that need to be taken to reach a decision

3. Proposed method

In this chapter input from the literature review is used to build a better MCA based on EA. To describe this method I again use the fictitious case mentioned in the paper of Buschle and Quartel (2011); for further details see *Appendix E*. This case describes a simplified version of a Swedish power utility firm that contains only three business services. Two investment options are added to make it more realistic and better show the practical applicability of the proposed method (Buschle & Quartel, 2011). A visual representation of these investment options can be found in *Appendix F*.

In the previous chapter I mentioned the flaws of the method proposed by Buschle and Quartel (2011). As projects usually do not improve complete architectural components but rather improve smaller parts of them, the following two adjustments are necessary to overcome these flaws.

- ***Performance indicators***

We should be able to define performance indicators (PIs) for every service in the architecture. For example, a service delivered by a server can be judged on *availability* and *speed*. A good way to establish these PIs is to use the balance scorecard (BSC) and input from SLAs that are based on the SOA principle. To keep the model manageable, it is advised not to use too many PIs; a good guideline is to use one per balance score card (BSC) perspective. In the case study section I will show the chosen PIs during the workshop sessions.

- ***Influence factors***

In order to create the causal model necessary for rational decision-making we should establish influence factors between the different PIs. For example, the *availability* and *speed* of an application service is influenced by the *availability* and *speed* of the service delivered by the server on which the application runs. This causality chain should be unfolded by the stakeholders of the service (one layer above) determining on which level their service is improved by the underlying PIs.

Using the abovementioned alterations to the e*xtended method of Bedell* should make causality clear and measurable. To see how this will works out in the method I propose in this thesis, I next discuss the related steps that should be taken when using it. This is followed by explaining the steps in the accompanying Excel tool.

3.1 Process steps

1. ***Create the ArchiMate model***

In the first step organizations should generate their current architecture, which can be a challenge given that architecture can be very complicated and include a wide variety of business processes and applications. While the architecture demonstrates the relationship between these components, it will be insufficient for creating a suitable causal model. See figure 20 below.

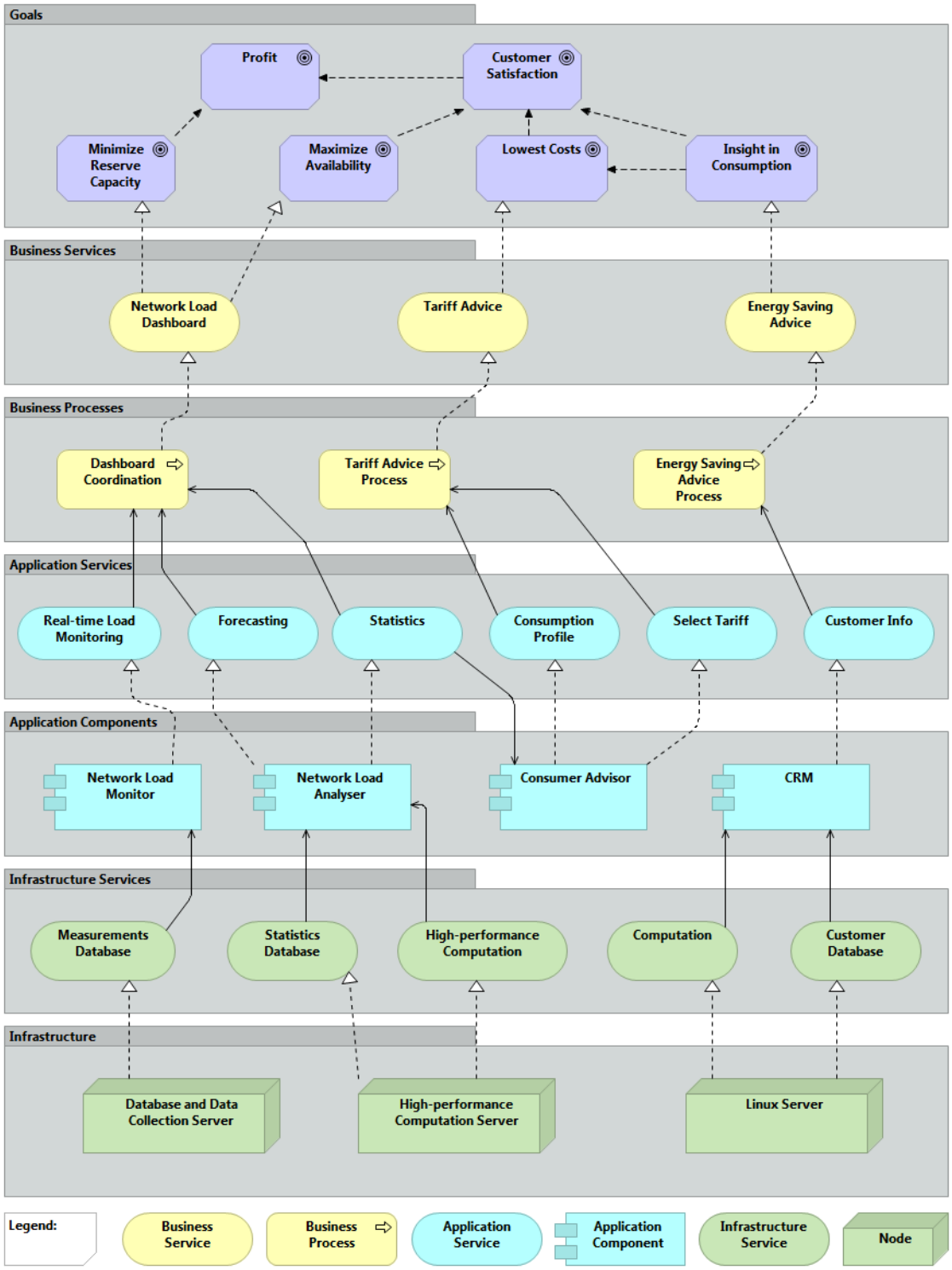

Figure 20 - Architecture model fictitious case Swedish power utility firm

2. *Determine PIs*

Second, organizations should be able to assign PIs to every service within the architecture (e.g. availability, accuracy and speed of the High-performance Computation Service). The reason I only apply PIs to the services is that a service's performance is what users eventually observe. It is not the intention to define as many PIs as possible, only those that makes the service important for others. An example is given in figure 21.

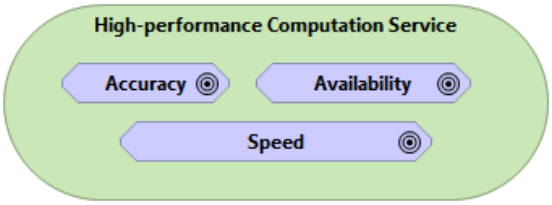

Figure 21 - PIs in high-performance computation service

3. *Install influences between PIs*

As clarified in the introduction to this chapter, the influence factors between the PIs in the services can be used to create the causal model. These influence factors are necessary to calculate the scores for the PIs that are dependent on others. An example is given in figure 22 below.

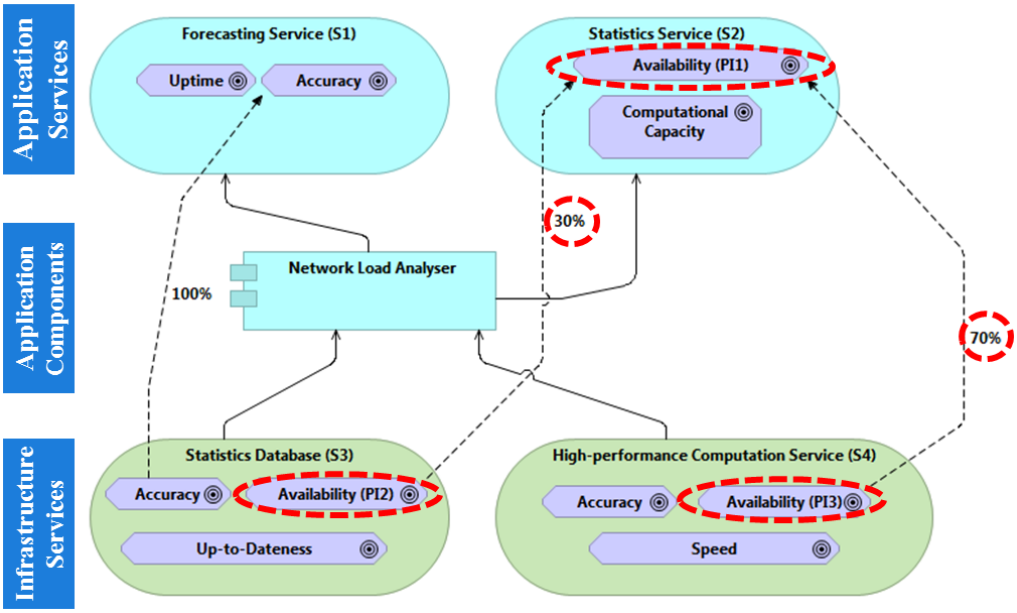

Figure 22 - Examples of influence rates (i.e. MCA weights)

**This kind of visual representation is clear for a simple example. However, one drawn for a real-world example would be so confusing that it would not add value. Such representations are therefore not necessary when the method is applied in a real-world setting.*

If, for example, the *accuracy* of the *forecasting service* is only determined based on the *accuracy* of the *Statistics Database Service*, we could assign an influence factor of 100% (or in terms of MCA; weight). However, if the score of a PI is determined based on two different PIs (e.g. ratio 30%-70%), these rates could be seen as relative weights.

4. Give scores to the PIs (not influenced by others)

Not all scores are determined by means of calculations; some are only dependent on the components that provide the particular service. For example, the uptime of the Customer Database Service is only dependent on the reliability of the hardware (if we do not take things such as power cuts into account). The proposed method uses a score scale from 0-10 for all of the services within the architecture. The *availability* of a server, for example will be determined as percentage. We therefore need a matrix that translates percentages into numbers from 0-10. In this example an *availability* of 71-80% results in a score of 3. See figure 23 for an example.

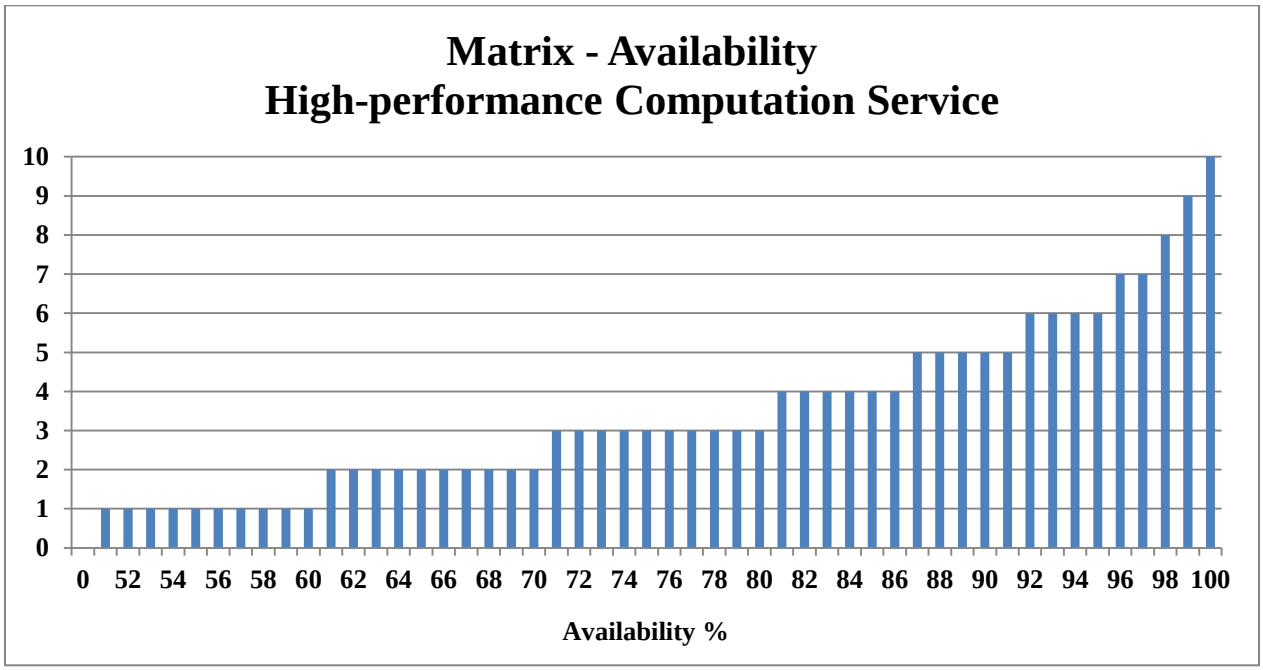

Figure 23 – Example scoring matrix (Sibenius Trip, 2014)

These score scales have to be developed for all of the PIs in the architecture. These matrices are important, because they make the scoring transparent for both current and future situations. If a project demands that a server is replaced, these matrices can be used to see what the replaced server's impact would be.

