Master's Thesis at the University of Twente

A rationalistic approach to IT investments using Enterprise Architecture

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Summary

In this thesis I present a discussion on the theoretical and practical implications of the use of Enterprise Architecture as support in the decision-making process surrounding IT investments. Using interviews and a working prototype, I debate the desirability and feasibility of a more rationalistic approach to IT investments decisions.

The complexity surrounding IT investments has left researchers and decision-makers looking for a method to attribute value to their IT and improve decision quality. I distinguish two ways of dealing with such complexity; reduction and enhancing one's ability to process information. This research focusses on the latter, using Enterprise Architecture as a structure in which the value of business processes is traced back to the supporting IT applications and infrastructure. The valuation method involves a Multi – Criteria Decision Analysis, with the Enterprise Architecture serving as a framework that structures the criteria.

A crucial part of the method is the accompanying tool in Excel, which automates the calculations, by which much of the complexity is transferred to a computer system (thus enhancing the decision-making capacity). This tool has proven to be capable of performing the calculations necessary for this method and can present the results so that they are easy to interpret.

The main presupposition that started this research is that a rationalistic approach is preferable to a political one, because it is more transparent, verifiable and more easily explained. This presupposition held during the course of this research, although I have found that the applicability of such an approach is subject to a number of conditions, most of which are not a matter of course. The political processes surrounding IT investment decisions are hard to replace and admittedly, seem to be in place for a good reason, simply: a rationalistic approach that is easy enough to work with, yet which is reliable and convincing enough to be accepted has not yet been developed. It is this gap that this research has attempted to fill, but it has become clear that much more research is needed to reach that goal.

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Introduction

As IT becomes ever more important in almost every kind of business, the need for proper IT investment decisions grows. IT investment decisions stand out from other investments because of the difficulty in determining the value of a certain investment option. Figure 1Error! Reference source not found. illustrates the struggle of researchers and businesses to determine in what way certain IT investments create value. Between the IT resources (on the left) and the Business Value (on the right) you see different approaches researchers have tried to attribute value to IT investments. This research field has been growing for years, simply because IT is becoming so important and we do not have a conclusive way to valuate it (Kohli & Grover, 2008; Mukhopadhyay, Kekre, & Kalathur, 1995).

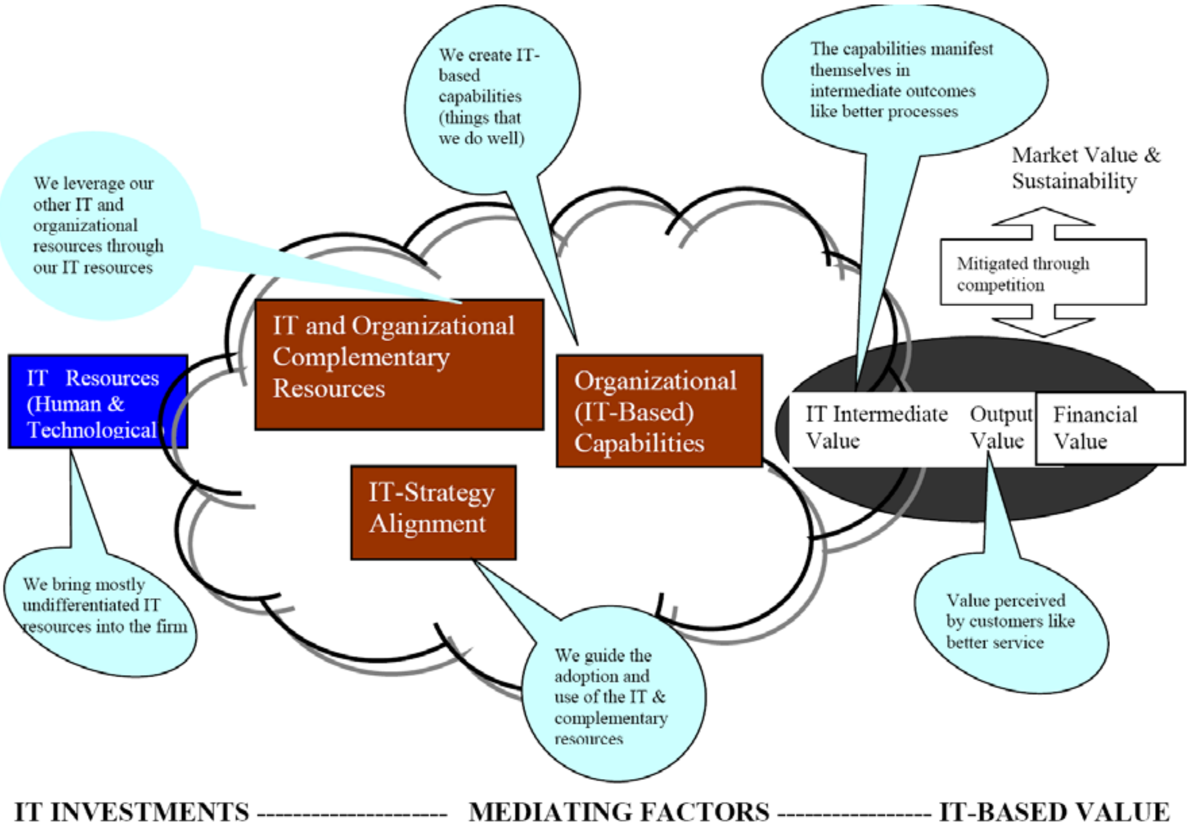


Figure 1 How do IT investments create IT based value? (Kohli & Grover, 2008)

As IT has become so intertwined with all sorts of business processes it has become extremely difficult to predict the result of any change to the IT landscape. And since it has become such an important part of business, improvement in IT can certainly effectuate an improvement in business. However, IT was and still is often viewed as merely a cost centre by the 'business side'(Buschle & Quartel, 2011). As a result the 'IT side' faces a continuing struggle: How to gain insight in the value of investment options? As IT often 'only' has a supporting function (i.e. it is not the core business of the organization), there are no (or very few) direct revenue streams generated by IT. This means that the value of IT has to be derived indirectly through the business processes it supports. As a single piece of technology can be used by several processes or activities throughout the organization, the complexity of IT valuation is considerable and only increases as IT dependency increases. Without the ability to valuate possible IT investments, the decision regarding these investments is often based on the outcome of a rather political process involving several non-IT stakeholders such as Finance, Operations and Human Resources, who may all have different interests, but lack the expertise and oversight to place investment options in the correct context and attribute value to it. In this process it can be difficult for IT to make themselves heard and understood. Technical details mean very little to most people, so they help IT very little to make their argument. This lack of expertise of the people who are so closely involved in the decision making process, may very well diminish the decision quality if this threat is not mitigated by a structured decision process. Apart from this political process between stakeholders, the IT side too, often lacks the oversight to place new ideas in their proper context and therefore have difficulty to convey their full value (Mukhopadhyay et al., 1995). Existing decision support tools are often not sufficient to present a thorough and comprehensive overview of what possible new IT investments might accomplish within the organization. Traditional cost-benefit analyses do not offer an appropriate analysis for IT projects as they are too inflexible and cannot take intangible benefits, costs, risks and other attributes into account that are inherent to IT investments (Angelou & Economides, 2008). Research in this field has yielded other methods and tools but none of them can give an accurate overview of how new IT projects may interact with each other and the existing IT landscape of the organization (e.g. (Bardhan, Bagchi, & Sougstad, 2004), (Quartel, Engelsman, Jonkers, & van Sinderen, 2009)).

In this thesis, I propose we use another IT related research field, that of Enterprise Architecture, to help us with this problem. Enterprise Architecture shows how IT Infrastructure is linked to the business processes and so can help in determining the benefits that can be expected from a change in IT infrastructure. The research conducted by Kohli & Grover that yielded Figure 1, started with the following thesis: "*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)*

The 'fuzzy cloud' that represented the mediating factors linking IT investments to IT-based value in Figure 1 can then be replaced by Enterprise Architecture as shown in Figure 2.

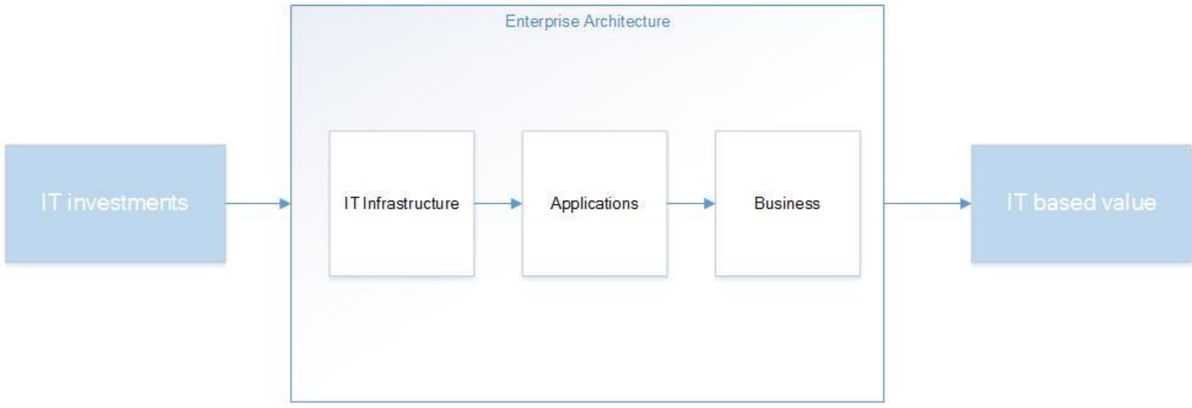


Figure 2 IT based value through Enterprise Architecture

So by using Enterprise Architecture as a structure, we will be able to determine how a particular IT investment is responsible for (extra) value created at the 'business side' of the organization. Thus the causality need no longer be elusive if we take the Enterprise Architecture as a representation of the 'complementary and mediating factors in the value creation process'.

By proposing an easy to use tool, based on the Enterprise Architecture (EA), which will enable a rationalistic evaluation of available investment decisions, I seek to make the entire decision making process more rationalistic instead of political, thereby improving the perceived decision quality. This thesis therefore, presents a theoretical study on the common decision making process surrounding IT portfolio decisions and the feasibility of the decision supporting tool, after which I will evaluate the theory by presenting it to those who make this kind of decision.

Research questions

As I have already mentioned, the decision-making process for IT investments is fraught with difficulties. The lack of insight into the effects of a certain investment option restricts our ability to take a rationalistic approach to IT investments and forces us to rely on the outcome of a group decision-making process wherein guesses on the outcome of the investment are the best we can do and the conflicting interests and different perceptions of the decision makers are allowed to take the place of a well-reasoned, rationalistic approach. Such an approach is bound to leave some doubt in the minds of the decision makers as to whether they are making the right choices.

The main presupposition from which I started is that the use of Enterprise Architecture can aid a more rationalistic approach, thereby enhancing the information processing capacity and improving the perceived quality of decisions on IT investments by creating more insight in the effects of IT investments on business value. Therefore, the research question this thesis addresses is: **How would an EA-based method for IT investment decisions affect the decision-making process and would it improve the perceived quality of investment decisions?**

In order to answer such a question and to make the presupposition from which I start more plausible, I must first answer the following questions:

- Why are current decision support methods insufficient for IT investments?
- How can a more rationalistic decision tool impact IT investment decisions?
- How can an Enterprise Architecture be used as a causal model to support decision-making?
- What information is needed to make a rationalistic investment decision?
- What practical implications need to be taken into consideration when implementing this method?

Literature Review

Decision-making processes

Before I go into the details of decision making processes surrounding IT investments, I first take a more general view of how decisions come about. This will help clarify the purpose and focus of this research and shows where and how a decision making process changes when one follows the method proposed in this thesis.

All decisions are prompted by problems. After all, a problem can be defined as a discrepancy between the actual situation and the desired situation (Heerkens & Winden, 2012). This is true for business decisions, for example the decision which applicant to hire (problem: we do not have a sales manager but we really should), but also for everyday decisions like which route to follow to work (problem: I am at home but need to be at work). Though we may not be aware of it, every decision we make is preceded by such a problem and a problem usually has multiple solutions, some more feasible than others, some more effective, some more expensive etcetera. It follows that the decision-making process includes (1) a set of alternatives, (2) a set of constraints on the choice between different alternatives and (3) a performance function which associates with each alternative the gain (or loss) resulting from the choice of that alternative (Bellman & Zadeh, 1970).