5. Calculate remaining scores

If all of the influence factors are installed and the scores for PIs (not influenced by other PIs) are given, the calculation presented below can be done. The example from figure 22 is used to illustrate how it works. The PI 1 of Service S2 ($PI_{S2}(1)$) is determined by PI 2 of Service S3 ($PI_{S3}(2)$) and PI 3 of Service S4 ($PI_{S4}(3)$). For this example we use a score of 6 for $PI_{S3}(2)$ and a score of 3 for $PI_{S4}(3)$. The score for the *availability* of the HPC Service can be retrieved (for example) from the matrix in figure 23 (71-80% *Availability*).

$$PI_{S2}(1) = PI_{S3}(2) * \text{Influence factor } PL_{S3}(2) \text{ on } PL_{S2}(1) + PI_{S4}(3) * \text{Influence factor } PI_{S4}(3) \text{ on } PI_{S2}(1)$$

$$\Rightarrow \quad PI_{S2}(1) = 6 * 30\% + 3 * 70\% = 3.9$$

This calculation should be made for all of the PIs right up to the organization's goals and sub-goals (which are influenced by the PIs of the business services).

> ***Note:*** *It could sometimes be the case that the score of a PI is partly determined by an intrinsic value of the service and is therefore not only dependent on the characteristics of the supporting IT service. If this is the case, an extra component needs to be added to the calculations.*

In this chapter it is not necessary to add an extra component to the calculations, as the abovementioned note does not influence the theoretical model.

Current situation on the organization's goals

When everything is installed (i.e. performance indicators, influence factors and scores) we should be able to see the current results for the goals and sub-goals of the organization.

6. ***Apply the investment options***

After the current scores for the goals and sub-goals are calculated, we can apply the investment options. This can be done by adding, removing or adjusting services, scores or influences. When using the method in this way, we should bear project interdependencies in mind. The increase or decrease of a PI could be more or less executing two or more investment options simultaneously.

To-be situation on the organization's goals

This method can be used to model the different investments. Doing so will yield different scores in relation to the organization goals for these investment options.

7. ***Choosing among options***

In the last step we will be able to select the project that best serves our needs (i.e. contributes to the goal that is recognized as being the most important at a certain moment). The method still uses the concepts *importance* and *effectiveness*; importance in modelled as influences between PIs and effectiveness is modelled through the results on the KPIs by the investment options. In the next section prioritization is made visible using different portfolios generated by the Excel tool.

3.2 Excel tool

In order to complete the large number of calculations necessary for the proposed method, I embed the method in an Excel tool. The current KPI reporting tool used within ASML contains a certain number of functionalities that were useful for the Excel tool developed for this thesis. For this reason, a connection was made between the prioritization tool used in this thesis and the KPI reporting tool used at ASML.

It is interesting how the ASML's KPI reporting tool relates different KPIs with each other to generate a KPI tree (i.e. causal model). Two types of KPIs are recognized in the ASML KPI reporting tool namely: **calculated** and **primary** KPIs. A calculated KPI is figured based on underlying primary KPIs. At this point we are able to show the relation of the KPI tree in the ASML KPI reporting tool with the prioritization method proposed in this thesis.

The proposed method also includes PIs that can be classified as either calculated or primary (the Excel tool clarifies how exactly this works). In order to demonstrate the proposed method using the Excel tool, I again use the case of the Swedish utility firm.

1. Adding architecture (i.e. services from architecture) and PIs in Excel tool

Figure 24 shows the start screen of the Excel tool. The screen enables the user to add the services in the ArchiMate model into to KPI reporting tool of ASML by translating the visual representation from figure 20. As only the PIs in the services are used for the calculations, it is not necessary to add the other components. The user can add/remove services from the different layers, as well as add/remove PIs from the specific services. At the top of the architecture the user is able to add/remove goals and sub-goals.

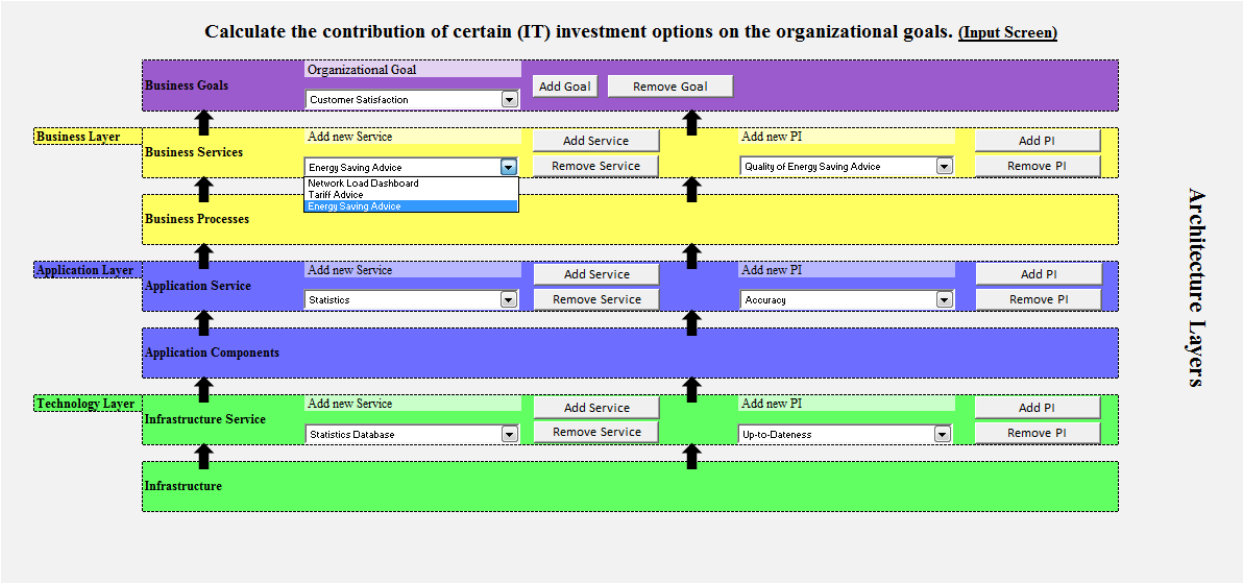

Figure 24 - Start screen of the Excel tool (adding services and performance indicators)

The information entered on the start screen is then used as input for the KPI reporting tool; a visual representation is provided in the figure below. As can be seen, every performance indicator (i.e. KPI) is assigned a unique ID.

[redacted]

1. Organizational Goals			
?	K08663*	**Customer Satisfaction**	Goals
?	K08662*	**Insight in Consumption**	Goals
?	K08666*	**Lowest Costs**	Goals
?	K08667*	**Maximize Availability**	Goals
?	K08664*	**Minimize Reserve Capacity**	Goals
?	K08665*	**Profit**	Goals
2. Business Services			
Network Load Dashboard			
?	K08618*	**Availability**	Business Services \ Network Load Dashboard
?	K08632*	**Comprehensiveness**	Business Services \ Network Load Dashboard
?	K08615*	**Speed**	Business Services \ Network Load Dashboard
Tariff Advice			
?	K08669	**Quality of Tariff Advice**	Business Services \ Tariff Advice
Energy Saving Advice			
?	K08638	**Quality of Energy Saving Advice**	Business Services \ Energy Saving Advice
3. Application Services			

Figure 25 - Visual representation of the PIs in the KPI reporting tool

2. *Install influences between PIs*

When the services from the architecture and associated PIs are added, it is possible to create causal relations between the different PIs. The built in formula builder in the KPI reporting tool enables us to install the different influence factors between the PIs.

Figure 26 shows the formula for calculating the *comprehensiveness* of the *network load dashboard service* in the *business services layer*. The *comprehensiveness* is calculated out of three underlying PIs, namely; *information quality (K08602)* of the *real-time load monitoring service*, the *comprehensiveness (K08611)* of the *statistics service* and the *comprehensiveness (K08612)* of the *forecasting services* (from the *application services layer).*

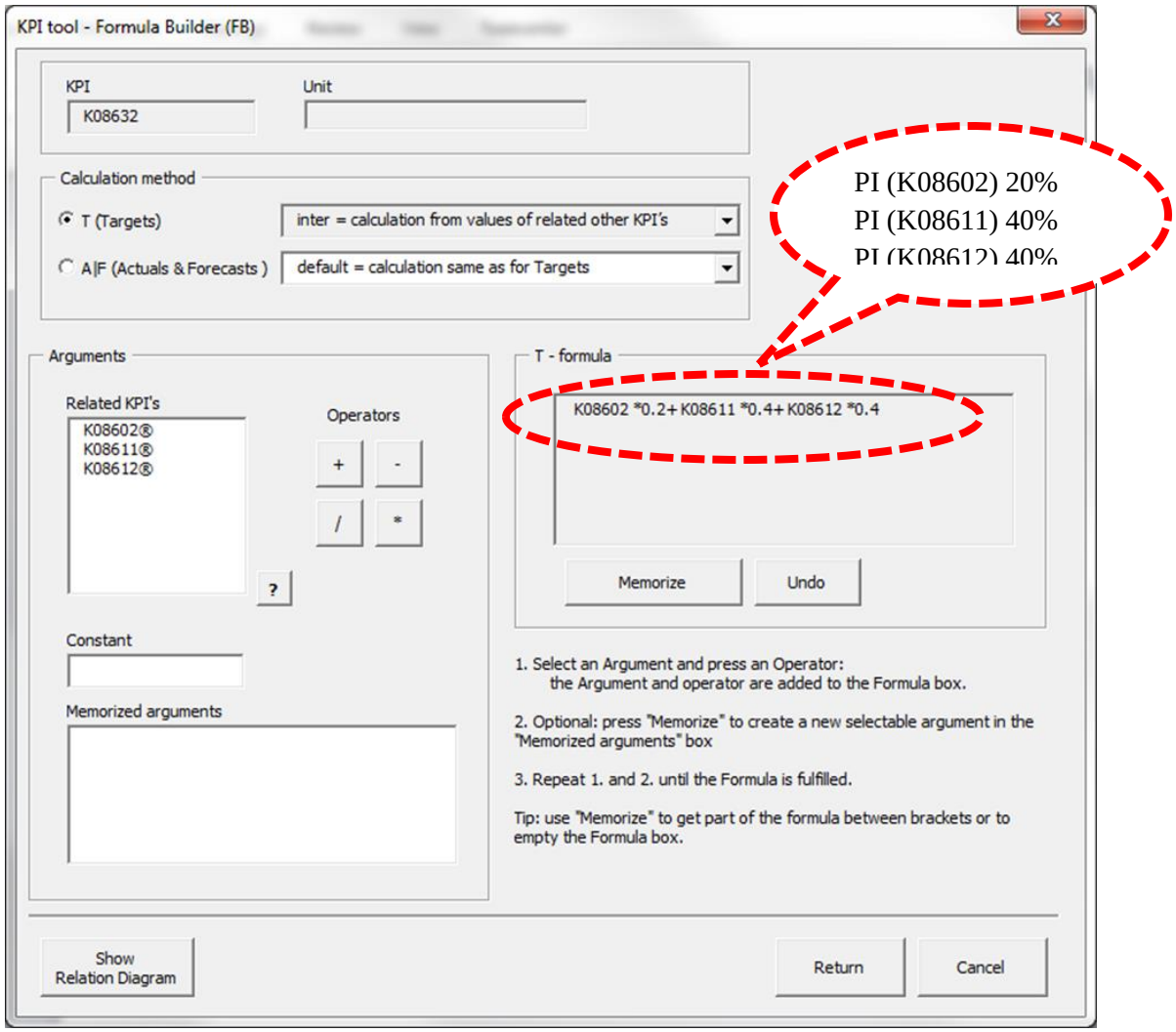

Figure 26 - Formula builder in KPI reporting tool

The KPI reporting tool of ASML has the functionality to generate an overview of the relations between all the PIs in the dashboard. This gives the opportunity to show the causal model. An example of this diagram structure is given in figure 27. The red circle shows the calculation made in figure 26.

[redacted]

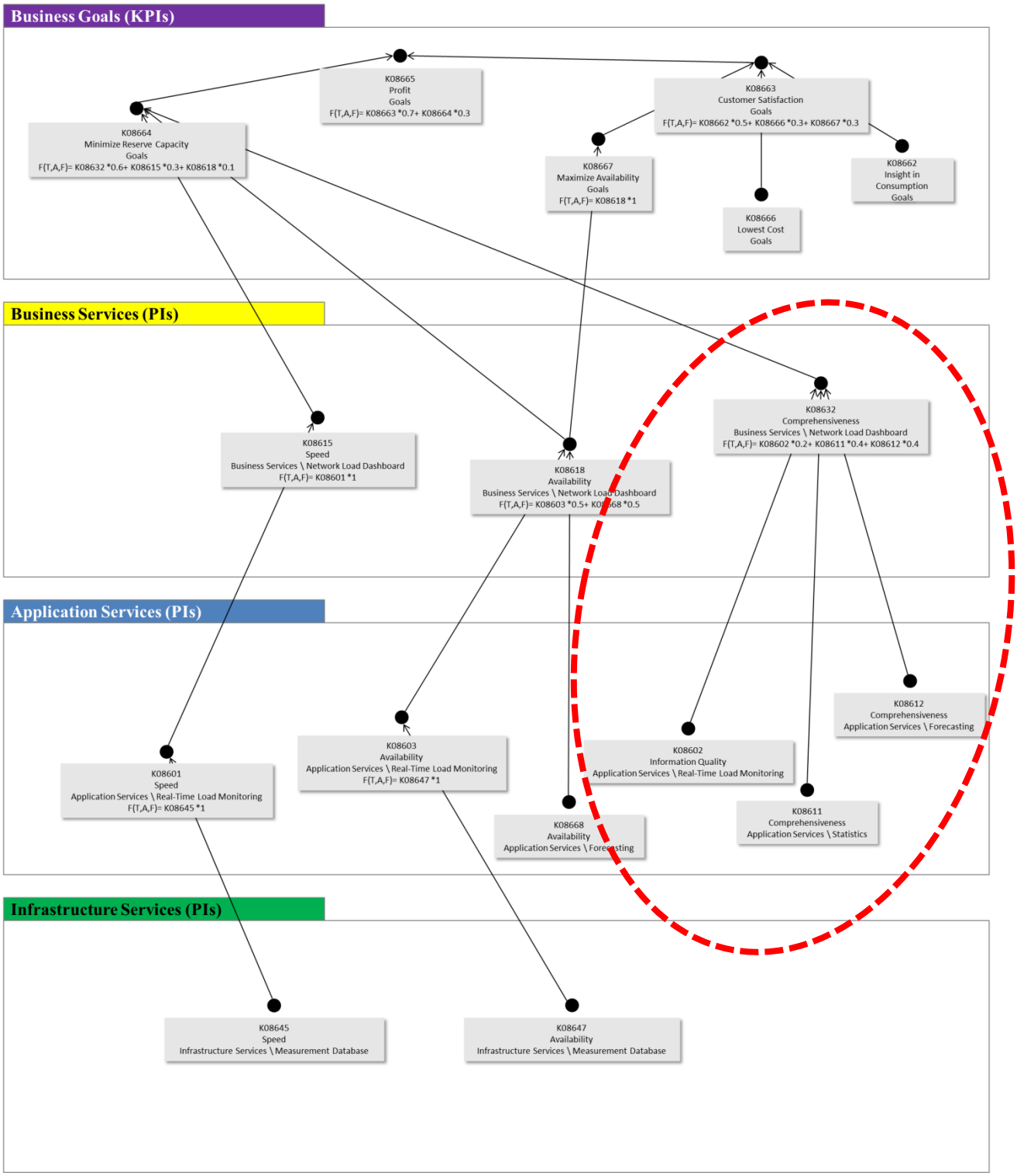

Figure 27 - KPI tree within the KPI reporting tool (causal model)

3. *Give scores to the PIs*

After the influence factors between the PIs are installed, scores can be given to those PIs not influenced by others (figure 28, left red column). The tool automatically calculates those PIs that are influenced by other PIs. Eventually, this should yield the current scores for the organizational goals and sub-goals.

KPI id	Today: 1607.7	Data Owner	What is measured (T = Target ▶ / A = Actual, F = Forecast ▶)	Current Situation (T / A)	Investment Option 1 (T / A)	Investment Option 2 (T / A)
4. Infrastructure Services						
Measurements Database						
? K08648	**Accuracy**	[redacted]	Infrastructure Services \ Measurements Database	7	7	7
? K08647*	**Availability**	[redacted]	Infrastructure Services \ Measurements Database	6	8	6
? K08646	**Maximum Size**	[redacted]	Infrastructure Services \ Measurements Database	5	5	5
? K08645*	**Speed**	[redacted]	Infrastructure Services \ Measurements Database	8	9	8
Statistics Database						
? K08649	**Accuracy**	[redacted]	Infrastructure Services \ Statistics Database	7	7	7
? K08651	**Availability**	[redacted]	Infrastructure \ Statistics Database	6	6	9
? K08650	**Up-to-Dateness**	[redacted]	Infrastructure Services \ Statistics Database	8	8	8
High Performance Computation						
? K08670	**Accuracy**	[redacted]	Infrastructure Services \ High Performance Computation	7	7	7
? K08617	**Availability**	[redacted]	Infrastructure Services \ High Performance Computation	7	7	9
? K08652	**Speed**	[redacted]	Infrastructure Services \ High Performance Computation	6	6	8
Customer Database						
? K08654	**Accuracy**	[redacted]	Infrastructure Services \ Customer Database	7	7	7
? K08655	**Availibility**	[redacted]	Infrastructure Services \ Customer Database	5	5	5

Figure 28 - Scores of current situation and investment options

4. *Apply investment options*

The user can now start entering the investment options in the tool (figure 29). The user is directed back to the screen in figure 28 after entering the project details. This allows the user to add the scores of the investment options.

	Project Description:	Costs:	Layer:
Add Project	Customer Application	€ 95,000.00	Application Layer

ID	Project Description	Costs	Layer
0	Current Situation	€ 0.00	
1	New High Performance Computation Server	€ 30,000.00	Infrastructure
2	Customer Application	€ 95,000.00	Application

Figure 29 - Adding investment options

Figure 30 shows the results on the organizational goals for both the current situation as for the two investment options. These scores are used to generate the result screens (portfolios) in figure 31.

KPI id	Today: 1607.7	Data Owner	What is measured	Current Situation	Investment Option 1	Investment Option 2
			T = Target ▶	T	T	T
			A = Actual, F = Forecast ▶	A	A	A
1. Organizational Goals						
? K08663*	**Customer Satisfaction**	[redacted]	Goals	**6.615**	**7.565**	**6.915**
? K08662*	**Insight in Consumption**	[redacted]	Goals	**6.63**	**8.13**	**6.63**
? K08666*	**Lowest Costs**	[redacted]	Goals	**7**	**7**	**7**
? K08667*	**Maximize Availability**	[redacted]	Goals	**6**	**7**	**7.5**
? K08664*	**Minimize Reserve Capacity**	[redacted]	Goals	**7.3824**	**7.6**	**7.6308**
? K08665*	**Profit**	[redacted]	Goals	**6.84522**	**7.5755**	**7.12974**

Figure 30 - Result screen (scores)

Figure 31 - Result screen (portfolios)

4. Evaluation of the investment decision method

This chapter describes the methodology used for the evaluation of the proposed method. The evaluation is done conducting a case study at ASML. The case contained two parts: a practical application of the proposed method (which entailed a workshop with the content group) and, semi-structured interviews with stakeholders (which were utilized to evaluate the proposed methods' ease of use and impact on decision-making).

The semi-structured interviews were held with individuals who fall into two different categories, namely: ***content and decision***.

Content: These individuals should be able to work with the method (*i.e. they prepare the decision)*.
Decision: These individuals should be able to make prioritization decisions based on the information provided using the method ('*i.e. they make the eventual decisions')*.

4.1 Case study and methodology

The case study methodology of Yin (2013) is widely accepted in social science research. Case studies are preferred in situations where the following three conditions are met:

- The main research questions are "why" and "how" questions;
- The researcher has little or no control over behavioral events; and
- The focus of study is contemporary (as opposed to entirely historical) phenomena.

As the research into ASML meets all of these conditions, *case study* research best serves our needs. The definition of *case study* research used by Yin (2013) is twofold:

"A case study investigates a contemporary phenomenon ('the case') in its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident. […] The second part of the definition points to case study design and data collection features, such as how data triangulation helps to address the distinctive technical condition whereby a case study will have more variables of interest than date points" (Yin, 2013, p. 2).

4.1.1 Objectives

This case study has four objectives:

1. To investigate what information is necessary to use the proposed method in its entirety;
2. To investigate how to determine which PIs are important and how to determine the influence factors;
3. To investigate if the proposed method is feasible for the stakeholders; and
4. To investigate the limits of such a rational approach for decision-making.

4.1.2 Scope

The case study conducted within ASML's OSI department, which is part of the *Operations and Order Fulfillment* business function. This department undertakes all structural improvement projects for *Operations* and can be seen as the link between business and IT. The improvement projects that it executes are not product related (i.e. non-PGP).

As shown in the below figure, the OSI department conducts projects and programs within six domains. The case study entailed selecting one of these domains (namely CS) to evaluate the proposed. To make the case more feasible, the *unscheduled down process (USD)* process was selected to demonstrate the proposed method in a real-world setting (see *Appendix H* for an illustration of the USD process).

[redacted]

4.1.3 Timeframe

Six week were allocated for the case study. I started the semi-structured interviews in parallel with the practical application of the method. In the first week I met with my company supervisor to discuss who within CS would be most suitable for the content and decisions groups. As it was sometimes difficult to people to spare 30/60 minutes that we needed for meetings, the interviews were spread over the five remaining weeks.

4.1.4 Sampling method

One of the most commonly used sampling methods in the behavior sciences is *convenience or accidental sampling.* In this approach the researcher simply uses participants who are ease to attain; they are selected on the basis of their availability and willingness to respond (Gravetter & Forzano, 2015). Convenience sampling is far from ideal and may threaten the external validity of our study.

For this research I used staff members from *CS* for both the semi-structured interviews and the workshop. For the practical application of the method I used the *USD process* within CS. I chose this convenience sample because my company supervisor is *Information Manager* for CS. Having this connection shortened lines of communication and facilitated my efforts to make contact.

To increase the success rate of scheduling meetings, my company supervisor first called most of the participants to inform them what was expected from them and explain the potential benefits of the research for ASML. These calls were intended to increase staff member's willingness to participate.

4.1.5 Research material

- The below table shows individuals who participated in the semi-structured interviews.

Title	***Content/Decision group***
Information Manager Customer Support	**Decision group**
IT Director Competence Center Sales & Service	**Decision group**
Manager Customer Support World-Wide Projects	**Decision group**
Customer Support Infrastructure Support – Senior Specialist	**Content group**
IT Service Delivery Manager	**Content group**
Global Infrastructure Manager	**Content group**

Table 3 - Participants interviews

- The following table indicates the individuals who helped to create the ArchiMate model in order to test the proposed method's ease of use.

Title
IT Director Competence Center Operations
Senior Manager Enterprise Architecture
Enterprise Architect
Senior Consultant CS PM QM ETM
Business Architect Customer Support
Key User – Business Application Owner
Business Process Change Manager

Table 4 - Stakeholders within CS/IT

- In addition to stakeholders within CS and IT, I also consulted internal process documentation in drawing early models of the *USD* process.

4.2 Difficulties/problems encountered

One of the major difficulties during the case study (especially the practical application of the method) was the absence of ArchiMate models that describe the current ASML landscape. At the moment, no common language (such as ArchiMate) is available for communicating with each other about investment decisions.

A second problem attached to the absence of ArchiMate is the immaturity of knowledge about this modeling language within the organization, which made it harder to describe and explain the proposed method to interview participants. In response to the first problem, I arranged a discussion with ASML staff members from both the IT and the business sides to help generate an ArchiMate model for the *unscheduled down process (USD)* within *CS*. In every conversation I used the same presentation as during the semi-structured interviews, drawing on a simplified ArchiMate model of the fictitious utility company (Buschle & Quartel, 2011) as an example. To ensure that I was making progress in my discussions, I always used input from previous conversations.

4.3 Semi-structured interviews

According to Clifford, French and Valentine (2010), semi-structured interviews are a useful way of researching, (as the interviewer provides the interviewee the change to explore issues that he or she feels are important in addition to those covered in the main questions.) A semi-structured interview unfolds in a conversional manner using a predetermined list of topics or questions, but it also includes the possibility for deviation (Clifford, French, & Valentine, 2010).