In other words the decision-making process involves:

- Gathering information on the alternatives
- Determining what you find important in the consideration of those alternatives (criteria and weights)
- Determining how you assess the score of each of the alternatives on the criteria
- Determine which of the alternatives is best according to your preferences

The way in which we pass through these stages determines the outcome of the process. For example, when buying a new car, one could gather all specifications of all known cars, use these specifications as criteria, determine the hierarchy of all those criteria and use logic and mathematics to determine the best car according to their preferences. Nearly no one follows this rationalistic process, even though it might yield the best result.

Mostly, people limit the amount of alternatives and criteria to make the process easier. Though they might still optimize their decision within the restricted set of alternatives, one might argue that they could have had a ‘better’ car (corresponding even more to their preferences), if they hadn't restricted the amount of possibilities. Still others might not use such a mathematical approach at all and just pick a car because it looks nice or can go really fast. Note that this is an even further restricted version of the same process, based on one or two criteria, probably considering only a few alternatives.

A rationalistic approach to decision making would demand the consideration of as many alternatives and criteria as possible. I will discuss rationality more in-depth further on, but it is important to keep in mind when discussing how the rationalistic method proposed in this thesis will alter the decision-making process.

First of all, as decision-making is a research field in its own right, I find it important to stress the points to which this thesis does **not** seek to contribute:

The proposed method does not give guidelines on how to determine weights, nor does it prescribe how to determine which alternatives to consider or which criteria to use in the consideration. Throughout this thesis, I will comment on rationalistic and political processes and the desirability of both, and it is important to note that these comments do **not** concern the processes of determining weights or which criteria to use. Determining what is important for an organization, or in any group of decision-makers, is very difficult and much research is has been done, and is still being done, to determine how that should be done (e.g. (Chiclana, Herrera, & Herrera-Viedma, 1998; Kim & Ahn, 1999; Sanayei, Farid Mousavi, & Yazdankhah, 2010)), but that is not the focus of this thesis.

However, there are certain aspects of the decision-making process that I do want to change. Through the structuring of the decision-making process along the lines of an Enterprise Architecture, the method I propose will alter the following aspects of the decision making process:

- It will allow the decision maker to consider more alternatives
- It will clarify and structure all criteria that are used in the process
- It will allow the decision maker to use more criteria to determine the best option

In later chapters I will clarify **exactly how** this method will contribute to these aspects of the decision-making process but this should help to place this research in proper context.

Rationalism in decision-making

I start this research from the presupposition that non-rationalistic decision-making practices are common in IT investment decisions, both intentionally and unintentionally. Intentionally because many scholars (e.g. (Simon, 1955), (March, 1978)) believe that in complex situations, we humans must accept that our capability for rationality is limited and we must therefore seek other ways to make our decisions. Some even pose that rational optimization may produce poorer results than heuristics (Gigerenzer, 2008). The widely accepted concept of bounded rationality does **not** preclude the enhancement of rationality by means of technology. *"Bounded rationality is a normatively sensible adjustment to the costs and character of information gathering and processing by human beings"* (March, 1978). This suggests that were those costs of information gathering and processing altered or transferred to technology, the rationality bounds of a decision-making process can be shifted.

Apart from the, theoretically founded, intentional use of non-rationalistic processes, we know that in many decision-making processes ratio is ignored. Especially in decision-making processes performed by a group, we find this to be true. Phenomena such as "Groupthink", first posed by Irving Janis, show that people in a group may choose a sub-optimal (or even erroneous) option, even though individually they may know another option to be much more beneficial(Janis, 1982).

It is, at this point, important to clarify what I mean by the **rationality** I intend to increase in the decision processes. I take a **rationalistic** view to decision-making which means I support the epistemological view of **rationalism**, which states that reason is the primary source of knowledge or justification (Proudfoot & Lacey, 2010). Therefore I view the employment of reason (rationality) to be the preferred method for decision-making. 'Proving' that certain investment options are better than others through causal links, fits with the logical structure intrinsic to reality (according to rationalism). From this notion stems the presupposition that more rationality, in the sense of logical and structured reasoning, will result in higher (perceived) quality of decision-making.

Now back to the problem I intend to address, whatever the cause, intentional or unintentional, one may infer that there is a limit to the rationality employed in decision-making processes. In this thesis I will focus on the decision-making process for IT investments, in which rationality is perhaps even more limited by the fact that it is so difficult to show the link between IT and the business' core activities, by the fact that IT is often difficult to comprehend by decision-makers who are not 'from IT' and more importantly, we lack the means to gain insight in the effects that an investment might have on the IT landscape and thereby the business processes. It is precisely that, which I intend to change by introducing an enterprise architecture-based tool that can show the impact of IT investments on business goals, thereby better informing all decision-makers.

Limited rationality in decision-making does not necessarily mean that the decisions are bad, in fact, as I have mentioned before, there is some evidence to the contrary (Gigerenzer, 2008). However, this is mostly the case when the amount of information is too vast to comprehend, or when too much is uncertain. In the case of IT investments, I intend to give more insight in the causal relations that connect the investment options to the desired outcome for the business processes. By doing so, I believe I can create a more comprehensible overview of the investment options which enables a more rationalistic approach to the decision-making process.

In order to be able to show that a more rationalistic approach is preferable, I must of course consider the less rational components of the decision-making process which I seek to lessen. These components are what we might call the heuristics or workarounds that have been put in place to replace the rationalistic process, because it was deemed to be outside the boundaries of human rationality. Now there are several generally accepted social heuristics in decision-making that we might consider; e.g. the recognition heuristic and the fluency heuristic which both use one's memory as a basis for a decision, the take-the-best heuristic which also uses one-reason decision-making but based on a single attribute rather than a person's memory (Hertwig & Herzog, 2009), (Gigerenzer & Gaissmaier, 2011).

In his article on Multi-Professional Decision-Making, Jon Harris concludes with the following guidelines to make better decisions (apart from some more procedural guidelines that are not relevant here):

- Insist that the whole decision-making process is a transparent one, so that all relevant people have the opportunity to make a relevant contribution to it

- Introduce more evidence into decision-making meetings that is based on research or on careful, reflective casework rather than on personal anecdote
- Insist on clear decision criteria, so that it is established in advance what the decision is expected to achieve (Harris, 1999)

These guidelines stress the importance of a more structured and evidence-based approach, in line with a rationalistic point of view. The method based on the Enterprise Architecture I pose in this thesis can certainly help to follow these guidelines. By structuring the IT landscape and using the architecture as a means for project evaluation, one is able to use the organizational KPI's as clear decision criteria and objective information on the investment options as basis for the decision. Also one can achieve a higher level of transparency in one's decision-making process by the structured manner in which the tool is constructed.

Politics in investment decisions

A common limitation of rationalism in investment decisions is the political process that goes with it. What I call a political process can best be defined from the philosophical point of view as a process based upon dialectics (method of conversation or debate (Proudfoot & Lacey, 2010)). This definition places it in contrast with rationalism and the detrimental effects on the quality of a decision can be shown by this paraphrase of Aristotle:

[Dialectics is] an inferior, though sometimes indispensable, method of enquiry because it has to start from premises which were agreed to by the interlocutors rather than those which could be demonstrated to be true. (Proudfoot & Lacey, 2010)

Not only the premises from which a decision-making process start, but also, by the lack of causality originating from these premises, the outcome need not be demonstrably true in the sense that the consensus reached need not be optimal even if the premises can be considered to be correct.

Examples of such political processes based on dialectics are bargaining, negotiation and voting, but also "groupthink" effects such as a hesitance to deviate to far from consensus or contradict a superior or authority figure within a group or organization (Janis, 1982).

In fact, there have been several studies that showed that within organizations, decisions reflect the preferences of powerful people and groups (Hills & Mahoney, 1978; Pfeffer &

Moore, 1980; Pfeffer & Salancik, 1974) Although the use of politics is an practical way to make decisions in lieu of rationalism, it has been shown to diminish organizations' performances(Eisenhardt & Bourgeois, 1988). Eisenhardt & Bourgeois performed several case studies that showed that a decrease in politics can bring about an upswing in efficiency and profitability.

So at least from a theoretical point of view it can be concluded that more rationalism is preferable to politics. However, we must of course acknowledge the fact that theory might not be applicable in practice and although this thesis focusses on the theoretical benefits and possible improvements an Architecture-based decision tool might provide, it is important to take the practice in which this tool is to be set into account.

Complexity in IT investments

A main threat to rationalism in the decision making process, and a reason to rely on political processes instead, is man's inability to cope with the complexity of the vast amount of information that has to be processed. The large amount of alternatives, criteria and relations needed for a rationalistic approach, as mentioned in the previous section, are the cause of this complexity (Meijer, 1998). There are basically two ways to cope with complexity that results from such a data overload: Firstly, one might try to reduce the complexity by decreasing the amount of considered alternatives and/or criteria. This is in line with the theory of bounded rationality, which states that we cannot process too much information at a time and must therefore limit it to what we *can* process (March, 1978). A second course of action is to somehow increase one's information processing capacity and thereby keep the ambition of a decision-making process that is as rationalistic as possible. A way to achieve this higher capacity is through "rationality carriers"; artefacts that embed rational models to regulate and support decision makers (Cabantous & Gond, 2011).

The research that has been done to determine the business value of IT can also be divided into these two categories: on the one hand there are those that seek to **reduce complexity** (e.g. (De Haes, Gemke, Thorp, & Van Grembergen, 2011; Meijer, 1998)), on the other there are those that want to **increase** the **processing capacity** (e.g. (Bardhan et al., 2004; Johnson, Lagerstrom, Narman, & Simonsson, 2007)).

As I take the rationalistic view, and state that it is better to consider as many alternatives and criteria as you can so that you can come to the most optimal solution, I do **not** want to reduce the complexity but increase the processing capacity to handle the complexity that is inherent to IT investment decisions.

Existing IT project valuation methods

As I mentioned in the introduction, there are several existing portfolio decision support tools and investment valuation methods, but these do not fit the specific need for the expanding IT portfolios of many organizations. In this section I will discuss several of these methods and highlight why I believe we need another. In this overview of past research and used valuation methods I will mainly focus on those that have the same objective in coping with complexity; increasing the processing capacity. However, in order to give a complete overview I first give some examples of some of the complexity reducing methods.

Complexity reduction

Traditional investment appraisal methods

A much used format for the assessment of investment options in business is the business case, for example the PRINCE2 format (Projects IN Controlled Environment, version 2) (Portman, 2009). In this format, and in many other business case formats, the investment appraisal is mainly concerned with a standard cost-benefit analysis, which is unfit to properly assess an IT investment. This kind of investment appraisal can be categorized in the 'reduce complexity' section as the criteria used to assess the options are restricted to monetary criteria only. Net Present Value (NPV), Return on Investment (ROI) or Discounted Cash Flow (DCF) calculations often give a very negative image of IT investment, either because it proves very difficult to quantify non-monetary benefits or because the IT investment has more benefits than those that a stand-alone business case may anticipate (Angelou & Economides, 2008). Structuring the investment appraisal along the lines of an Enterprise Architecture will allow for an improvement of both these flaws; firstly, because the non-monetary benefits can be derived from the characteristics of the EA components, which makes them easier to quantify and secondly, because of the many relations already defined in the EA, it becomes easier to incorporate secondary benefits into the investment appraisal. Once the EA is properly constructed, all benefits of an investment are automatically calculated, which ensures that a decision can be made on more accurate information. (Buschle & Quartel, 2011)

Hierarchical business and IT roles

A good example of an effort to reduce complexity without resorting to oversimplification is the case by de Haes et al. which explains how the Dutch airline company KLM revised the governance of their IT (De Haes et al., 2011).

In 2001 the CEO of KLM decided the IT governance needed a complete overhaul and appointed a new CIO and established a CIO office that was to incorporate the many IT functions scattered throughout the organization. The newly appointed CIO was to design simple IT governance principles to restore cost controls, enable steering and provide guidelines for outsourcing and investment decisions. The most important result of his efforts, apart from the guidelines for outsourcing, was a division of responsibilities and authority across two dimensions, IT function (Demand or Supply) and IT costs (Continuity and Innovation costs). The IT demand is a function of the 'business' side of the organization and decides on *what* IT should be able to do. The IT supply is covered by the actual 'IT' side and decides on *how* this IT demand is to be met.

By separating the continuity and innovation costs, KLM separates two entirely different types of IT costs and the (investment) decisions that go with them. This division led to four organizational entities, each with authority on a specific portion of all IT investment decision (see **Error! Reference source not found.**).