To support the interviews I used a presentation to first introduce the new approach to IT decision-making before asking questions about it. The following main stages were discussed, *Appendix G* give a detailed description of each of these stages:

Process

- ***Introduction***
- ***Problem statement***
- ***How to solve this problem***
- ***EA (ArchiMate)***
- ***Illustration***
- ***Discussion & questions***

After conducting the interviews, I wrote a report that I sent together with the presentation to the participants. I did this to give the participants an opportunity to both review the interview report and look more closely at the presentation. I asked them to add any information that was missing and to send the adjusted report back to me. Summaries of the interviews held for each group are provided below.

** It should be noted that all interviews were conducted in Dutch; statements in English included here are therefore translations.*

<u>Decision group:</u>

Information Manager Customer Support

The method as presented during the presentation will constitute a compelling contribution to the decision-making process and will help us to reduce the complexity inherent to IT investment decisions. Eventually, it will lead to better control and more focus on the things that really matter. This refers not only to larger structural improvements (i.e. innovation projects), but also to the smaller (maintenance) jobs that arise on a day-to-day basis. According to the participant, ArchiMate can serve as a common language between business and IT; if we speak the same language the proposed prioritization method will serve as a decision-support tool with distinct merits.

IT Director Competence Center Sales & Service

During this interview we discussed the details of the method quite extensively. In general, this IT director thinks that such a method should lead to better decisions given that we will have more information and insight. He noted that in order for such a method to work, we need guidelines for the influence rates and PIs; without them, the proposed method serves as a platform that facilitates political processes. He feels that the method will have its limits if we are not able to make the scores and weights objective.

Manager Customer Support World-Wide Projects

We first spoke about the use of SLAs as input for the prioritization method. I mentioned that if we set up our SOA in the right way, we should be able to define a service layer between the different levels in the architecture. Furthermore, an SOA that is set up correctly would also enable us to define an SLA on the service layer between the levels.

The PIs mentioned in these SLAs could then serve as input for our prioritization method. According to this manager, current SLAs are defined for the applications themselves (e.g. COACH SLA) and not on the services defined between the levels. Our SLAs are internally focused; hence in-case of noncompliance there is no explicit way to be compensated for at this level. Another issue we discussed had to do with the scores we will assign to the PIs. The difference between 99% and 100% server availability may look small, but it could have a large influence. As an example he mentioned a banking company with an online banking application: 1% of server down time could eventually result in 10 days down time yearly for the application. This probably has a bad impact on the company's image. One of the other questions was if it will be possible to look into the future using this method. How does it incorporate lifecycle management? How does it deal with the phasing out, maintenance and upgrading of components within the architecture? His final remark was that the approach needs success criteria in order to be successful.

Content group:

Customer Support Infrastructure Support – Senior Specialist

When I interviewed this participant I discovered that the method I presented has many boundary conditions that must be met if it is to be used fully. Enterprise architecture serves as a large part of the solution. This way of working, modeling and thinking is currently not in common use at ASML. The method has the ability to make the process much more rational and thereby decrease the number of political processes. This participant stated that it would be difficult to objectively define the different parts of the method, although having clear guidelines would make it easier.

IT Service Delivery Manager

ASML currently does not have an EA repository, and therefore also lack the knowledge. Using EA with the ArchiMate modeling language gives us the possibility to link IT to the business side of the company (and eventually to ASML's predefined goals). Currently, the greatest challenge is how to make these links. This is made even harder by the fact that IT and business sides of the house do not speak the same language. Given the maturity level of the organization, we currently do not define application services that link IT to the business; however, there is, also a lack of business services that could be linked to our organizational goals.

Currently, business services, level 2/3 (IT Terminology), from SLA documentation is linked with our applications (e.g. COACH and Maintenance Manager/SMS). There is no bridge between the goals of the business (i.e. the KPI's) and our applications.

Global Infrastructure Manager

This participant said: using the proposed method will make the process much more rational; making it more rational will in turn make the less rational components (i.e. political processes) more visible. According to him, this is one of the proposed method's greatest direct benefits and will make the decision-making process more transparent. He feels that the interaction between services that lead to the end goals will be made visible. The flaws he mentioned related to the subjectivity of the dependencies between services and the weights attributed to them. He believes that the new method will not decrease the political processes without clear guidelines.

4.4 Practical application (unscheduled down process)/workshop

As mentioned under *difficulties/problems*, the lack of a complete architectural model of ASML was one of the largest issues I needed to deal with. The scope for the practical application was narrowed down to one specific process within CS in order to create a simplified model that is easy for most people to understand and does not add too much information that is not needed explaining and testing the prioritization method.

To overcome the problems mentioned, I invited several people within CS and IT (see table 4) to assist in creating the ArchiMate model I needed for the case. This was a difficult job given that most people only know one part of the ArchiMate model or do not use the same modeling language and structure as mentioned in this thesis.

As my first attempt was not as fruitful as I expected I also arranged a workshop with the people I had interviewed earlier as part of the *content group*. The process I followed for this workshop is presented below.

Process

For the setup of the workshop I used a similar process as during the interviews. Instead of asking questions and start a discussion at the end, we went together through the steps of the proposed method in a workshop setting. The workshop had two main parts and duration of two hours.

- Recapitulate the prioritization method I had presented to them earlier.
- Provide details and expectations for each step, following the same steps as in the example.

As input for this workshop I made an ArchiMate model of the unscheduled down (USD) process based on the conversations I had with several people form CS and IT. In the model I only included those components and services that I was totally sure of, I kept those, I was not completely sure of, in mind as input for the discussions during the workshop. In order to make it easy to work on the ArchiMate model together, I printed the model in A0 and put it on the wall.

** Time issues made it impossible to completely go through all of the prioritization model's steps. However, after the workshop we agreed that if all boundary conditions are met, the new approach could have several merits.*

Results

In general I believe that the workshop yielded a great deal of fruitful information, insights and discussions. The benefits of the new proposed method became clearer to me and the participants as the discussion progressed.

The results of this session are presented in *Appendix I*. They may seem somewhat disappointing but I still think the session represented a good step in the right direction. During the workshop session, consensus was reached on a couple of topics, namely:

- ***The ArchiMate model created for the USD process;***
- ***Use of PIs in the services only;***
- ***Use of identical PIs in all the layers; and***
- ***Use of four PIs, namely: Quality, Availability, Capacity and Performance***

4.5 Results

In this section, the results of the *case* study are used to provide a general overview of the following topics:

- **Results on objectives**
- **Political processes vs. rationality**
- **Feasibility of the method**

Results on objectives

In the introduction to this chapter the following objectives were mentioned:

1. To investigate what information is necessary to use the proposed method in its entirety;
2. To investigate how to determine which PIs are important and how to determine the influence factors;
3. To investigate if the proposed method is feasible for the stakeholders; and
4. To investigate the limits of such a rational approach for decision-making.

Due to the difficulties and problems during the case study not all objectives are fulfilled. However, we know what information is necessary is needed to fill the proposed method. Due to the interviews and workshop we know that when boundary conditions are met the method can be feasible. The limits of the method are reached when criteria or influence rates cannot be objectively determined.

Political processes vs. rationality

Political processes will never be erased from a decision making processes and that will also be the case at ASML. However, the proposed method will increase rationality and establish more transparency. This is made possible installing the causal chains in the ArchiMate model. The rational parts will become clear, but also the less rational parts. Enhancing the amount of rationality in the decision-making process eventually leads to higher quality decisions.

Feasibility of the method

The feasibility of the method depends on a lot of boundary conditions. So, the proposed method is feasible unless these boundary conditions are met. First, the method need guidelines how to determine; PIs, scores and influence rates to maintain objectivity. Second, organizations should have a certain maturity level in order to make full use of the proposed method. In the recommendations section more information about these maturity levels is given.

5. Conclusions and recommendations

This chapter begins with the study's overall conclusions, which are then used as the basis for recommending next steps for ASML to take. The chapter ends with some suggestions for future research and directions for further exploring this prioritization method.

5.1 Conclusions

This conclusions paragraph starts with a general conclusion on decision-making surrounding IT investments. On an abstract level it shows the theoretical and practical conclusions and already some brief recommendations. The subsequent subsection gives answers to the research questions and central research question of this thesis.

General

(IT) decision-making can be seen as a balance between the amount of ratio involved and the amount of non-rational parts (e.g. political processes). The preposition of this thesis is that increasing ration should decrease the less rational parts of the decision-making process and thereby increasing the quality of the decisions.

During the interviews held at ASML and the practical application of the method (including the workshop session) I found some confirmation that the proposed method potentially could contribute the following parts; provide more and better information, increase transparency of the tradeoffs and thereby giving also insight in the less rational parts of the current decision-making process.

As I said, the method could potentially increase the quality of IT investment decisions. During the *case study* I also found out that the proposed method has some boundary conditions which need to be fulfilled in order to use the method properly. Guidelines are needed in order to guarantee objectivity in the process. Organizations should commit on guidelines regarding; how to determine which PIs are important for them, how these PIs can be scored and about the way they determine the influence rates between these PIs.

Besides, the aforementioned guidelines does the method require a certain maturity level (three or higher) in order to make full use of the proposed method (or parts of it). The proposed method has the potential to increase rationality and thereby decrease the less rational parts (e.g. political processes). By following such a procedural rational approach as presented in the method the quality of the decisions should be increased. However, as mentioned earlier requires the method knowledge about the process surrounding IT investment decisions.

The paper "*Measuring and Managing Technological Knowledge"* by Bohn (1994) describes a scale for measuring knowledge about a process. According to Bohn ranges a company's knowledge about a process from total ignorance to very formal and accurate mathematical models (complete understanding). Knowledge about a process allows organizations to make predictions, causal associations, or predictive decisions about what to do (Bohn, 1994). As there is always some uncertainty in the process full knowledge could never be reached.

At ASML the following definition of organizational maturity is used: *"Organizational Maturity is the level of an organizations readiness, ability and experience to efficiently perform a given task".* This gives a strong relation between theory and practice and links with the paper of Bohn (1994).

In order to show how mature ASML is in a certain competence or process (i.e. how much knowledge do we have of the process), ASML uses the CMMI Maturity Model. CMMI is an acronym for Capability Maturity Model Integration and is developed by the Carnegie Mellon University and has his origin in the software development (Kulpa & Johnson, 2008). Section 5.2 provides more information about the CMMI Maturity Model and fills the model for the purpose of this thesis; a maturity model for decision-making surrounding IT investments.

Answers to the research questions

1. What is the current state of research on prioritizing a portfolio of IT investments using MCA and Enterprise Architecture?

   I showed why current prioritization methods not completely fulfill the requirements. It was also made clear that in order to show how organizations could create IT based value from their IT investments, EA is an indispensable part of the solution. Current literature already tries to use EA in combination with MCA. The method proposed in this thesis build on prior research and searched to make it practically useful.

2. How could the MCA method be improved on previously researched strength and weaknesses?

   The proposed method in this thesis built on a previous developed method. Two adjustments are made to better meet the requirements set from the field. Building on the work of Buschle and Quartel (2011), performance indicators and influence rates were added. Both extensions were needed in order to create the causal model necessary for rational decision-making.

3. Is the method developed using MCA and Enterprise Architecture feasible for decision-makers?

   The method will be feasible for decision-makers, but in order to be feasible guidelines are necessary to ensure objectivity. Besides, a certain maturity (i.e. level 3 or higher) of the organization required in order to make full use of the proposed method.

4. What are the limits of a rational approach for IT investment decisions?

   The method reaches its limits when objectivity is replaced with subjectivity or gut feeling. This relates to the earlier mentioned guidelines (boundary conditions). If organizations are not able to objectively determine PIs, scores and influence rates, the proposed method will serve as a platform where decision-makers could execute their political behavior.

Main research question

What is the contribution of a MCA approach using Enterprise Architecture to IT project prioritization?

Using the method proposed in this thesis, gives the decision-makers the possibility to show the contribution investment options have on the goals of organizations. Given that the method make use of a causal model contributes to rational decision making which should enhance the quality of these decisions.

5.2 Next Steps for ASML

The conclusion section above made clear that in order to make the proposed method to a success within ASML a certain maturity level is needed. CMMI is presented to give shape to the different maturity levels in decisions-making surrounding IT investments. This section is structured as follows; first it will give general information about the five maturity levels in the CMMI model. Then the maturity model regarding IT investment decisions will be given and the current level of ASML. This section will end with a high level roadmap for ASML. CMMI defines the following maturity levels, given in figure 33.

Levels:	1. Initial	2. Managed	3. Defined	4. Predictable	5. Optimizing
Description:	• Almost no repeatable process. • Reactive Management.	• Process dependent on individuals.	• Standard processes are defined and institutionalized.	• Standard processes. • Proactive managed based on metrics.	• Feedback loops are in place to update standards.