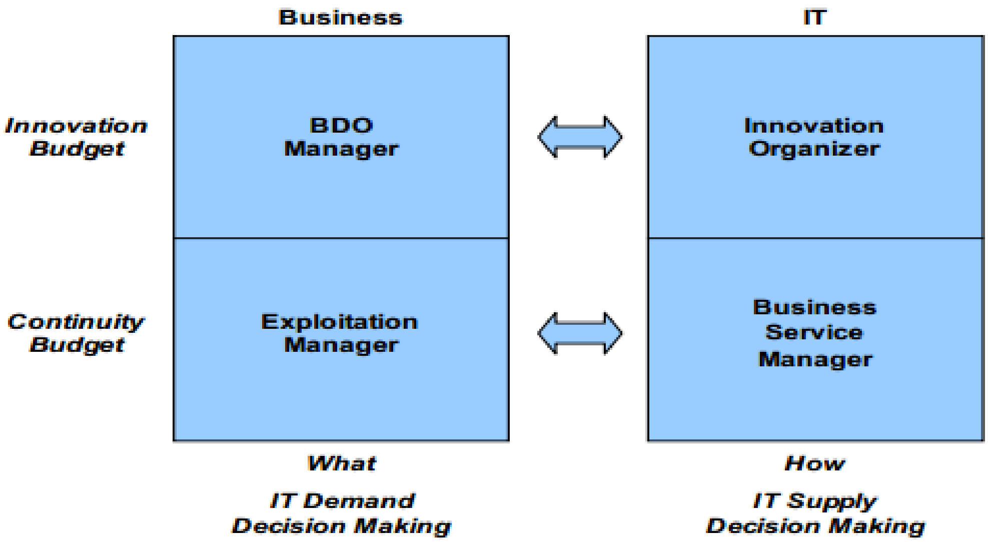


Figure 3 Division of Authority at KLM (De Haes et al., 2011)

The separation of these responsibilities ensures that the focus areas of each of these managers are clearly delimited, thus reducing the complexity with which they have to cope.

The solution to the complexity problem that KLM implemented is a purely procedural one. It takes away some of the complexity for an individual decision-maker by restricting his focus and authority, thereby reducing the alternatives and relations to other entities he has to take into consideration. Such an approach seems to have its merits, it certainly helped KLM structure their IT governance. But you can only reduce the complexity so much without losing sight of the big picture, and in any case the structuring of the responsibilities gives us no guidelines as to what the decisions are ultimately based on.

Increasing the information processing capacity

Now we come to the more specific research field of this thesis, that of finding a way to allow the decision maker to process the vast amount of information necessary to follow a rationalistic approach and optimize the decision as much as possible. The traditional valuation methods like Net Present Value and Return on Investment can also be said to attempt a rationalistic approach but as it disregards the many non-financial aspects related to IT investments it is best classified as complexity reducing, and as I've already discussed it in that section I will not repeat it here.

Value net and real options approach

An attempt to increase the information processing capacity of decision-makers was made by Bardhan, Bagchi & Sougstad. In an effort to incorporate the many interdependencies which make IT investment appraisal so very difficult, they used a value net approach to help take the different stakeholders into consideration who might benefit from a particular IT investment and they combined this with a nested real options model to calculate the value of an investment option (Bardhan et al., 2004).

"A value net is a map that links a firm to various player segments: customers, competitors, suppliers, and complementors/partners who increase the value of a company's services to its customers." (Bardhan et al., 2004) Such a value map is used as a starting point for the real options analysis to make sure all added value is taken into account, be it directly to the firm or indirectly via one of the other actors in the value net. The main contribution of this paper by Bardhan et al. was the development of the *nested real options model* which helps to incorporate the many interdependencies between projects into the valuation process. A basic example of such a dependency is that an IT infrastructure itself might not create much value, but it enables applications and business processes which do create significant value, but could only do so by using the infrastructure. Such a dependency is called a 'hard dependency'. A 'soft dependency' occurs when a capability of one project *enhances* the capability of another, but is not necessary to enable it.

These dependencies are then incorporated in the calculation of the real option value of a project (V_j) by the following formula:

$$V_j = B_j N_j (d_{1j}) - C_j e^{-r_f t} N (d_{2j})$$

$$\text{Where } d_{1j} = [\ln(B_j/C_j) + (r_f t + \sigma_j^2 t/2)] / \sigma_j \sqrt{t}$$

$$d_{2j} = d_{1j} - \sigma_j \sqrt{t}$$

$$B_j = PV (cf_j * (1 - \textstyle\sum_k s_{kj}))$$

In this formula, the expected benefits of project j are given by B_j and the expected costs are given by C_j. The value increase of project j which is enabled by other projects is incorporated by the use of s_{kj} which stands for the dependency of project j on project k. This way, the value that is added to project j by project k, can be attributed to project k (the definitions of all the variables can be found in appendix B). Apart from the fact that the proposed model uses rather advanced mathematics, which might harm the adoption of this model, there are a few other disadvantages. First and foremost, the real options model does not enable the incorporation of non-financial benefits. Although it is an interesting addition to the traditional investment appraisal methods, it is just that, and therefore restricts the decision-maker in his deliberation of many other (qualitative) criteria. Secondly, in order for the real options method to work, one would need to know all future options and their value beforehand, otherwise a project might be undervalued. Also, Bardhan et al. do not give instructions on *how* the value of the future options is to be determined. So although the idea of the real options model is an interesting addition to calculating the monetary value of a project, it does not give a comprehensive overview of the actual value, especially the value that is often expressed in qualitative criteria.

ROAHP

Closely related to the work of Bardhan et al. is that of Angelou & Economides who combined real options (RO) analysis with the analytic hierarchy process (AHP) (Angelou & Economides, 2008). The real options model is roughly the same as the one used by Bardhan et al. and is used to model the interdependencies between projects. Again, the model's purpose is to calculate the Extended Net Present Value (ENPV) by adding the value that can be directly contributed to the project in phase one to the net present values of the possible future investments that are enabled by that first project(Taudes, Feurstein, & Mild, 2000). As more than one investment might be made in phase one, and all project can influence the value of the others, it is necessary to calculate all ENPV's for all possible investments, in all possible combinations. I have already mentioned the flaws of traditional investment appraisal methods such as NPV when it is used for IT investments and these flaws are the same even for the extended version. Angelou & Economides also stress this point and have therefore combined the quantitative nature of the (E)NPV with the AHP which allows for qualitative criteria to be taken into consideration as well. The AHP was developed by Thomas Saaty and like many other multi-criteria decision analysis techniques **scores** the available set of **alternatives** based on **criteria** which are **weighted**. (Winston, 2004) This general definition of multi-criteria decision analyses can be expressed in the following formula:

$$A_j = \sum_{i=1}^{i=I} (w_i \times s_{ij})$$

Where A_j =Total score of alternative j
W_i = weight of criterion i
S_{ij}= Score of alternative j on criterion i

AHP differs from other multi-criteria decision analysis techniques, not in the way of calculating the scores, but in determining the criteria weights. To determine the weights of each criterion, the decision-maker has to make pairwise comparisons of all criteria. Imagine a decision in which four criteria are important to consider (criterion A, B, C and D). We place these criteria in a **pairwise comparison matrix**, in this case a 4x4 matrix (as there are 4 criteria). In this matrix we show how much more important one criterion is compared to one other. So for example we decide that criterion A is 3 times as important as criterion B, just as important as criterion C but only a fourth as important as D. When we do this for all criteria we might end up with a matrix like this:

$$\begin{array}{c} \\ A \\ B \\ C \\ D \end{array} \begin{array}{c} \begin{array}{cccc} A & B & C & D \end{array} \\ \begin{bmatrix} 1 & 3 & 1 & 1/4 \\ 1/3 & 1 & 1/3 & 1/10 \\ 1 & 3 & 1 & 1/4 \\ 4 & 10 & 4 & 1 \end{bmatrix} \end{array}$$

This matrix can then be normalized by dividing each entry by the sum of its column, and then the weight of the criterion is determined by the average of the row. So for our example matrix we would get the following weights: weight A = 0.162, weight B = 0.057, weight C = 0.162 and weight D = 0.619 which add up to 1. In ROAHP, the outcome of the ENPV's can be taken as one of these criteria (for example D, as monetary values are often the most important) and the other criteria are the 'intangible' or qualitative factors.

Though the idea behind the use of real options and a multi-criteria analysis seems good and it is certainly an improvement over the method of Bardhan et al. because of the inclusion of qualitative factors, there are certain aspects of ROAHP that leave something to be desired. First of all, Angelou & Economides do not specify how the decision maker is to score the alternatives when using the AHP. There are no guidelines as to what the basis for these scores should be. Secondly, the real options model can only be employed when the future options of a current investment are known. And finally, the use of AHP can result in an unnecessary increase in complexity of the decision-making process due to the necessity of pairwise comparison, and because the weights have to be determined by the decision-maker, this complexity cannot be transferred to a computer system.

EA analysis with extended influence diagrams

Another method to support decision-making using Enterprise Architecture was developed in 2007 by Johnson et al. (Johnson et al., 2007) and proposes to use extended influence diagrams (which in themselves are extended Bayesian networks) to provide insight in the causal links from investment options to business goals. Though the use of these influence diagrams help structure the causality among performance indicators, this method does not link these indicators to the specifications of the architecture components. As shown in **Error! Reference source not found.** Figure 4 and Figure 5**Error! Reference source not found.**, every capability of an EA component is converted to a property of a component of the influence model, which can then be used to show how that property influences the business goals. The idea of linking the properties of EA components to business goals is rather similar to the one I propose in this thesis, however by using several separate models, the link between the IT component and the business value is blurred and becomes more difficult to trace and so attribute value to an infrastructure or application component. What is more, the dependency of application on infrastructure is no longer visible, which further diminishes the apparent value of the IT components. Enterprise Architecture makes these links and dependencies explicit and so is more suitable for investment valuation.

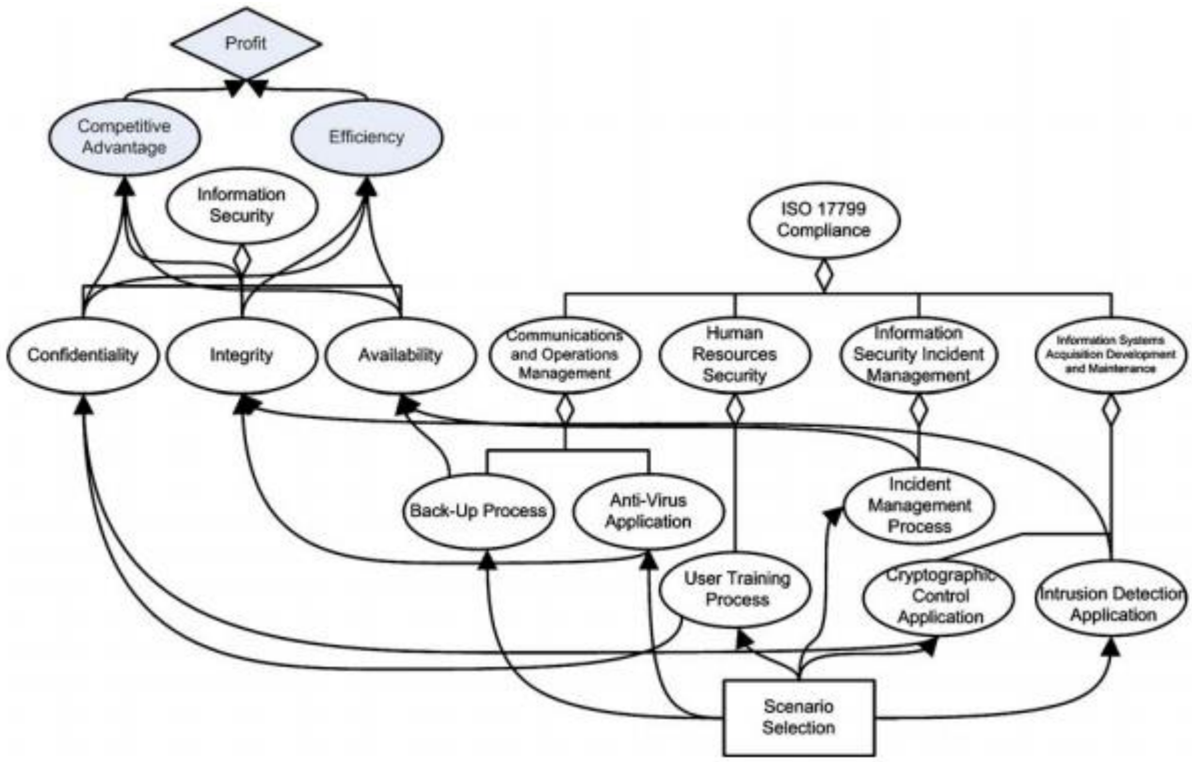


Figure 4 Extended Influence Diagram (Johnson et al., 2007)

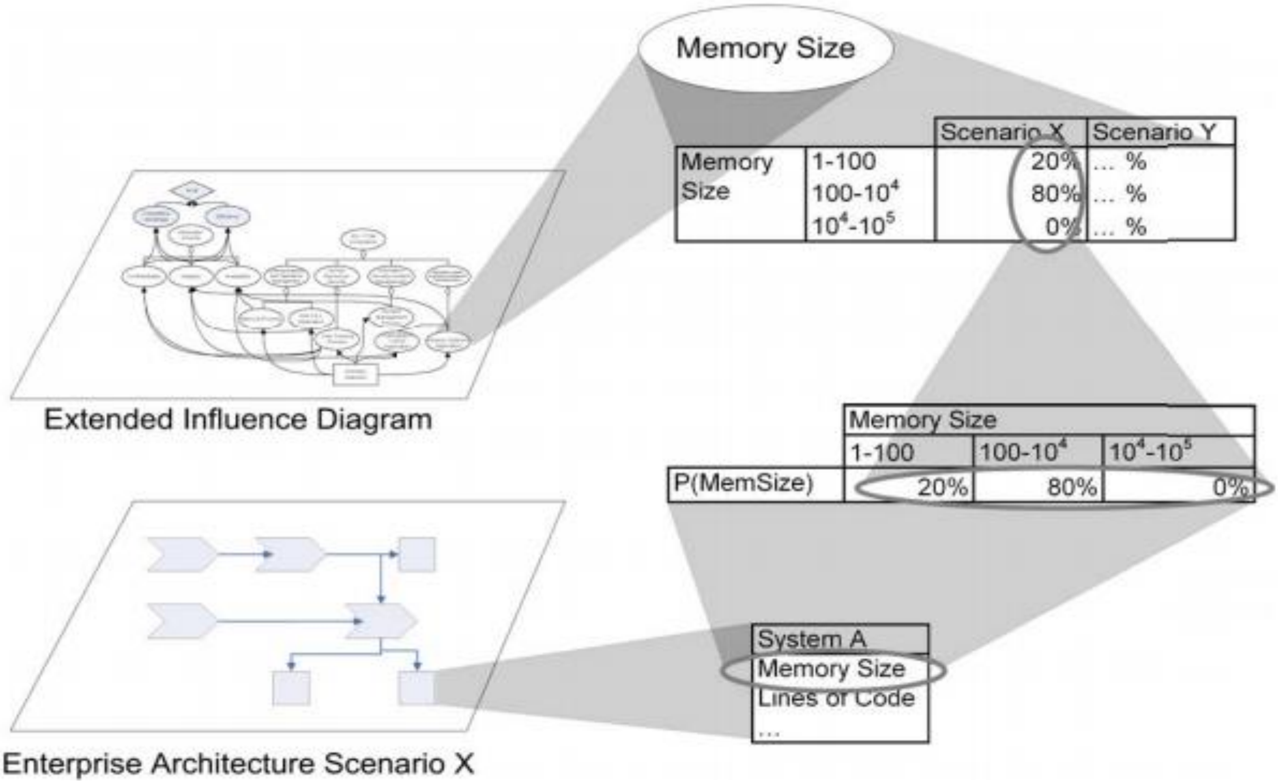


Figure 5 Relating the Influence diagram to the EA(Johnson et al., 2007)

Method of Bedell

A method by Eugene F. Bedell, outlined in his book "The Computer Solution: Strategies for Success in the Information Age"(Bedell, 1984) can be considered the ultimate basis for this research. But because this book was written in 1984 and it considered IT as separate from business, several scholars have revised this method to adapt it to the current views of IT and business alignment (e.g. (Buschle & Quartel, 2011), (Schuurman, Berghout, & Powell, 2008)).

The method of Bedell revolves around two main concepts; *effectiveness* and *importance*. The most important principle of this method is that the level of effectiveness of the information systems should ideally be approximately equal to their level of strategic importance. A system is regarded effective if it is cost-effective, has a high technical quality, and is functionally appropriate, and it is strategically important when the activities supported are crucial to the organization or business process in achieving its strategic objectives (Schuurman et al., 2008). The scores for strategic importance are determined by answering the questions in Figure 6 **Error! Reference source not found.**.

IS management then scales the effectiveness from low (0) to high (10) in cooperation with the business organization based on their perception of the cost-effectiveness, technical quality and functional appropriateness. This method claims to link the IT to business success and in a way it does, but the link is rather indirect. The effectiveness of the *activity supported by* the IT is assessed (not measured) but is not linked to the *characteristics* of the IT. This makes it very difficult to determine what makes it less effective than desired. By adding KPI's to the specific IT components and the supported business processes, this is made easier and thereby more suitable for decision support. The addition of the Enterprise Architecture by Buschle and Quartel helps make the link to IT more specific and the causal links between the KPI's I add in this thesis even more so, plus it helps to create a workable overview of secondary benefits an investment might induce.

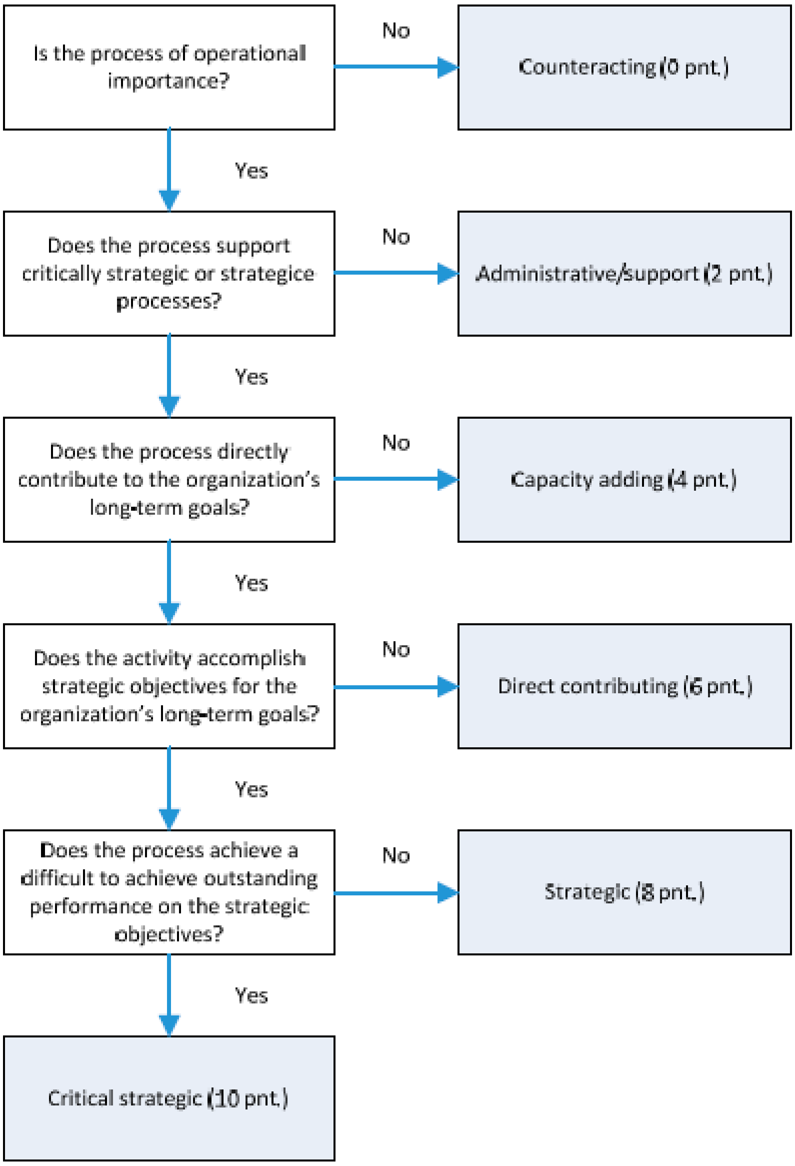


Figure 6 Determining strategic importance scores based on Bedell (1985)(Schuurman et al., 2008)

Modelling framework and language

In order to give structure to the Enterprise Architecture that forms the basis of this research, I use the modelling framework and language ArchiMate, which has been developed by The Open Group, a vendor neutral developer of IT standards (TheOpenGroup).

ArchiMate divides an EA into three layers; the technology layer (or infrastructure layer), the application layer and the business layer. The Open Group defines these layers as follows:

> "The *Business Layer* offers products and services to external customers, which are realized in the organization by business processes performed by business actors.
>
> The *Application Layer* supports the business layer with application services which are realized by (software) applications.
>
> The *Technology Layer* offers infrastructure services (e.g., processing, storage, and communication services) needed to run applications, realized by computer and communication hardware and system software." (Group, 2012)

The choice for ArchiMate is rather self-explanatory when we consider the purpose of the EA in this tool. The EA is meant to create insight in the IT landscape and lay the foundation for the causal model that helps us calculate the IT value of IT investments. The layered structure of ArchiMate is particularly suitable for constructing these causal links, whereas other EA frameworks such as TOGAF, which do not have such a structure, cannot be transformed to incorporate causal chains. In a later chapter I will explain how the proposed tool makes use of these layers and how it helps to create a causal model that can support decision making.

An important addition to the ArchiMate framework was made by Quartel et al. when they developed the modelling language ARMOR, which incorporates the business goals into the framework (Engelsman, Quartel, Jonkers, & van Sinderen, 2011; Quartel et al., 2009). This is done by adding a fourth layer, on top of the business layer, that shows the business goals which are linked to the business processes described in the business layer.

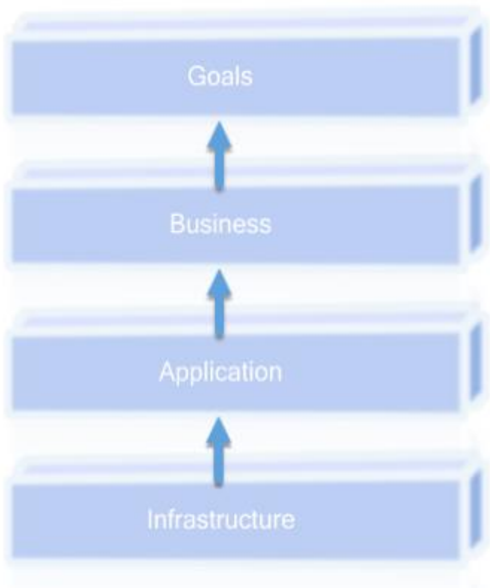


Figure 7 ArchiMate extended with Business goals

In Figure 7 you can see how logically a causal model follows from this ArchiMate structure; Infrastructure enables Applications, Applications enable Business processes and the Business processes fulfill the Business Goals.

Service Oriented Architecture

To make sense of an organization's IT infrastructure, a service oriented architecture has its distinct merits. Although not all organizations implement it, it is my strong belief that SOA can enable what traditional architecture has failed to do, making better IT investment decisions. Because the traditional architecture is a set of hardware, software and business services and is fairly rigid, it is extremely difficult to predict the effect of a new investment on the whole IT landscape. With the modular nature of SOA, this becomes much easier (Papazoglou & Heuvel, 2007). When the modules of the current architecture are all modelled, the result of a replacement or addition of a module can be easily computed. That is the basis of the tool that I propose in this thesis as the replacement or addition of a module represents the investment opportunities under consideration.

Causation and effectuation

The causal chains in the architecture can be used in two ways which we may call causation and effectuation (Sarasvathy, 2001). Sarasvathy defines these terms as follows:

"*Causation processes take a particular effect as given and focus on selecting between means to create that effect.*"

"Effectuation processes take a set of means as given and focus on selecting between possible effects that can be created with that set of means."

In the terms of the Enterprise Architecture; we can use the causality within the architecture for a causation process, in which we set specific goals for the business layer KPI's and create the necessary infrastructure and application layer components to achieve these goals. Or, in an effectuation process, we can use the causality to try and envisage certain new business processes which can be established with the current infrastructure and application layers. In this research I will mainly focus on the causation decisions enabled by Enterprise Architecture, but it is important to be aware of the possibility of enabling effectuation processes because it can show IT value that is apparently hidden in the current IT landscape but is not being used.

Research Methodology

This thesis follows a design science methodology, which fits the research purpose of creating an artefact to address an existing business problem. In particular I will be using the Design Science Research Methodology (DSRM) for Information System Research created by Peffers et al. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) for the general structure of this research. The evaluation of the proposed method will need a more detailed methodological structure, especially as it is an important aspect of this thesis, and I will therefore use a large variety of research variables to structure this part.