Figure 33 - Maturity levels CMMI

The general descriptions for the various levels of CMMI are used to develop the CMMI model for IT investment decisions, depicted in figure 34. From the model presented below the current maturity level of ASML can be retrieved. This is displayed in figure 35.

Levels:	1. Initial	2. Managed	3. Defined	4. Predictable	5. Optimizing
Description:	• No consistent process defined.	• Enterprise Architecture not in place. • Basic MCA • Driven on knowledge of the decision-makers.	• Common Language for Business and IT (ArchiMate) • Enterprise Architecture models are in place. • Decision preparers know what EA and Archimate are and how to work with it.	• Service Oriented Architecture modelled in the right way. • Known what services are important for every layer in the EA. • Service Level Agreements defined on the services in the architecture. • Commitment on the performance indicators and organizational goals.	• Influence between performance indicators installed. • Determined on which level PI's of Service are influences by other PI's. (Influence rates)

Figure 34 - CMMI Model for IT investment decision-making

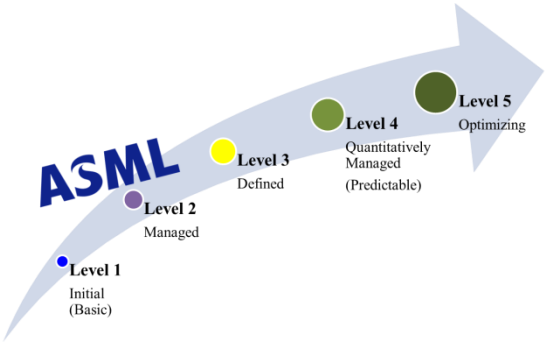

Figure 35 - Capability Maturity Model Integration

ASML first needs to decide if they want to continue with this research. If they wish to continue with the method the following steps needs to be taken into account. [redacted], [redacted] [redacted] [redacted] [redacted]. [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted].

ASML is on the right track. In order to make full use of the proposed method the below roadmap can be used. This can be a long, time consuming process given that only creating an ArchiMate repository requires a lot of time and money from a company.

Figure 36 - High-level roadmap to increase maturity level

5.3 Future research

This research was a first attempt to test the proposed prioritization method in a practical setting. As known ASML should grow in maturity if they want to prioritize their IT investment options using the method proposed in this thesis. This subsection will give some directions for future research with the intention to strengthen this research topic.

First, I think that Enterprise Architecture can be seen as an indispensable part in *prioritizing a portfolio of IT investments*. In order to show the contribution of certain IT investments on the goals of an organization enterprise architecture (EA) is a necessary component.

One direction for future research could focus on current decision-making surrounding IT investments. If a research should take the Netherlands in their test case, what percentage of companies currently uses EA and also what percentage uses EA in their IT investment decisions? Another interesting question could focus on the reasons to use or not to use EA. Is it purely a financial aspect or are there other aspects that withhold organizations to use EA.

Another interesting direction for future research could be finding the connection between the following three topics; S*ervice Oriented Architecture (SOA), Service Level Agreements (SLAs), Service Level Reports (SLRs) and combined business/IT reporting.*

Could a better collaboration between these three topics enhance the prioritization method proposed in this thesis? Is it possible to increase the relation between these topics?

Third research direction could focus on applying the proposed method in another organization with a higher maturity level regarding EA modelling. A case study could then be used to determine the details of the proposed method. Questions might be; Are the four performance indicators mentioned in this thesis sufficient? Do we also need performance indicators in the component of the architecture instead of in the services only? Is it possible to objectively determine the influence rates between the performance indicators?

Finally, as mentioned in section 5.2 does this method require a couple of changes in the decision-making process and also in the organization self. Changes always have to deal with resistance in the organization. A research could focus on how change management could facilitate a smooth transition.

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Appendix A: Enterprise architecture and modelling language ArchiMate

Enterprise Architecture

Enterprise architecture plays a central role in the prioritization method proposed in this thesis. It is therefore important to know what EA is, how it adds value to a company and the way in which it supports the rationalistic view on decision-making. In the introduction of this research it is stated that while causality is elusive, it is difficult to show the business value created by IT investments. We could understand how to create value by extending our knowledge of the complementary and mediating factors that create this value (Kohli & Grover, 2008). The prioritization method proposed in this thesis makes use of EA to provide a holistic overview of the organization and make the causal chains visible in order to show how investment options create business value.

It is necessary to understand the basics of EA before its connection with the prioritization approach may be understood. Architecture raises many meanings itself, and even more when it is used in combination with another term. In IT, the term is also used both appropriately and inappropriately. The addition of another term to architecture should indicate the topic the architecture relates to. To achieve a more common understanding the following definition is used for EA.

Lankhorst defines EA as "a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure" (Lankhorst M. , 2009, p. 3).

Enterprise architecture should focus on the coherence of the organization, business, information, applications and technical infrastructure. Using EA in this way reveals the organizational structure and coherence from a broader vision than solely IT and can add great value to the organization. The emphasis is on using EA as a management-tool, due to the growing importance of flexibility, transparency and complexity control within organizations (Rijn, Driel, Gils, Oord, & Santema, 2013).

ArchiMate

To provide a structure and frame for the EA that forms the core of this research, I make use of the ArchiMate language. This language has been developed by a project team from the *Telematica Instituut* in cooperation with several Dutch partners from government, industry and academia. Today, ArchiMate is part of *The Open Group*, which is a consortium of large companies within the IT sector. *The Open Group* acts as a standardization organization and focuses on the development and management of open IT standards.

The ArchiMate modeling language deconstructs an organization along two orthogonal dimensions: layers and aspects. The layer concept depicts the different abstraction levels at which an organization can be modeled.

<u>The layer dimension distinguishes between three main layers:</u>

- **The business layer,** offers products and services to external customers that are realized by business processes in an organization;
- **The application layer,** which is supported by application services realized by (software) application components; and
- **The infrastructure layer,** which (as the lowest and the technology layer) provides the infrastructure services (e.g. processing, storage and communication), needed to run the applications one level above. These services are realized by system software and communication devices.

Aspects, on the other hand, represent the different concerns of an organization that need to be modeled (Quartel, Engelsman, Jonkers, & Sinderen, 2009).

<u>The aspect dimension distinguishes between the following modeling aspects:</u>

- **Information (passive structure),** which represents the objects on which behavior is performed;
- **Behavior,** which represents the processes and services performed by the actors and the way in which they interact; and
- **Structure (active),** which represents the actors involved and how these relate to each other (e.g. systems, components, people, department, etc.) and how they relate to each other.

The aspect dimensions and the different layers in the ArchiMate language can also be found in the picture below.

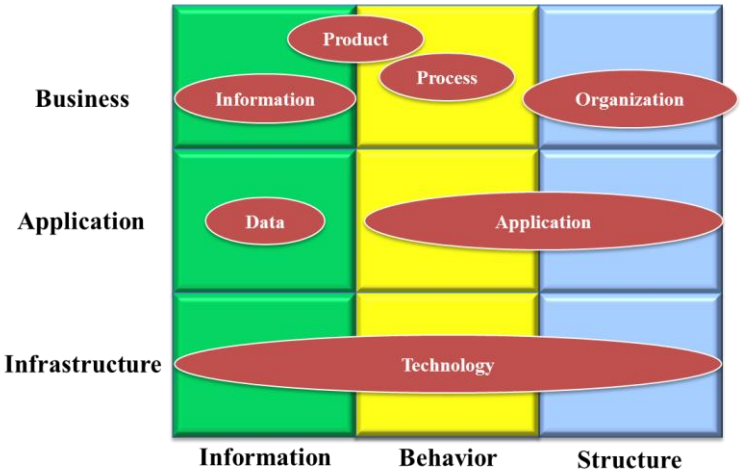


Figure A1 - ArchiMate modeling framework (Quartel, Engelsman, Jonkers, & Sinderen, 2009)

Dimensional structuring makes it possible to model an organization from different viewpoints. The position along each dimension is characterized as the modeling viewpoint. (Quartel, Engelsman, Jonkers, & Sinderen, 2009) For the purpose of this thesis I use the ***behavior viewpoint*** for all three layer dimensions, given that we only need the *infrastructure & infrastructure services, application components & application services, business processes and business services* of the ArchiMate framework.

Appendix B: Determining the importance scores for Bedell's method

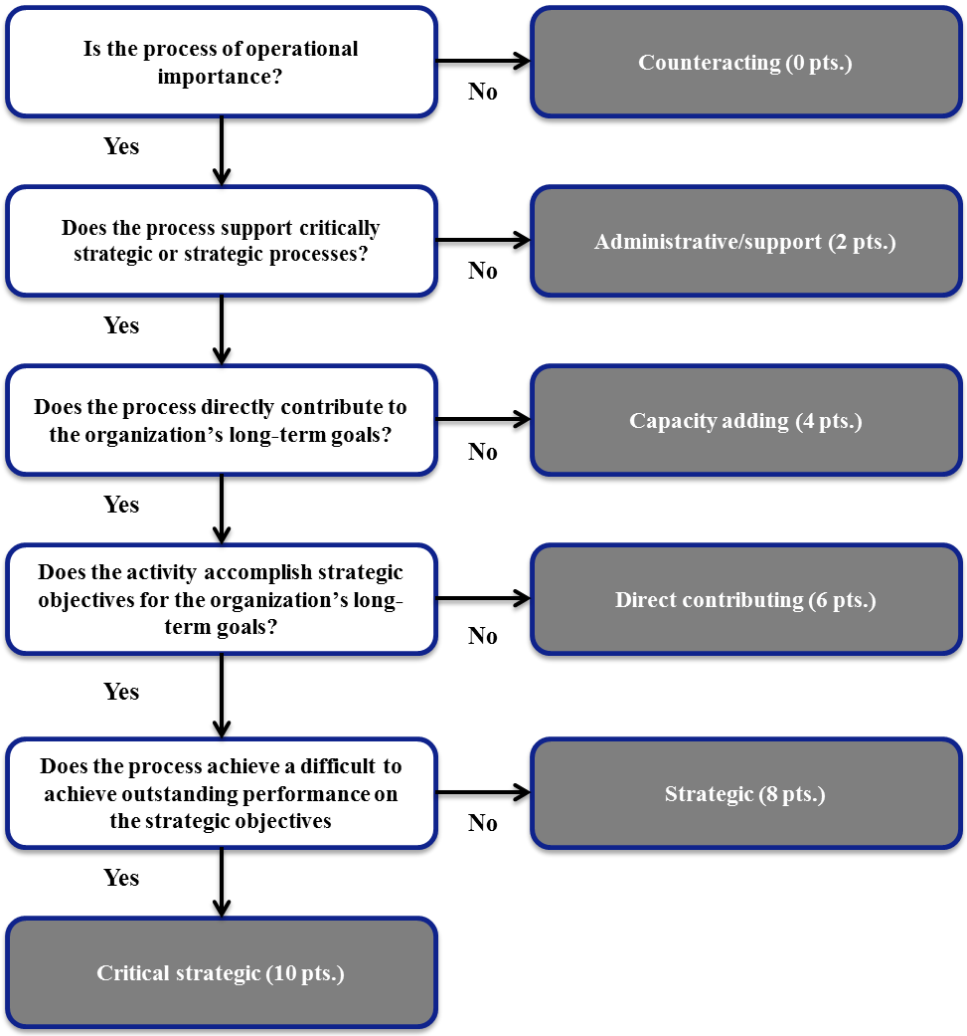


Figure B1 - Determining strategic importance scores (based on Bedell 1985) (Schuurman, Berghout, & Powell, 2008)

Appendix C: Explanation of the calculations made Bedell's method

In a bottom-up approach, the effectiveness of an information system (IS) in relation to the activities is adjusted on a step-by-step basis for the level of importance of IS to the intended organizational level. The results are combined into portfolios that are then assed top-down. This appendix describes the equations necessary at each step to calculate the portfolios (Schuurman, Berghout, & Powell, 2008).

The first step entails calculating the effectiveness of the single IS in relation to the business processes (ESB). This is done by weighting the effectiveness of the single information system to the activity (ESA) by the activity to the business process it supports (IAB).

Equation 1)

ESB = ESA * IAB

IAB = Determined using the model in Appendix A.
ESA = Determined by IS management in cooperation with the business organization based on their perception of the cost-effectiveness, technical quality, and functional appropriateness.

After the effectiveness of IS on the several business processes is determined, the separate calculations can be combined in order to calculate the total effectiveness of IT in supporting the business processes (EIB). This can be done by dividing the effectiveness scores of the information systems into the business processes by the importance scores of the activities to the business processes.