The DSRM for IS research by Peffers et al. consists of 6 steps:

1. Problem identification and motivation
2. Objectives of a solution
3. Design and development
4. Demonstration
5. Evaluation
6. Communication

Throughout this report I will elaborate on each of these steps, but in order to get an overview of this research I will briefly address all these steps, so that I can use this structure later, when I work out each step in more detail.

Identify problem & motivate

As I have already stated, many organizations have difficulty making well-informed decisions when it comes to IT. This is mainly due to the immense complexity of the IT landscape and the difficulty of assessing the effects of IT investments. As IT is still becoming more and more important in many organizations, it becomes ever more important to find a way to decrease the complexity and create insight in the effects of investment decisions.

Define objectives of a solution

In this thesis I work from the presupposition that a rationalistic approach to decision making is preferable, but that the complexity of IT makes this difficult, if not impossible. Therefore I propose an artefact (consisting of a tool to support my method) to decrease complexity and enable rationalism, which (by the terms of the presupposition) will lead to better decision-making.

Design & development

I intend to achieve this decrease in complexity and increase in rationalism by introducing an Enterprise Architecture- based method effectuated in an Excel tool that will allow the user to calculate the effects of investment decisions on the organization's KPI's.

Demonstration

This EA-based method and the accompanying tool will be demonstrated to several professionals who make IT investment decisions in the course of their work and I will discuss the method with them and ask for their feedback its expected impact on the perceived quality of the decision and the extent to which it would enable a more rationalistic approach.

Evaluation

I will evaluate the method based on the feedback I get from the interviews with IT professionals and discuss its strengths and weaknesses. Because this is a very important part of this research I will discuss a more detailed methodology for evaluation which will handle the exact boundaries of the proposed method.

Communication

Obviously the results of this research will be published in this thesis and hopefully it will yield enough interesting material to publish an article on the outcome.

Evaluation of the artefact

Within the Design Science methodology there are many possible courses of action to take when it comes to the actual evaluation of your artefact. As can be seen in Figure 8, there are many variables to consider when conducting a design science research. The overview of these variables was made by Cleven et al. in their study of the existing methods. (Cleven, Gubler, & Hüner, 2009)

Variable	Value				
Approach	Qualitative	Quantitative			
Artifact Focus	Technical	Organizational	Strategic		
Artifact Type	Construct	Model	Method	Instantiation	Theory
Epistemology	Positivism	Interpretivism			
Function	Knowledge function	Control function	Development function	Legitimization function	
Method	Action research	Case study	Field experiment	Formal proofs	
	Controlled experiment	Prototype	Survey		
Object	Artifact	Artifact construction			
Ontology	Realism	Nominalism			
Perspective	Economic	Deployment	Engineering	Epistemological	
Position	Externally	Internally			
Reference Point	Artifact against research gap	Artifact against real world	Research gap against real world		
Time	Ex ante	Ex post			

Figure 8 Variables in Artefact Evaluation (Cleven et al., 2009)

This overview of variables in artefact evaluation was specifically designed to be part of the DSRM designed by Peffers et al. (Cleven et al., 2009) and intended to aid structuring and documenting the evaluation process alongside its fundamental characteristics. Below I will use all the variables to clarify the purpose and dimensions of my research, which will then allow me to set up the method of analysis as comprehensive as possible.

Approach: As I will use the insights gained from semi standardized interviews with people who actually make IT investment decisions to create an overview of the pros and cons of the method, the evaluation approach is *qualitative*.

Artefact focus: "DSR (Design Science Research) artefacts on the strategic level are for example designs for decision support systems, roadmap development methods, or balanced scorecards" (Cleven et al., 2009). As the method I propose is a method for using the architecture as support for investment decisions it is clear that the focus is on the *strategic* level, which is why it was important that the participants in the interviews operated at that level. From this it also follows that the **Artefact type** is *Method*.

Epistemology: "A positivist epistemological attitude implies that the evaluation of an artefact leads to the same objective results, regardless of the individual characteristics of the evaluating person. Under an interpretive stance, in contrast, it is assumed that the results of an artefact evaluation highly depend on the individual characteristic of the evaluating subject." (Cleven et al., 2009) As the applicability of the artefact may be highly dependent on the organization in which it is implemented I expect and intend to find organization-specific feedback on the artefact from the evaluation interviews, which will give me a broader view of the pros and cons of the proposed method. Therefore my epistemological attitude with regard to the evaluation of the artefact can be classified as *interpretive.*

Function: The function of the interviews is to gain insight in the (perceived) strengths and weaknesses of the proposed method and use this to assess whether or not the method is feasible and if so how it should developed; what aspects of the current prototype can remain unaltered and which need to be changed and how. Therefore I can classify this as a *development function*.

Method: I use a semi standardized interview to gather my information from the participants, which can be classified in the same category as *case studies* under the definition used by Cleven et al. (2009): "Case studies depict a broadly used means for describing or analysing real world phenomena. Sources for information gathering are e.g. interviews, documents, or measurements. A decisive characteristic of case studies is the deliberate admitting of uncontrolled influences that emerge from the context (e.g. a company) an artefact is evaluated in."

Object: In this case the object of evaluation is the method (*artefact*) itself.

Ontology: "Realists hold the opinion that the world exists regardless of human perception, i.e. regardless of whether the world is thought or spoken about. Accordingly, for realists reality (objects as well as structures) is objectively given. Nominalists, in contrast, postulate that the world is not given in the form of objective facts, but rather construed in inter-subjective communication and other social processes." (Cleven et al., 2009)

As the success of the proposed method is highly dependent on the perceived usefulness and feasibility expected by the user (during this research the participants of the interviews) one cannot take the realist's point of view. The 'reality' of the methods usefulness is largely determined by the social processes that determine acceptance.

Perspective: "The *deployment* perspective considers comprehensibility and acceptance aspects of implementing and using DSR artefacts." (Cleven et al., 2009) In the evaluation interviews I intend to get feedback on what the participants think are the chances of success of the proposed method, both with regard to the intrinsic value of the method as well as the probability of it being accepted as a decision support method.

Position: As I am the one who does both the evaluation (along with the participants of the interviews) and the development of the method this evaluation is internal.

Reference point: During the interviews this *artefact* will be set *against the real world* because I discuss its usefulness and feasibility with 'real-world' decision-makers.

Time: The evaluation takes place before the artefact has been implemented (the prototype is still under development).

All these characteristics can now be summarized into an overview of the intended evaluation process. (see Figure 9)

<table>
<tr><th>Variable</th><th colspan="10">Value</th></tr>
<tr><td>Approach</td><td colspan="5">Qualitative</td><td colspan="5">Quantitative</td></tr>
<tr><td>Artifact Focus</td><td colspan="3">Technical</td><td colspan="4">Organizational</td><td colspan="3">Strategic</td></tr>
<tr><td>Artifact Type</td><td>Construct</td><td colspan="3">Model</td><td colspan="2">Method</td><td colspan="3">Instantiation</td><td>Theory</td></tr>
<tr><td>Epistemology</td><td colspan="5">Positivism</td><td colspan="5">Interpretivism</td></tr>
<tr><td>Function</td><td colspan="2">Knowledge function</td><td colspan="3">Control function</td><td colspan="3">Development function</td><td colspan="2">Legitimization function</td></tr>
<tr><td rowspan="2">Method</td><td colspan="2">Action research</td><td colspan="3">Case study</td><td colspan="3">Field experiment</td><td colspan="2">Formal proofs</td></tr>
<tr><td colspan="3">Controlled experiment</td><td colspan="4">Prototype</td><td colspan="3">Survey</td></tr>
<tr><td>Object</td><td colspan="5">Artifact</td><td colspan="5">Artifact construction</td></tr>
<tr><td>Ontology</td><td colspan="5">Realism</td><td colspan="5">Nominalism</td></tr>
<tr><td>Perspective</td><td colspan="2">Economic</td><td colspan="3">Deployment</td><td colspan="3">Engineering</td><td colspan="2">Epistemological</td></tr>
<tr><td>Position</td><td colspan="5">Externally</td><td colspan="5">Internally</td></tr>
<tr><td>Reference Point</td><td colspan="3">Artifact against research gap</td><td colspan="4">Artifact against real world</td><td colspan="3">Research gap against real world</td></tr>
<tr><td>Time</td><td colspan="5">Ex ante</td><td colspan="5">Ex post</td></tr>
</table>

Figure 9 Evaluation of the proposed method

Design of the method and prototype

In order for this EA-based method to be implemented effectively, it has to be structured. In this section I will give explicit instructions on how to make good use of this method.

Before we can evaluate the impact of a possible IT investment, we need to gain insight into the current architecture. Having experience in Enterprise Architecture modelling is not a prerequisite of working with this method, but it can make the process a lot easier. The ArchiMate language can model the organization in quite extensive detail. Within ArchiMate there is, next to the layer dimension, the aspect dimension which enables the following modelling aspects (Quartel et al., 2009):

- Structure aspect, which represents the actors involved and how they are related;
- Information aspect, which represents the problem domain knowledge that is used by and communicated between the actors
- Behaviour aspect, which represents the behaviour (e.g. processes and services) that is performed by the actors and the way the actors interact

Each of these aspects helps to model the enterprise from a different viewpoint and each serves its own purpose. Not all are necessary to serve our purpose in evaluating the investments for which we only need the processes and services that create value and the way they are supported by IT. Therefore I use the behaviour aspect along all layers as my modelling viewpoint.

For each layer (Infrastructure, Application and Business), we need to determine the services that are delivered and the components that deliver them. For example, in the infrastructure layer we may find an employee database, which is a service enabled by a server. Now we need to determine the Key Performance Indicators (KPI's) for each of these services and determine how the performance is influenced by the specifications of the underlying components. So in the example of the employee database, if the KPI's are maximum size and speed of access, these can be directly linked to the capacity of the server. This needs to be done for every service in all three layers, with links between them, finally mounting to the KPI's on the business level. These are the most important of all because the IT should ultimately support your business (even when IT *is* your business). I can show this process more clearly by demonstrating it, using an example. The following example is the same case that is used to explain the proposed method to the participants of the interviews and which I used to test the prototype of the accompanying tool in Excel. First I will give the case description which is largely copied from the case used by Buschle and Quartel (Buschle & Quartel, 2011) but altered to fit my needs. After the case description I will explain the method in more detail and show its implementation in an Excel tool.

Case description

This scenario is taken from a case study that was performed at a Swedish power utility in September 2009 (Buschle & Quartel, 2011) and has been extended to make it a more realistic case so that participants can truly relate to the problem. In this example we only consider a subset of the activities that are performed at the utility.

The utility has three business services that are *Network load dashboard*, *Rate advice*, and *Energy saving advice*.

- *Network load dashboard* aims to evaluate the current state of the electricity network. This service is used internally. In order to realize the underlying business process three application services are used; ***Real-time load monitoring, forecasting and statistics***. Those services on the one hand monitor the current state of the network. On the other hand one service forecasts how the power network will perform in the future and one application service uses statistics to evaluate how the electricity network behaved in the past. In order to fulfil this task two applications are used that consume infrastructure services (***a measurement database*** and a ***statistics database***) provided by two nodes (***A data collection server and a high performance computation server***).
- The service *Rate Advise* aims to help the customers of the utility to find the best rate based on its individual consumption profile. Additionally the utilization of the electricity network is considered as the utility is able to offer lower rates in moments of less utilization. To get this information the ***Statistics*** application service is used again. Using the statistics the consumer advisor can help construct a ***consumption profile (service)*** and ***help select an appropriate tariff (service)*** which help support the tariff advice process.
- The third business service *Energy saving advice* supports the customers to save energy. It takes into consideration the user profile that he or she has stored in the individual account on the utility's webpage. Based on the customer's preferences an individual mix between fossil, nuclear, and renewable energy is suggested. This is enabled by a ***CRM application*** which runs on a ***Linux server*** which can perform the necessary ***computations*** and keep a ***customer database***

Goals

The utility has the overall goal to be profitable. This should be achieved based on a satisfied customer base (sub goal *Customer satisfaction*) and a minimal reserve capacity (sub goal *Minimize reserve capacity*), into which the main goal is decomposed.

The goal ***Customer satisfaction*** is in turn decomposed into:

- *Maximize availability*
- *Lowest cost*
- *Insight in consumption*

Of course, more factors can influence customer satisfaction, but for this example we can use this (simplified) subset.

The previously described business service ***Network load dashboard*** contributes to the two goals ***Minimize reserve capacity*** and ***Maximize availability*** as the employees of the utility use it to identify an optimal over capacity. The business service *Rate advice* contributes to the ***Lowest cost*** sub goal as it helps the customers to identify the best rate. Finally the business service ***Energy saving advice*** contributes to the sub goal ***Insight in consumption***.

Possible investments

1) In order to improve customer satisfaction we would like to give them more insight in their energy consumption by giving them access to the real time data pertaining to their situation. In order to do so we would need to develop an application that would support this and in order to secure enough data space and computational power the data collection server would have to be replaced by a more sophisticated model. The development and maintenance of the application would cost approximately €85.000 (maintenance costs for coming three years discounted in the price) and the new server approximately €10.000.

2) Another project might be to add another high performance computation server in order to decrease the possibility of downtime and thereby increase customer satisfaction and reduce costs of loss of data or downtime. The cost of such a server is approximately €15.000 and in order to implement the synchronization and perform the maintenance another €15.000 should be set aside.

Procedure

First of all, I create the Architecture for the current situation, so without any of the possible investments, as can be seen in Figure 12. In this figure, one can see the relation between the components in the architecture layers. However, these relations are not enough for a usable causal model; for instance how would an improved measurements database result in an improved network load monitor? In order for such causality to become clear and measurable, we assign performance indicators to every component. For example, we judge the measurements database on the accuracy of its data, which is also important for the network load monitor. We can then assign the causal link between the score on the accuracy of the measurements database and the score on the accuracy of the network load monitor. When the accuracy of the network load monitor is influenced by nothing else than the accuracy of the database, we assign this 'influence rate', or in terms of a MCDA 'weight', of 100%. Obviously with an influence rate of 100% there isn't really a weight, but let's say it was influenced by 2 factors in the ratio 30%-70% than these can be interpreted as relative weights.

Now we do this for the entire architecture, assigning multiple performance indicators to each component. Thus the actual causal model would look like the part seen in Figure 10.

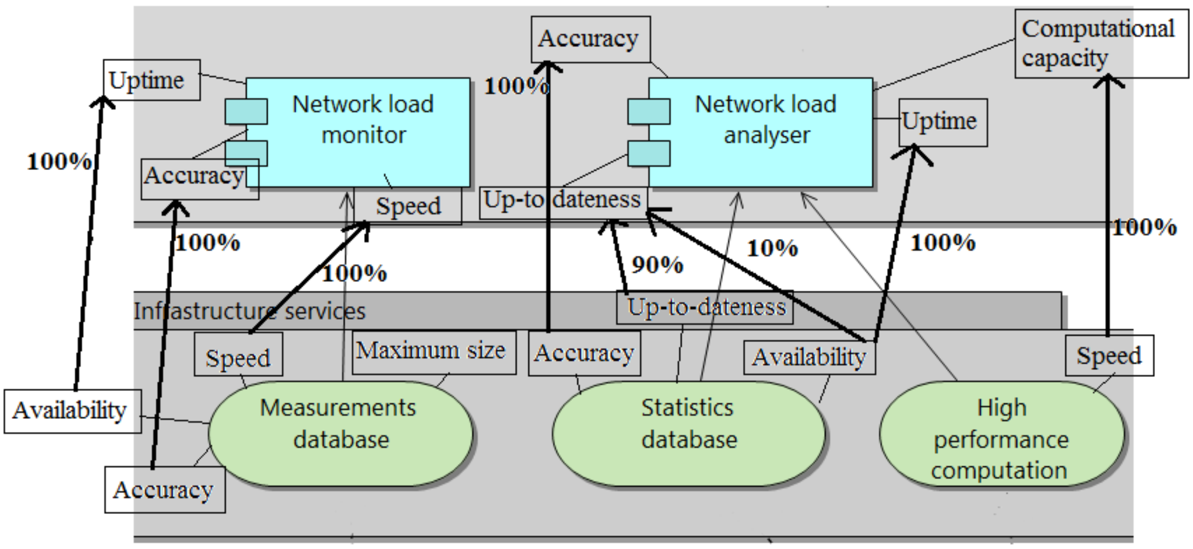


Figure 10 Influences amongst the performance indicators

As a visual representation of all these performance indicators does not add value (in fact it makes quite a mess) we do not actually show them in the architecture. They are, however, the basis for the calculation of value added by investment projects. For example if the investment in a new statistics database will result in a higher availability for that database then that increases the uptime and up-to-dateness of the network load analyser, which in turn will result in better application services and so on. So for all the components we determine their performance indicators and for all the performance indicators we determine their relationship with those of other components.

Now that the influences have been determined we need to be able to add scores to the performance indicators of all components. In order to do this, we start at the lowest level, with the infrastructure components. These are easy in the sense that they do not depend on anything but the capabilities of the component. For example, the uptime of a server is not dependent on anything but the reliability of the hardware (disregarding such things as power outages). For all performance indicators the decision maker develops a score scale going from 0 to 10. Uptime of a server for example; a server that is down 50% of the time or more is considered worthless and gets zero points, 50%-60% is still considered very bad and gets 1 point. In this manner the uptime is scored until one has the following score scale.

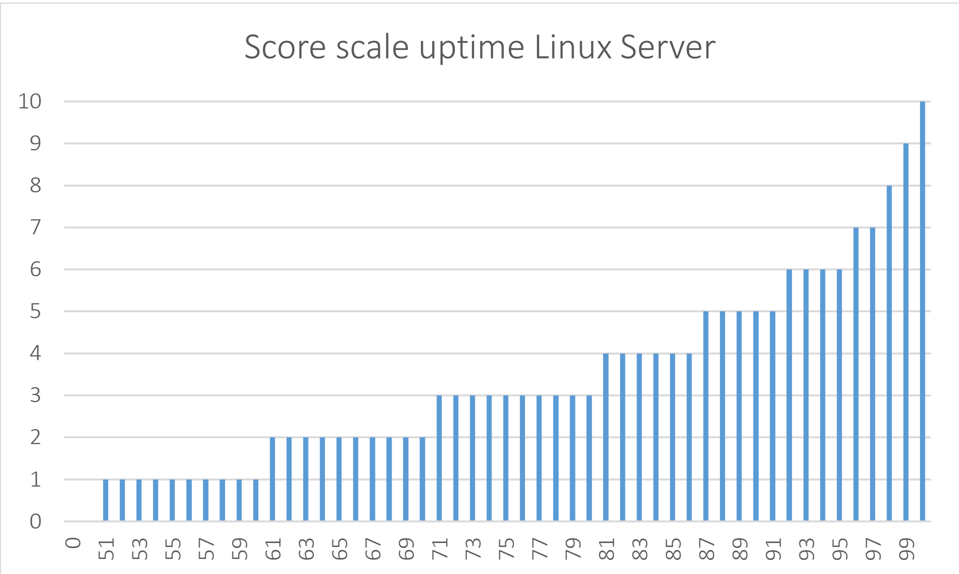


Figure 11 Example of a score scale

These score scales are important because they make the allocation of scores clear for the current situation but also for future situations, for example; if a project demands the replacement of the server, one can easily see how the new server scores compared to the old one.

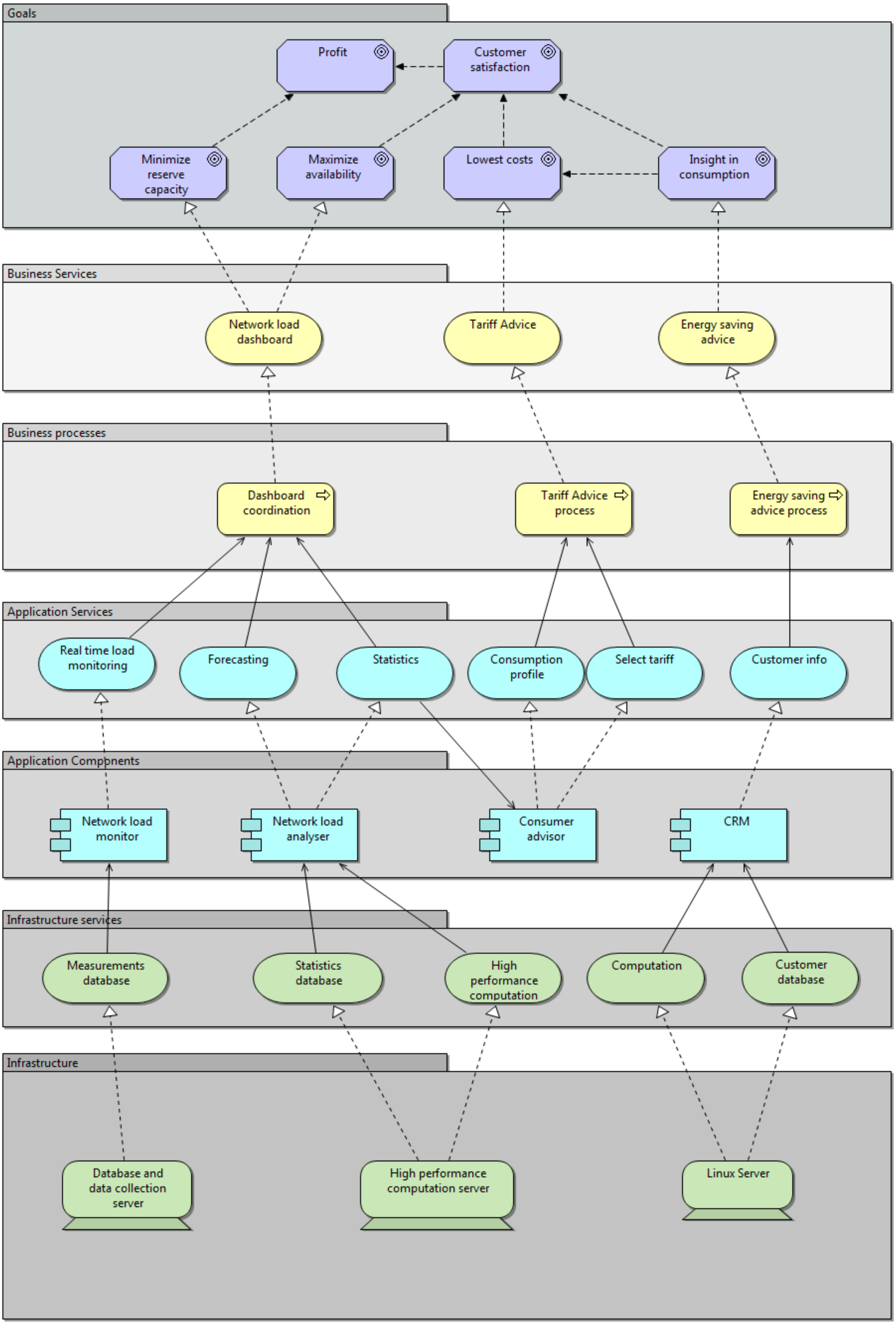


Figure 12 Architecture of the current situation

Once all the components that are only dependent on their own capacities have had scores allocated to their performance indicators, we can calculate the scores of the indicators for the components that are influenced by them. For example, say that performance indicator 1 of component C ($PI_C(1)$) is determined by indicator 2 of component A ($PI_A(2)$) and indicator 3 of component B $PI_B(3)$ the calculation would be:

$$PI_C(1) = PI_A(2) * \text{Influence factor } PI_A(2) \text{-> } PI_C(1) + PI_B(3) * \text{Influence factor } PI_B(3) \text{-> } PI_C(1)$$

(so in this example: $PI_C(1) = 7 * 30\% + 9 * 70\% = 8.4$)

In this way all scores are calculated based on the scores of the components they are influenced by and the corresponding influence factors, right up to the scores for the business goals which are influenced by the performance indicators of the business services.

Note: It is important to note that it may be necessary to add an extra component to the calculation of the scores. If, for example, a score for performance indicator of a service is partly determined by an intrinsic value of the service and therefore not solely reliable on the scores of the IT components it depends on, then this needs to be added to the calculation. I have chosen not to elaborate on this because it does not affect the theoretical model. However, it is important to know that this is possible and keep it in mind when applying it to a real-life situation.

Once all the scores are calculated our description of the current situation is complete. We can then change the scores and influences where necessary for the investment options, by adding, removing or altering components/scores/influences. The architectures for both investment options can be found in the appendix. The results from these calculations show scores on the business goals which allow us to compare the investment options. Because it is too much work to perform all these calculations manually, we use a tool in Excel to make this easier which I have altered to fit this method more precisely.

The tool

In the next few figures, I give an overview of how the tool is used. In these figures you can see how I have modelled the example case of the Swedish utility company.