Equation 2)

$$\mathbf{EIB} = \frac{\sum(\mathbf{ESB})}{\sum(\mathbf{IAB})}$$

In order to move a level up, the effectiveness of the information systems to the organization (ESO) can be calculated by weighting the effectiveness scores of the information systems into the business processes by the importance scores of the business processes to the organization (IBO).

Equation 3)

$$\sum (ESO) = \sum (ESB * IBO)$$

As systems can only contribute to the organization via the activities they enhance we also need to calculate the importance of the activities to the organization. The importance of the activities to the business processes are therefore also weighted against the importance of the business processes to the organization.

Equation 4)

$$\sum (IAO) = \sum (IAB * IBO)$$

After both the effectiveness of the information systems and the importance of the different activities to the organization are calculated, we should also be able to determine the total effectiveness score of IT to the organization. This can be done by dividing the effectiveness scores of the information systems into the organization by the importance scores of the activities to the organization.

Equation 5)

$$EIO = \frac{\sum(ESO)}{\sum(IAO)}$$

In order to calculate the *focus factor* (FF), the importance of the business processes to the organization needs to be weighted against the importance of IT to the business processes.

IIB = Determined by management by taking the maximum scores of IAB for each business process.

Equation 6)

$$FF = IBO * IIB$$

One additional calculation needs to be made before we can begin to assess the portfolios. Equation 7 calculates the future potential of information systems to the organization by dividing the FF by the importance scores of the business processes to the organization.

Equation 7)

$$\mathbf{IIO} = \frac{\sum(\mathbf{FF})}{\sum(\mathbf{IBO})}$$

After the above calculations have been made, it should be possible to create the three different portfolios by applying the right variables. *Appendix C* provides a sample calculation in which the portfolios are incorporated.

<u>Portfolios:</u>

- **Vertical axis/Horizontal axis**

- Importance of IT to the organization/Effectiveness of IT to the organization (organizational level)
- FF/Effectiveness of IT to the business process (business process level)
- Importance of the activity to a certain business process/Effectiveness of the system to a certain business process (activity/information system level)

In order to prioritize the improvements, we first need to determine the to-be effectiveness of the information systems. Once the to-be effectiveness is known, it is possible to calculate the added effectiveness of the improvements.

Equation 8)

$$\mathbf{Added} = (\mathbf{ESA_1} - \mathbf{ESA_0}) * \mathbf{IAO}$$

The *project return index (PRI)* provides an overview of the improvements. To calculate the PRI, the added effectiveness is divided by the realization and exploiting cost.

Equation 9)

$$\mathbf{PRI} = \frac{\boldsymbol{Added}}{\mathbf{Cost}}$$

The main purpose of Bedell's method is to bring the effectiveness of IT to the organization as close as possible to the importance of IT to the organization. The organization should therefore best select those improvements that would bring the future effectiveness of information systems to the organization closest to the importance.

This can be done by dividing the total of PRIs for the **chosen improvements** by the total importance of the activities to the organization.

Equation 10)

$$\mathbf{EIO_1 = EIO_0 + \frac{\sum(PRI)}{\sum(IAO)}}$$

Appendix D: Sample calculation of Bedell's method

To demonstrate how Bedell's method works, I use the same example as in the paper by Schuurman, Berghout and Powell (2008). This example uses a fictitious banking organization to describe the different steps that need to be taken select which projects to invest in. The process contains a total of 10 steps, each of which is clearly described below.

<u>Description of the banking company:</u>

Name: International Banking Group (IBG)

The four business processes that are relevant to IBG:

- Asset management
- Transaction banking
- Retail banking
- Services

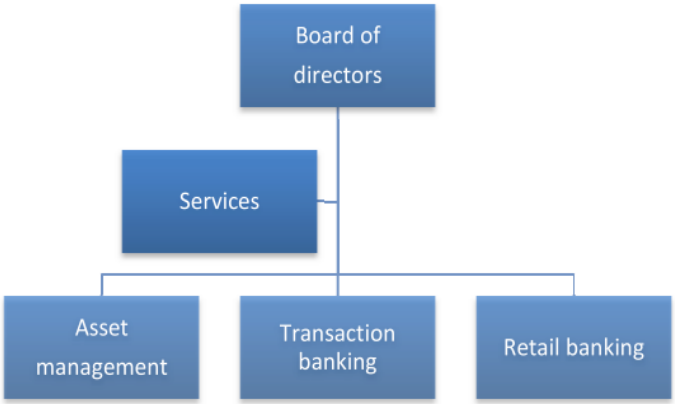


Figure D1 - Organizational diagram of a fictitious banking organization. (Schuurman, Berghout, & Powell, 2008)

Step 1: Determine the importance of all business processes to the organization (IBO)

This assessment is done by the board of directors using the diagram in *Appendix B.*

Business Process		IBO
Asset Management		10
Trasaction Banking		8
Retail Banking		6
Services		2

Figure D2 - IBO scores for IBG

Step 2: Determine the importance of all activities to the business processes (IAB)

The managers responsible for the respective business processes determine these importance scores using the same diagram as used in step 1 (see *Appendix B*).

Business Process	Activities	IAB
Asset Management	Trading	5
	Mergers & Acquisitions	10
	Risk Management	10
Trasaction Banking	Operations	10
	Policy & Portfolio	10
	MIS	5
Retail Banking	Private Banking	5
	Corporate Clients	10
	Bankshops	5
Services	Finance & Risk Management	1
	IT	1
	HRM	5

Figure D3 - IAB scores for IBG

Step 3: Determine the effectiveness of the current systems in place for the different activities

These effectiveness scores are determined jointly by managers from IT several business processes. The diagram from *Appendix B* is again used. It can be seen that several activities (i.e. the systems supporting these activities) have an effectiveness score of zero. The underlying reasons range from efficiency failures to total lack of (computerized) information systems.

Business Process	Activities	IAB	ESA
Asset Management	Trading	5	5
	Mergers & Acquisitions	10	0
	Risk Management	10	5
Trasaction Banking	Operations	10	5
	Policy & Portfolio	10	5
	MIS	5	10
Retail Banking	Private Banking	5	10
	Corporate Clients	10	2
	Bankshops	5	0
Services	Finance & Risk Management	1	5
	IT	1	5
	HRM	5	10

Figure D4 - ESA scores for IBG

Step 4: Calculate the effectiveness of the single systems on the business processes and the effectiveness of IT on the business process

Multiplying the importance of the activities by the business processes and the effectiveness of the information systems to the activities yields the effectiveness of the information systems to the business processes (ESB).

Business Process	Activities	IAB	ESA	ESB
Asset Management	Trading	5	5	25
	Mergers & Acquisitions	10	0	0
	Risk Management	10	5	50
Trasaction Banking	Operations	10	5	50
	Policy & Portfolio	10	5	50
	MIS	5	10	50
Retail Banking	Private Banking	5	10	50
	Corporate Clients	10	2	20
	Bankshops	5	0	0
Services	Finance & Risk Management	1	5	5
	IT	1	5	5
	HRM	5	10	50

Figure D5 - ESB scores for IBG

Combining these calculations enables us to determine the effectiveness of IT for the different business processes (EIB). This is done by dividing the sum of all ESB scores by the sum of all IAB scores.

Business Process	∑(ESB)	∑(IAB)	EIB
Asset Management	75	25	3.0
Trasaction Banking	150	25	6.0
Retail Banking	70	20	3.5
Services	60	7	8.6

Figure D6 - EIB scores for IBG

Eventually it is our intention to calculate the current effectiveness of IT to IBG. However, in order to do so we must first calculate the effectiveness of the systems to the organization (ESO) and the importance of the activities to the organization (IAO). Dividing the total of ESO by the total score of IAO yields the current effectiveness of IT to IBG (EIO).

Business Process	∑(ESB)	∑(ESO)	∑(IAB)	∑(IAO)	EIB
Asset Management	75	750	25	250	3.0
Trasaction Banking	150	1200	25	200	6.0
Retail Banking	70	420	20	120	3.5
Services	60	120	7	14	8.6
Total:		**2490**		**584**	
	EIO	**4.3**			

$$EIO = \frac{\sum(ESO)}{\sum(IAO)}$$

$$\sum(ESO) = \sum(ESB * IBO)$$

$$\sum(IAO) = \sum(IAB * IBO)$$

Figure D7 - EIO score for IBG

Step 5: Determine the potential importance of the information systems to the business processes and calculate the FFs and the potential importance of the information systems to the organization

These potential importance scores are determined based on the information from the previous steps as well as market knowledge. Here IBG decided to make the process less complex by taking the maximum IAB scores for each business process.

Business Process	IBO	IIB
Asset Management	10	10
Trasaction Banking	8	10
Retail Banking	6	10
Services	2	5

Figure D8 - IIB scores for IBG

In order to calculate the importance of an information system (IIO) to IBG, we should first calculate the FF. This can be done by multiplying IBO with IIB.

Business Process		IBO	IIB	FF
Asset Management		10	10	100
Trasaction Banking		8	10	80
Retail Banking		6	10	60
Services		2	5	10
Totaal:		26		250
	IIO	9.6		

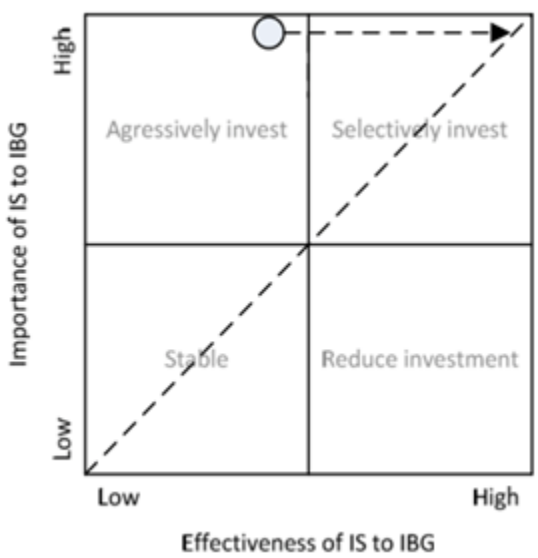
$$FF = IBO * IIB$$

$$IIO = \frac{\sum(FF)}{\sum(IBO)}$$

Figure D9 - FF scores for IBG

Step 6: Determine whether to invest in information systems as a whole

Creating the highest level portfolio enables us to determine if IBG should invest in IT as a whole. The importance of IT to IBG gives us the *to-be* situation, while the current effectiveness of IT to IBG provide us with the *as-is* situation. The idea behind Bedell's method is that effectiveness and importance should score equally (see the dotted diagonal from lower-left to upper-right in the below figure).



In line with the "aggressively invest" quadrant, it would be advisable for IBG to try to create an additional overall effectiveness of 5,3 (9,6-4,3).

Figure D10 - Organizational level portfolio

Step 7: Determine which business processes to make (IT) investments in

The next portfolio provides us with information about which business processes are most in need of improvements. It can be seen that *asset management and services* diverge in particular quite a lot from their ideal ("positive and negative").

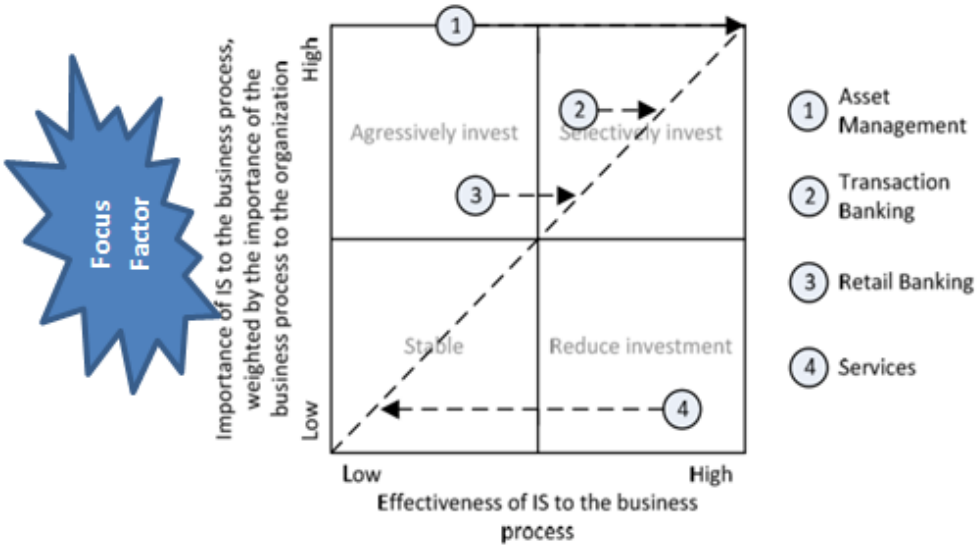


Figure D11 - Business process level portfolio

Step 8: Determine which activity to invest in for the business process

In this last portfolio, we use the example of *asset management*.