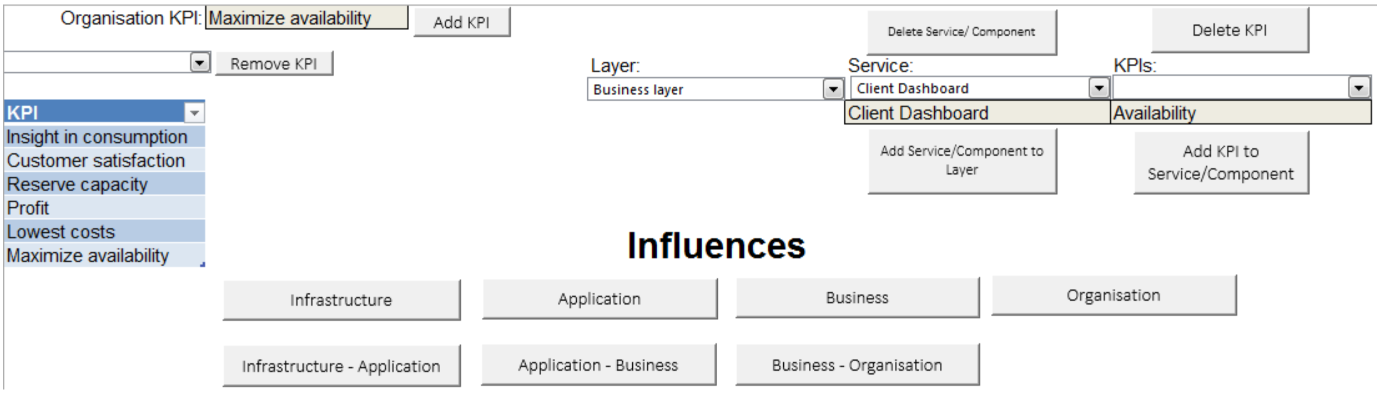


Figure 13 Adding the KPI's and components

In this first screen (Figure 13) the user can add and delete components of the architecture and KPI's (both organizational KPI's and component KPI's). Basically, this is the step were the visual representation as seen in Figure 12 is computed in the Excel file. Then, the user selects where the component has any influence and he is directed to the next screen. (Figure 14)

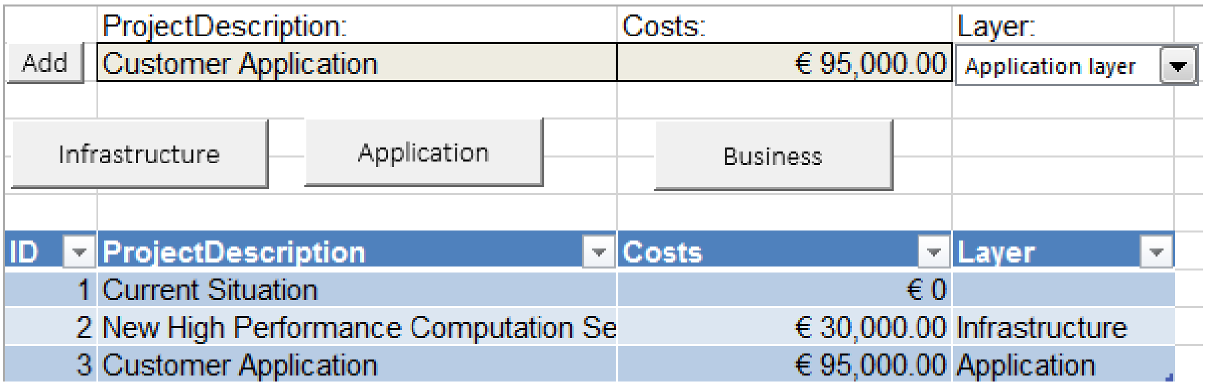
	Influence of	Real-time load monitoring			Statistics		Forecasting		
Influence on		Speed	Information quality	Availability	Comprehensiveness	Accuracy	Accuracy	Availability	Comprehensiv
Dashboard Coordination	Comprehensiveness	0%	20%	0%	40%	0%	0%	0%	40%
	Speed	100%	0%	0%	0%	0%	0%	0%	0%
	Availibility	0%	0%	50%	0%	0%	0%	50%	0%

Figure 14 Determining the impact

Here the components and KPI's are all automatically added to a matrix so that the user can determine the impact a change in a KPI of one component (the horizontal KPI's; Speed, Information quality etc.) has on the KPI's of the other components (the vertical ones; Comprehensiveness, Speed, Availibility).Once this is done for all components, the user can start entering the potential investments (Figure 15). By clicking on either infrastructure, application or business the user is directed to a screen where he can enter the scores of the investment on the predetermined KPI's (Figure 16).

Only scores for KPI's that are not influenced by any other KPI's are added manually to each of the projects. All the others are calculated automatically based on the KPI's of the underlying components.

The results are calculated and shown in the "results" tab (Figure 17). There, all the projects can be compared based on the organizational KPI's they have influenced.



ID	ProjectDescription	Costs	Layer
1	Current Situation	€ 0	
2	New High Performance Computation Se	€ 30,000.00	Infrastructure
3	Customer Application	€ 95,000.00	Application

Figure 15 Adding projects/investment options

	Measurements Database				Statistics Database			High Performance Computation	Computation	Customer Database
	Speed	Maximum size	Availability	Accuracy	Accuracy	Up-to-datenes	Availability	Speed	Speed	Accuracy
Current Situation	8	5	6	7	7	8	6	8	6	7
New High Performance Computation Server	8	5	6	7	7	8	9	9	6	7
Customer Application	9	5	8	7	7	8	6	8	6	7

Figure 16 Adding scores to the projects

	Insight in consumptio	Customer satisfactio	Reserve capacit	Profit	Lowest costs	Maximize availability
Current Situation	6.63	6.615	7.3824	€ 3,423,000	7	6
Performance Computation Server	6.63	6.915	7.6308	€ 3,535,000	7	7.5
Customer Application	8.13	7.565	7.6	€ 3,693,000	7	7

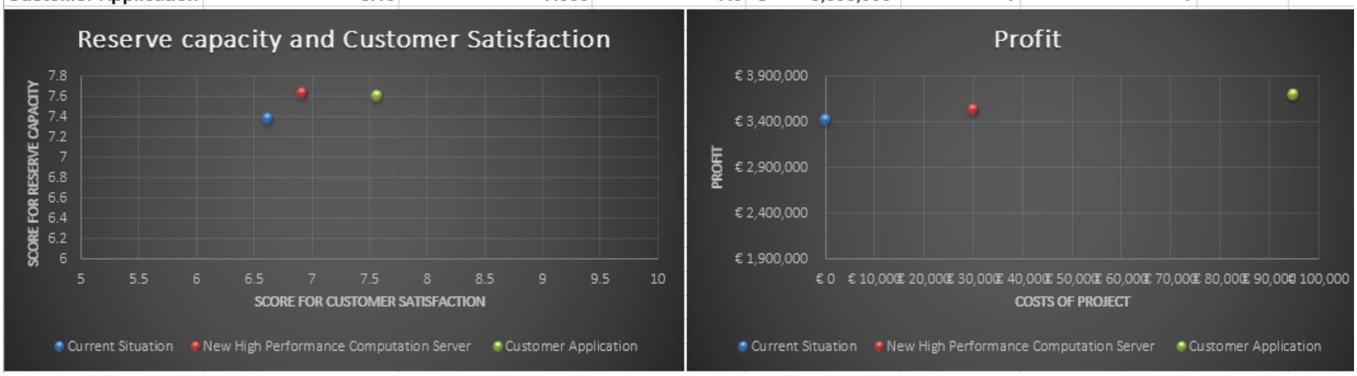


Figure 17 Result screen

Testing the method

In an attempt to verify that the use of this EA-based tool can lead to a more rationalistic approach to IT investment decision-making, and thereby a higher perceived decision quality, I have introduced it to several professionals who make this kind of decisions during the course of their work. I have conducted interviews in order to use the expertise of the participants to get feedback on the method, its strengths and weaknesses, how those weaknesses can be overcome, whether or not this method makes for better decisions and more rationalistic decision making. Also, it is important to know whether they think it desirable to create a more rationalistic approach to IT investment decisions.

The interview

In order to give the participants the opportunity to give complete and extensive feedback on the proposed method, I chose to use a semi standardized interview (Berg, 2006) (or general interview guide approach (Patton, 2002)). This way, if the participant presents a new view on the method, a reason why it may or may not work for example, I can then engage in a discussion with the respondent in order to clarify their view, expound on it or perhaps disprove it where necessary. This structure can also help clarify the current decision-making process in the participant's organization in order to compare is to the proposed method. Another reason for choosing a semi standardized interview over a structured one is the different backgrounds of the participants. Their organizations differ from one another in several ways which makes a structured interview rather difficult, if not impossible. Attempting to structure it too rigorously might cause one to omit important issues and may even harm the validity by limiting answers of the participants.

In a semi standardized interview, validity and reliability depend, not upon the repeated use of the same words in each question, but upon conveying meaning (Denzin, 1989). This is ensured by allowing the participants to ask questions and comment throughout the interview and by repeatedly explaining the meaning of the method and its components.

The interview I conducted consisted of four main stages.

1) Introduction
2) Review of current practice
3) Explain the method
4) Discussion

The **introduction** stage consisted of a personal introduction, both from the participant as well as myself, and a first verbal explanation of the proposed method, its presuppositions and its purpose. This first explanation of the tool served the dual purpose of explaining why I was conducting the interview as well as starting an iterative cycle to ensure that the participant understood the proposed method properly. Later on in the interview the explanation of the method becomes gradually more detailed and each 'explanation cycle' gives the participant the opportunity to comment and ask questions if necessary.

In the '**review of current practice**' stage I ask the participant to explain how IT investment decisions are made within their organization. I ask specifically about rationality vs. politics, about multi-criteria decision analysis and Enterprise Architecture. All these topics have been addressed in the introduction as part of the presuppositions and purpose of this research and are therefore considered known and understood by the participant.

After the participant has explained the current practice I **explain the method** again, this time in more detail than during the introduction. I explain about the use of scores, performance indicators and influences between the components of an Enterprise Architecture. I also make it clear that the use of ArchiMate has the distinct advantage of a layered structure, which simplifies the creation of a causal model to support a multi-criteria analysis. I clarify this with the aid of Figure 12**.** Then I show and explain the accompanying case of the utility company. To ensure maximum understanding I then show the use of the Excel file which shows the results of the calculations.

Now that I have given the participants a full explanation of how the Enterprise Architecture is supposed to help them make IT investment decisions I ask their opinion on this approach and engage them in a **discussion** on its usefulness, its strengths and its weaknesses. Two main topics are of course decision quality and rationality. Does the participant think the decision quality will/might increase when using this method? Will it become a more rational process? Is that desirable? And throughout the discussion; is it all feasible?

The participants

As I pointed out earlier, I have interviewed people with very dissimilar professional backgrounds, yet all have experience with IT investments and all are currently (partly) responsible for the IT investment decisions within his or her organization.

Organization's name	Type of organization	Name of interviewee	Position of interviewee
Rabobank	Bank	Mirjam Verlinden	Lead Business Architect
PGGM	Pension Institution	Hans van der Zwaag	Director ICT and Facility Service
		Richard Lugtigheid	Lead Information Architect
Alliander	Utility provider	Hans Fugers	Manager CIO Office
University of Twente	University	Jan Evers	Director of Information Management

Table 1 Interview Participants

Evaluation

As discussed in the previous chapter, the interviews had two main topics, rationality and decision quality, and interwoven in the entire discussion is the feasibility (and the strengths and weaknesses) of the proposed method. I will therefore present the results of these discussion along the same lines.

Rationality

I began this research from a desire to create a means of improving IT investment decision making, which I believed to be possible through rationality and the enhancing of information processing capacity to deal with the complexity of investment decisions. To this end I enhanced the prototype of the EA-based excel file created by Verburg (2013) which could then be fitted in a multi-criteria decision analysis.

Before I present the outcome of the discussions on rationality, I must add a note on the desirability of rationality. An important prerequisite of the supposition that more rationality will result in higher perceived decision quality, is that rationality, and the transparency that results from it, is indeed desired. In other words, even if we can all agree that rationality results in a more transparent and verifiable decision-making process, we must be aware that this is not always desired by the one making the decision. As Hans van der Zwaag put it on the outset our interview: "When you create transparency through rationality, other people can and will comment on your decision-making process. However, when the decision involves a project you just want no matter what, you do not want to be bothered with what others think. And so transparency is not useful at all, and nor is rationality." [1]

Keeping this in mind for further discussion, I will now address the key results of my discussion on rationality in IT investment decisions for each of the organizations in turn.

[1] All interviews were conducted in Dutch. All quotes are therefore not literal but a translation made by the author.