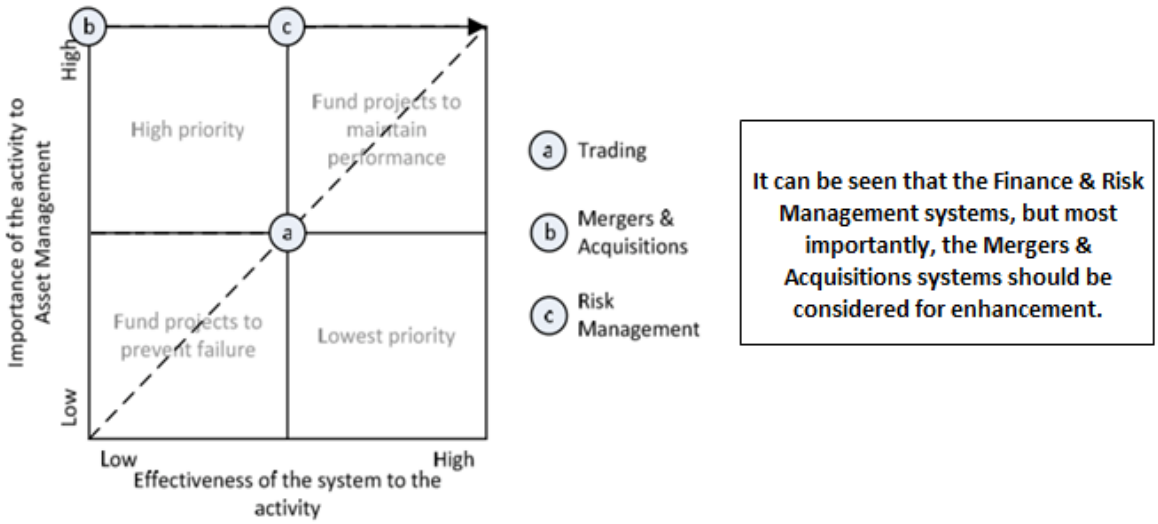


Figure D12 - Activity level portfolio

Step 9/10: Select investment proposals

In the last phase of the portfolio management cycle, IBG must decide which project proposals to implement (naturally, smaller changes could also be assessed).

Business Process	Activities	ESA	ESA'	Cost (K€)
Asset Management	Trading	5	10	100
	Mergers & Acquisitions	0	5	300
	Risk Management	5	5	-
Trasaction Banking	Operations	5	5	-
	Policy & Portfolio	5	10	50
	MIS	10	10	-
Retail Banking	Private Banking	10	10	-
	Corporate Clients	2	2	-
	Bankshops	0	5	120
Services	Finance & Risk Management	5	5	-
	IT	5	10	75
	HRM	10	10	-

!! Note that even though the *Services* business process is far from needing investments, a project was proposed in this area.

Figure D13 - ESA' (i.e. to-be situation) for IBG

Prioritizing is based on the level of added effectiveness per invested euro!!

Business Process	Activities	IAO	ESA	ESA'	Added "ESO"	Cost (K€)	PRI
Asset Management	Trading	50	5	10	250	100	2.50
	Mergers & Acquisitions	100	0	5	500	300	1.67
Trasaction Banking	Policy & Portfolio	80	5	10	400	50	8.00
Retail Banking	Bankshops	30	0	5	150	120	1.25
Services	IT	2	5	10	10	75	0.13
				Total (Trading & Acquisitions / Policy & Portfolio):	650		
				Total:	1310		

$$\text{Added} = (ESA_1 - ESA_0) * IAO$$

$$PRI = \frac{Added}{Cost}$$

Figure D14 - Added ESO and PRI

EIO	4.3	
EIO'	5.4	If only the projects for "Trading" and "Policy & Portfolio" are done.
EIO'	6.5	If all projects are done.
IIO	9.6	

Figure D15 - EIO' scores for different project portfolios

As a project to be realized is dependent on the available resources, IBG should always keep less ambitious ESAs and less expensive scenarios in mind; after all, they might have a better PRI.

Appendix E: Case description of a fictitious power utility firm

This case description is copied from a paper of Buschle and Quartel (2011). It provides details of a case study performed at a Swedish power utility firm in September 2009. For ease of use, only a sub-set of the activities exploited at the utility are considered in this context. The utility owns part of the Swedish power network and has several thousand customers.

The utility offers three **business services**: a network load dashboard, rate advice and energy saving advice.

1. The network load dashboard business service is used with the aim of evaluating the current state of the electricity network.

Business process:

- **Dashboard coordination**

Application services: In order to realize the business process of dashboard coordination, the utility uses three application services:

- **Real time monitoring**, which entails monitoring the current state of the network;
- **Forecasting,** which involves forecasting how the power network will perform in the future; and
- **Statistics,** which are used to evaluate how the electricity network behaved in the past.

Applications:

- **Network load monitor**
- **Network load analyzer**

Infrastructure services:

- **Measurement database**
- **Statistics database**
- **High-performance computation**

Infrastructure:

- **Database and data collection server**
- **High-performance computation server**

2. The rate advice business service aims to help the utility's customers find the best rates based on their individual consumption profiles. The utilization of the electricity network is also considered, as the utility is able to offer lower rates in times of lower utilization.

Business process:

- **Tariff advice process**

Application services:

- **Statistics**: Used indirectly via customer advisor **(Application)**
- **Consumption profile**
- **Select tariff**

Application:

- **Consumer advisor**

3. The energy saving advice business service supports the customer in saving energy. It takes the profile a user has stored in his or her individual account on the utility's webpage into account. Based on the customer's preferences, an individual mix of fossil, nuclear and renewable energy is suggested.

Business process:

- **Energy saving advice process**

Application service:

- **Customer info**

Application:

- **CRM**

Infrastructure service:

- **Computation**
- **Customer database**

Infrastructure:

- **Linux server**

Organizational goals: The utility has the overall goal of being **profitable,** which should be achieved on a satisfied customer base (sub-goal **customer satisfaction)** and a minimal reserve capacity (sub-goal **minimize reserve capacity)** in which the main goal is decomposed into.

Customer satisfaction (decomposed into):

- Maximize availability
- Achieve the lowest cost
- Provide insight into consumption

- **The network load dashboard business service** contributes to two goals (*minimizing reserve capacity and maximizing availability)*, seeing as the utility's employees use it to identify an optimal overcapacity.

  - **Minimize reserve capacity**
  - **Maximize availability**

- **The rate advice business service** contributes to the *lowest cost* sub-goal as it helps the customer to identify the best rate.

  - **Lowest cost**

- **The energy saving advice business service** contributes to the sub-goal *insight in consumption*

  - **Insight into consumption**

Investment options

1. In order to improve customer satisfaction, we would like to provide customers with more insight into their energy consumption by providing them access to real-time data pertaining to their individual situations. In order to do so, we need to develop a supporting application. Furthermore, in order to secure enough data space and computational power, we also must replace the data collection server with a more sophisticated model. The cost of developing and maintaining the application is approximately €85,000 (maintenance costs for the coming three years discounted in the price), while the new server costs approximately €10,000.

2. An additional project might be to purchase another high performance computation server, which would decrease the possibility of downtime and thereby increase customer satisfaction (and reduce costs of loss of data or downtime). Such a server costs approximately €15,000. Another €15,000 would be required to implement synchronization and perform maintenance.

Appendix F: Visual representation of the investment options

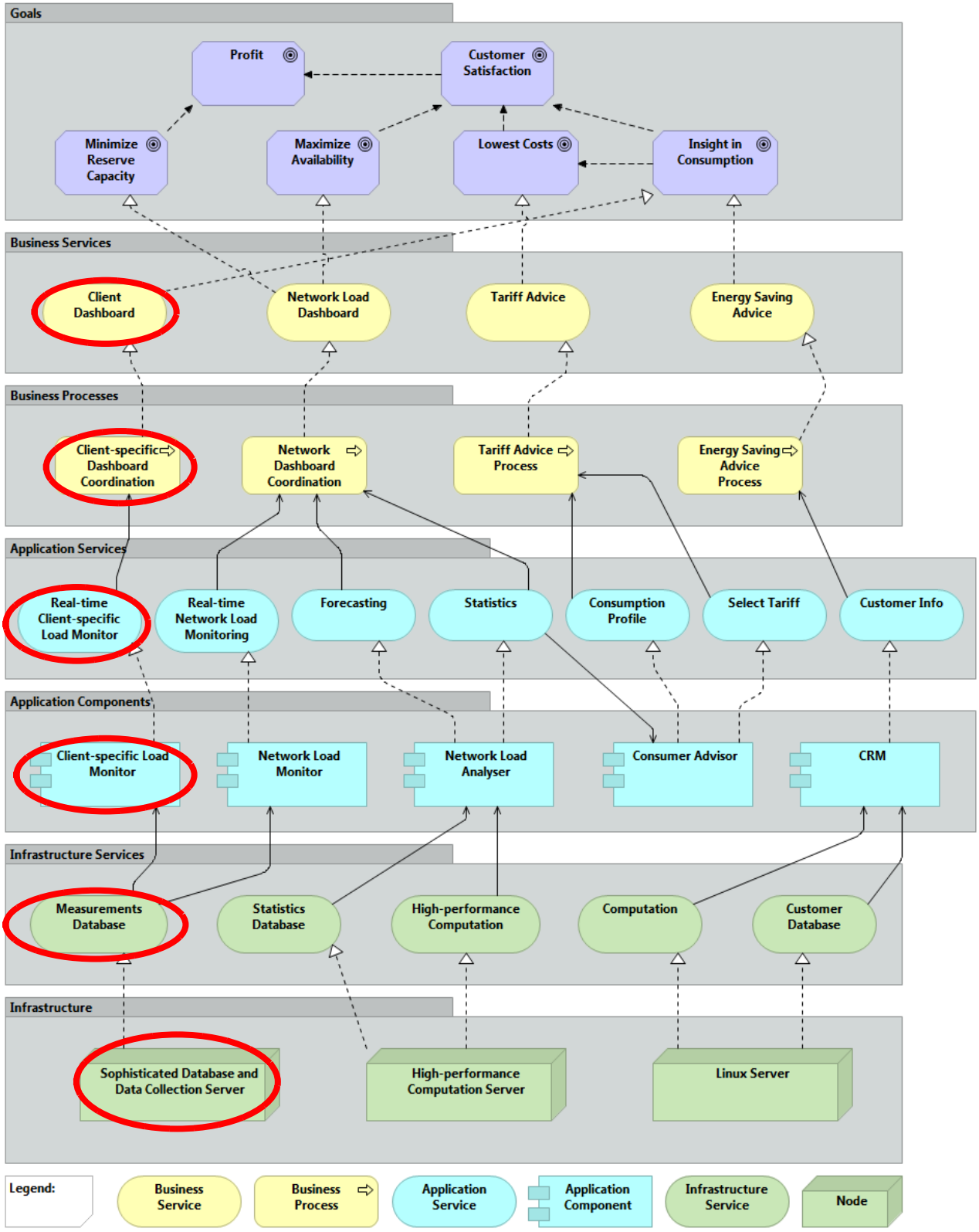


Figure F1 - Investment option 1

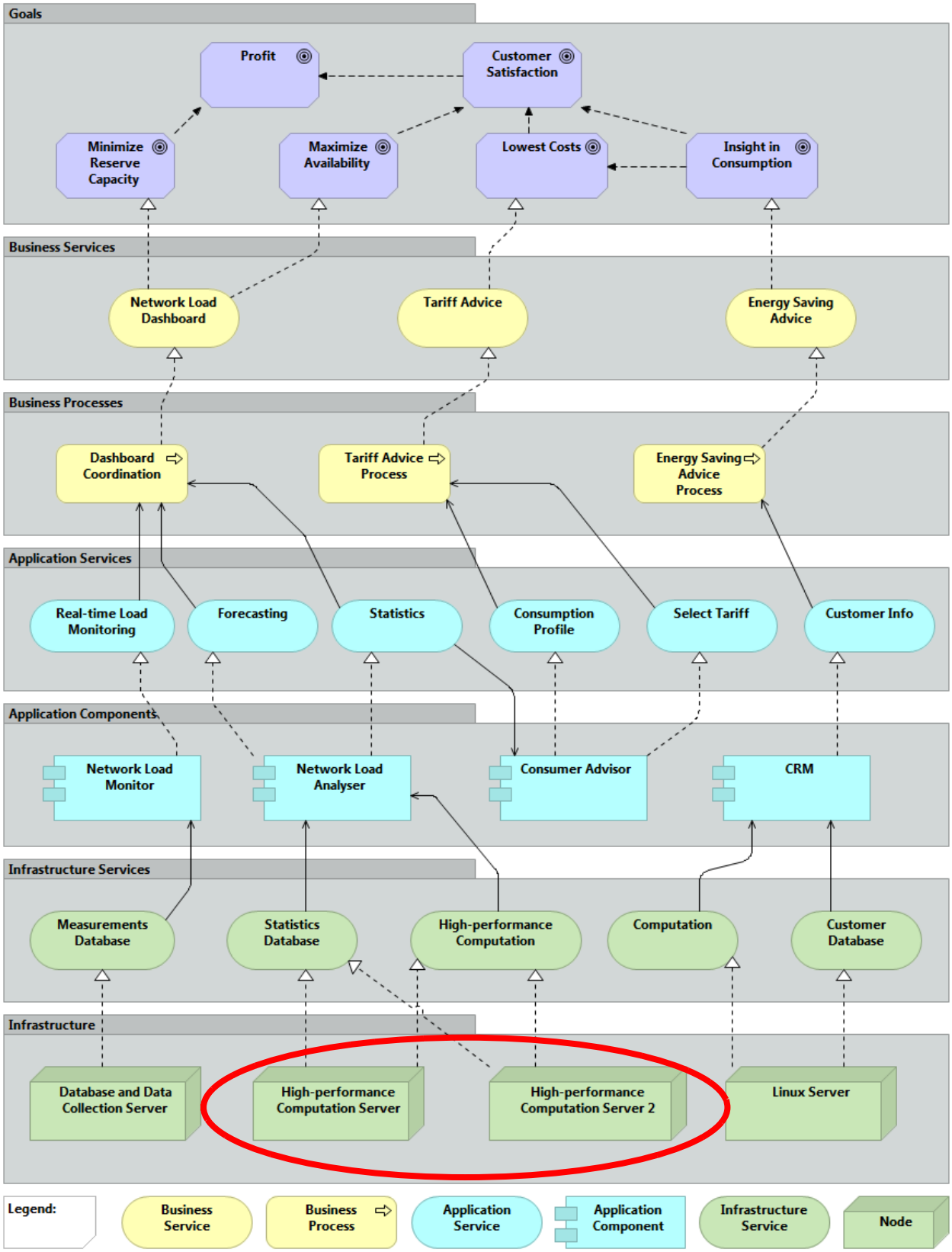


Figure F2 - Investment option 2

Appendix G: Detailed process steps semi-structured interviews

During the semi-structured interviews, I used almost the same introductory presentation for the people from the decision and content groups; only the discussion and end questions were slightly different. This is logical given that I expected slightly different inputs from both groups. The process I used was as follows:

- **Introduction**

The interviews started with mutual personal introductions. I then presented a general introduction to the research topic and explained the reasons why it had been chosen.

- **Problem statements**

I next began explaining why ASML needs a different approach for prioritizing its portfolio of IT investments. I provided some problem statements relating to the current approach and demonstrated what the results may be.

The problem statements I mentioned in my presentation were as follows:

- The current decision-making process is not considered transparent, and politics may influence outcomes.
- It is not always apparent why certain investment options contribute more to our organizational goals than others.
- A lack of information sometimes leads to decisions that are not entirely obvious for all decision-makers.

I suggested that the results might be:

- That we do not execute the right projects;
- That we do not spend our money effectively; and
- That the decision-making process lacks a backbone.

- **How to solve this problem**

Thereafter I presented a brief overview of the solution's main direction. I introduced EA as part of the solution and state that the relations in the EA could be used to create a causal model that should provide us with insight into the extent to which certain IT investments contribute to our organizational goals. I noted that reason (i.e. rationality) would serve as the primary source of judgment. In order to make this visible I used figure G1 in my slide.

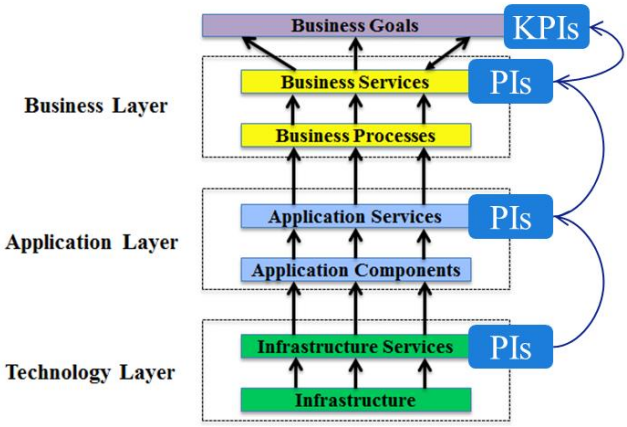


Figure G1 – Visual representation of the proposed method

- **EA (ArchiMate)**

To provide better insight into what I exactly meant with EA and the ArchiMate modeling language, I used the slide included in the figure below. I also showed the parts of ArchiMate that are required in order to use the method properly.

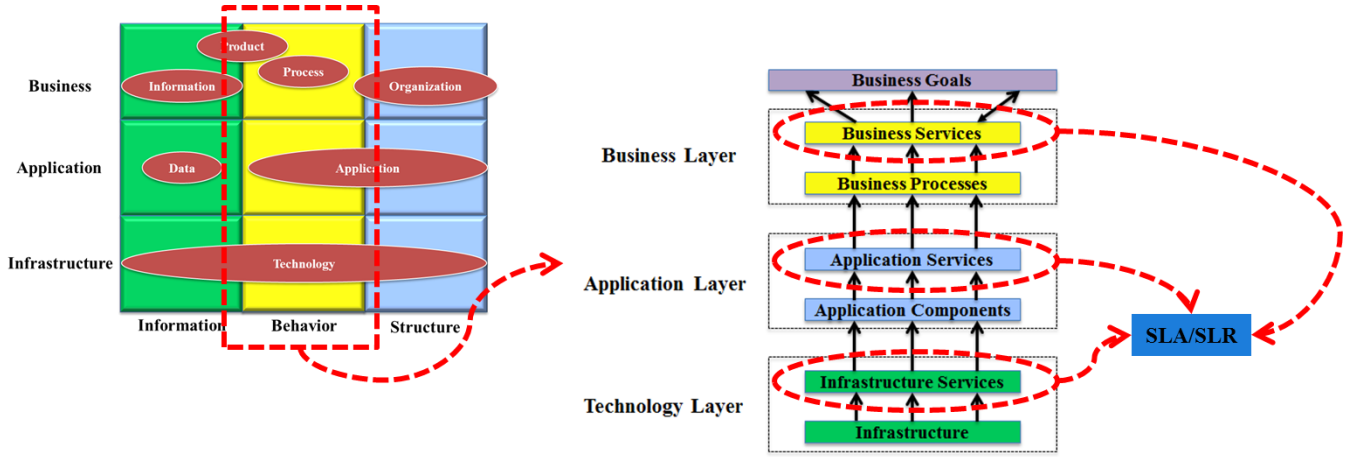


Figure G2 - Relation between ArchiMate, SOA and SLAs

I made the following remarks on this slide:

- I only consider the *behavior* aspect along all the three layers (i.e. business, application and infrastructure) of ArchiMate. This is sufficient for creating the causal model necessary in the prioritization method proposed in this thesis.
- I suppose that the ArchiMate model is built using the **SOA** concepts in which a service is defined between all layers. For every service layer we should be able to create an **SLA** that could serve as input for the prioritization method (i.e. PIs).
- **Example of the approach/steps to take in the process**

The slide presents the details of the proposed method based on the predefined steps. To make it more tangible I use the same fictitious case as earlier. The figure below shows the content of this slide.

- Steps:
  - 1. Create the Archimate Model
  - 2. Determine PIs
  - 3. Install influences between PIs
  - 4. Gives scores to the PI's (not influenced by others)
  - 5. Calculate remaining scores

  Current Situation on KPIs

  - 6. Apply investment options

  To-be Situation on KPIs

  - 7. Choose among options

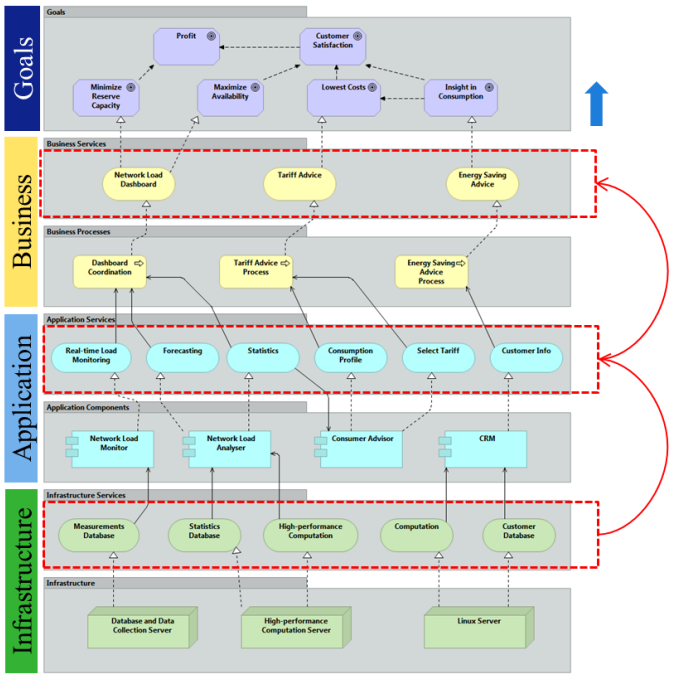


Figure G3 – Process steps in the prioritization method

- **Illustration**

In this illustration slide I demonstrate a calculation example of the proposed method. In order to stay consistent, the same fictitious case mentioned earlier is used.

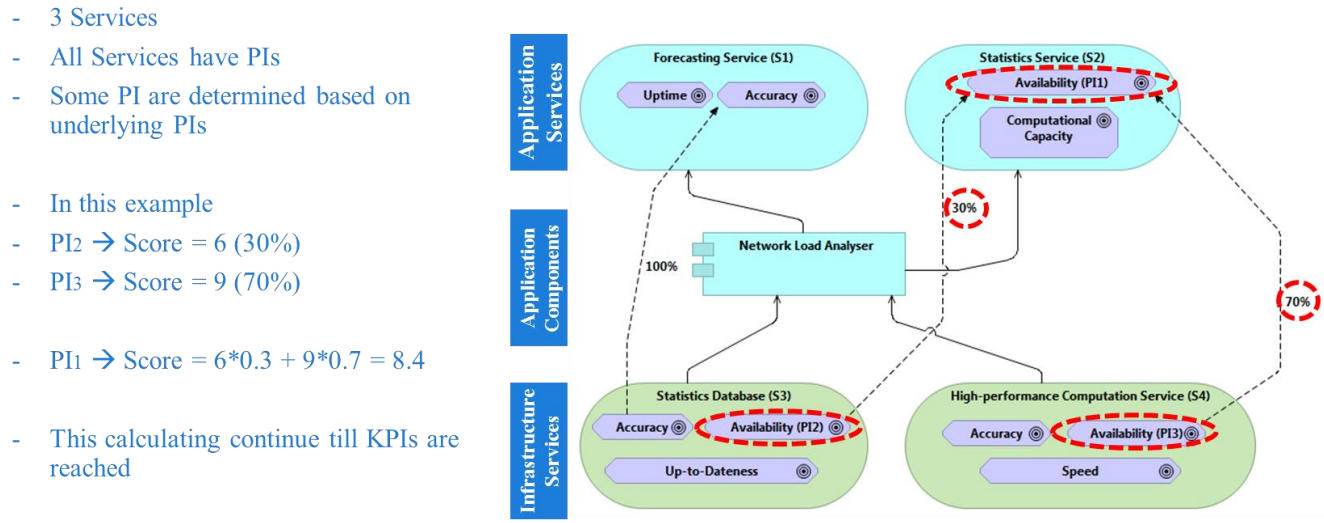


Figure G4 - Example calculation of the proposed method (from slide)

- **Discussion & questions**

In the final slide I asked for feedback on the method proposed during the presentation. Although, semi-structured interviewing was the chosen method the following questions were common along the interviews:

- What benefits do you see with the proposed method?
- Are we able to make better informed decisions with the information provided by the method?
- Is the approach easy to use, or do you see some flaws?
    - If so, what are these flaws and how do you think we can resolve them?
- Do you think it will be easy to determine the PI's?
    - How could we make this easier?
- Do you think it will be easy to establish the influence factors?
- Does this method decrease politics or just facilitate a platform for political processes?

Appendix H: The process used to execute unscheduled and scheduled maintenance (ASML)

[redacted]

Appendix I: Result of the workshop session at ASML

[redacted]

[redacted]