PGGM

In PGGM the current practice is as follows: the list of all proposed investments has three sources; first the business side, second the maintenance calendar, third innovation. This list is far more extensive than the budget allows so it is first prioritized and shortlisted based on the general strategy of the organization. This does not produce a definite portfolio. Now begins the political process. Strictly speaking all new investments are then supposed to be presented in a business case, although this does not always happen. The only time they use a kind of multi-criteria decision analysis is when the decision to invest in a particular project has already been made, but there are several different ways to fulfil that project. However, the strictness of such an analysis varies; "basically we decide how difficult we want to make it for ourselves, whether we use weights for the criteria" (van der Zwaag).

"Note, not everything is 'open to politics', we work with strict guidelines and objectives derived from IT strategy to which all new projects must contribute in order to be considered." (Lugtigheid)

Rabobank

At the Rabobank there is already a rather rationalistic approach to IT investment decisions in place. Proposed investments are scored on predetermined indicators which are derived from the business strategy. These scores are not derived from the IT components themselves but are a result of the combined estimation of three people (the Triangle); one person from the 'business side', one architect and a program manager. The business side requests a certain IT service, the architect decides how that is to be fitted in the IT landscape and determines what IT components would be needed to grant that request. The program manager then estimates the costs involved based on experience and consultation with the architect. The actual architecture, in the sense of the visual representation, is not used in this process. Once these estimations are finished and combined in a business case, and this is done for multiple possible project, the Triangle reviews the strategic business goals. Based on the prioritization of these business goals combined with the scores of the proposed projects they determine which projects are most urgent, and so which ones will be carried out. The use of scores point to a rationalistic approach but the fact that these scores are not based on the technical capabilities of the IT components and the services they deliver, leaves room for interpretation and manipulation based on personal preference. This danger is partly mitigated by the composition of this Triangle, as it represents different parts of the organization and therefore different interests. The discussion on enhanced rationality by means of the EA-based multi-criteria analysis is ultimately not an issue at the Rabobank. The nature of IT investment decisions and its decisive factors is completely different from the decisions to be made in the example case and for companies such as the utility company. "Although infrastructure and application development costs are often substantial these are as nothing to the savings in terms of full-time employees which is often the decisive factor in the business case." (Verlinden)

This points to a completely business-driven approach to IT investments and IT is therefore mainly viewed as a cost centre, whereas the business side gets credited with the benefits.

Alliander

At Alliander there is a change in progress in the way they decide on the direction the company is heading and how they make investment decisions accordingly. "We are currently trying to think more in terms of business capabilities which can enable us to prioritize better. We are also changing from being project-minded to program-minded. These programs, or functional domains, are analysed and a long term strategy is devised for each of them. These strategies are mainly based on our application landscape. We assess the current developments and estimate what the application landscape will/should look like in 2 to 5 years." (Hans Fugers)

Architecture is used to create more insight in the link between business and IT and when business has a request, architecture can shed light on what that requires from the IT and how it can be granted. All investment options for the coming two years can be divided in three categories. Category one is legally required projects. As a utility company Alliander is subject to many laws and regulations and this means there are certain IT investments they simply *have to* do. These can be disregarded for the point of this discussion as these do not involve a decision process. The other two categories are 'pure business cases' and 'step changes'. Step changes means bringing a business capability to the next level which allows future benefits. These categories involve decisions and all these projects are business-driven. As a result, all expected benefits are defined by the business side and IT only estimates the costs and uses architecture to see how they can bring about the project in the cheapest and most efficient manner.

"But changes in the infrastructure or application layer might bring about benefits or costs in other applications or business processes that cannot be foreseen by the business side. This might mean that this information is not taken into account when assessing the projects. A more rationalistic approach, in which you calculate the value based on your IT capabilities, would help with that and thereby make the decision better, wouldn't it? "

Hans Fugers: "This reminds me of how SAP consultants try to convince you that you need more SAP, with what they call value mapping. It is my belief that the business side is very skilled in estimating the business value of the projects they coin. It is then up to the IT side to assess and minimize the financial consequences."

"The main presupposition of my research is that the decision-making process is often riddled with politics and that a rationalistic approach would be much better…"

Hans Fugers: "Can you name a single decision in your life you have made on pure rational grounds? That is wishful thinking. It is true that most of the decisions are made on political, even irrational, grounds. It is, however, a laudable aim and KPI's are important and are determined at every level. The relation between the strategic level KPI's and operational KPI's are often very unclear, and politics are important to make that bridge. (….) I do however see value in the rationalistic approach when it is used to specify where the architecture shows unused capacity, even hidden business capabilities."

This view shows, yet again, that politics is viewed as a necessity (not to say necessary evil) when it comes to the daily activity of investment decision making.

University of Twente

At the University of Twente the rationalization of IT investment decisions is a current topic. The relatively new IT board is currently devising methods to gain insight in how the current and proposed IT projects help realize the university's strategic goals. In the past two years there has been an increasing focus on IT strategy and last year the IT board developed a 4-year IT strategy (Evers, 2013) in which they outline the IT strategy in terms of four domains: Research, Education, Support and General IT. They intend to create a dashboard to monitor the realization of the goals specified in this strategy for each of the four domains. Each year a project portfolio is created which contains all IT projects that will be started in the coming year. In order to create this portfolio choices need to be made on which projects to start and which to dismiss. This is done by prioritizing the projects based on their contribution to the long term IT strategy. Because it is deemed impossible, or at least very difficult, to assign absolute scores to projects on their contribution to strategy, this is done with relative scoring (e.g. project 1 contributes four times as much as project 2). Although this method is not very comprehensive, it does aim to lessen the dangers of politics in the decision making process and it creates a rational process in the sense that it uses a form of scoring based on a predetermined set of criteria.

Although Enterprise Architecture is not yet used to support decision making, this is the intention. Up until very recently there were no architect positions at the university but they are now in place and once they are properly settled they are supposed to help gain insight in which projects contribute the most to the university's goals. It is not yet clear how *exactly* they are supposed to do this. Yet it is clear that they are meant to aid a rationalistic approach to investment decisions.

The rationality envisaged in the method proposed in this thesis is as yet, perhaps, a bridge too far. Jan Evers is not convinced that it is possible to quantify the many qualitative criteria that have to be taken into account and says that a business case is better suited to convey the value of a qualitative criterion.

Decision quality

To get an idea of the expected effect this method might have on decision quality I have asked the participants to consider three factors of decision quality (Hart, 1985); Process, Content and Outcome. About the process of the decision, I asked them what they thought would be the effect on the difficulty of the decision-making process. In order to avoid confusing this question with the question of feasibility, I made it clear that they were to envisage the hypothetical case that this method is implemented as intended. In such a case there is consensus that the process becomes considerably easier, especially once the current architecture has been modelled.

An important indicator for the quality of the content of a decision-making process is the number of alternatives that can be considered when this method is employed. Again, supposing a successful implementation, the general idea is that it becomes much easier to compare many different projects because the complexity of such a comparison is taken over by the automated calculations.

The quality of the outcome can be assessed by the confidence the decision maker(s) are likely to have in the outcome of the proposed method. This is a point of disagreement. Some (e.g. Fugers and Verlinden) predict that people are likely to have greater confidence in a decision that is based on such a method, others (Evers, Lugtigheid) think that confidence in the outcome will not be very high and that it is unlikely to be accepted.

Feasibility

Regarding the perceived feasibility there are a few things that have been mentioned several times in this series of interviews.

First of all, the concern that a purely rationalistic approach might not possible or accepted within the organizational structure. Not possible, because it is too difficult to define the scores or influences, or not accepted because it limits the possibility to get one's pet project approved without substantiation.

Second, the level of detail. The level of detail described in the example case is regarded as too high; "make it more abstract, we do not model on this level of detail" (both Verlinden and Lugtigheid). In a way this is closely related to the first point of concern. Both Richard Lugtigheid and Mirjam Verlinden advised a more abstract, high level model which would make it easier to make estimations on scores and influences and creates a definite opportunity for such a rationalistic model to be useful and feasible.

Third, the timing of this method. Considering that the accuracy of the scoring is very important to the outcome, it is important that one only calculates the value using this method when there is sufficient information available to determine the scores. It might therefore be necessary to have a pre-selection of possible investments and to make sure enough is known about each of the projects, for example after a business case has been made. Of course this devaluates this method considerably as one of the intended advantage of this method was that a lot of options can be taken into consideration. It is therefore important to find the right balance between certainty of scores and amount of considered options.

And finally, the amount of work involved. There is general agreement that once the current architecture has been transferred to the Excel tool, it is relatively easy to add the properties of the proposed investments. However, it would take a large amount of time to transfer it in the first place and it is doubtful that it is worth it considering the uncertainty of its usefulness. Further empirical research is needed to prove that it would be worth investing the time and effort.

Conclusion

To start off on a positive note, I believe I can conclude that the main presupposition from which I started, the belief that more rationalism in the decision process would lead to decisions of better quality, can be upheld. The participants of the interviews acknowledge that the decision-making process surrounding IT is riddled with politics, and that this leads to (partly) unfounded or at least unverifiable decisions. As I pointed out earlier, sometimes this is deliberate. After all, when you really want something without contradiction, it is better when you don't have to justify it. But generally speaking it is in the organization's interest, and ultimately in that the decision makers, to have a transparent and verifiable decision process, not in the least because it gives confidence in the quality of the decision.

The second conclusion I can draw from this research is that politics *does* play an important role in investment decisions and that it is unlikely to be replaced completely by rationalism. In some cases the transparency that comes from a rationalistic approach is unwelcome and in some cases the political processes are necessary to communicate (strategic) goals to those with other interests.

The third conclusion I can draw is that the proposed method still has a lot of uncertainties and aspects that need further research before it can be implemented, such as; the level of detail used in the architecture and in the establishment of KPI's, the moment when this method is to be used (after the business case or as a replacement) and the manner in which it can be implemented so that the outcome is trusted and accepted.

However, I have also experienced that there is indeed a struggle to find a more structured and rationalistic approach to the immensely complex and difficult world of IT investments, which leads me to believe there is hope for an approach such as the one I propose in this thesis. Each of the organizations I have visited are trying, each in their own way, to reduce arbitrary decision-making and to find a method to prioritize their investment options so that they add the most value to their organization. For each of the organizations I've visited, and I think this goes for most other organizations as well, it is important to stress the importance of the qualitative benefits that result from IT investments. This leads me to believe that the use of a multi-criteria analysis is crucial for an effective investment valuation, and that we indeed need a new method. The growing popularity of EA, and the fact that it links infrastructure to business processes, where the actual value is added within an organization, indicates that it may indeed be the key to finding that elusive method of attributing value to IT. Because all the participants of my interviews, whether they use EA for decision support or not, agree: Architecture is indispensable when it comes to gaining insight into your IT landscape.

Further Research

As the level of detail for the architecture has been a recurring point of doubt on the feasibility of this method it can be worthwhile to conduct a separate study aimed at finding the right level of detail in which this method is both feasible as well as useful. This would require a more practical implementation of the method than just a test case such as in this thesis. By actually implementing a multi criteria analysis based on an architecture on several levels of detail, one might determine at what level the architecture is still of value to reduce complexity and support rationality but where it is also still feasible to predict influences and assign scores and weights.

Besides the use of this model for portfolio decisions one might consider other uses. Instead of reviewing possible investments, the EA can be used to formulate the requirements of the components in the IT landscape, which can be very useful when considering cloud computing or other outsourcing activities. In this case the minimum requirement can be calculated given a certain set of threshold values for the KPI's of the services delivered in the business layer. As discussed earlier on in this thesis, I have only explored the *causation* processes the causal chain in the Enterprise Architecture might enable, and of those processes only a few. But the other application of these causal links, that of *effectuation* processes, I have not explored, though I have remarked that, in theory, this might show some very interesting and valuable results.

Because political processes are so deeply seeded in the choice of IT investments, it is also necessary to conduct a study on how change management might help the implementation and acceptance of a more rationalistic approach.

And finally, I return to the problem of complexity which I used to categorize different methods of improving IT investment decisions. In this thesis I chose to focus on the goal of enhancing the information processing capacity of decision-makers as a way to cope with complexity. Though it is necessary to make the distinction between the efforts to reduce complexity and those to enhance our capacity to deal with it, this does not mean that the one precludes the other. The procedural changes KLM made in an effort to simplify their IT investment decisions might well prove valuable, if not necessary, to implement methods to optimize those decisions. And conversely, a procedural change may still result in poor decision-making if not combined with an unstructured decision-making process. In future research these two ways of dealing with complexity should therefore be taken into consideration, and ideally merged into a single method.

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Appendix A

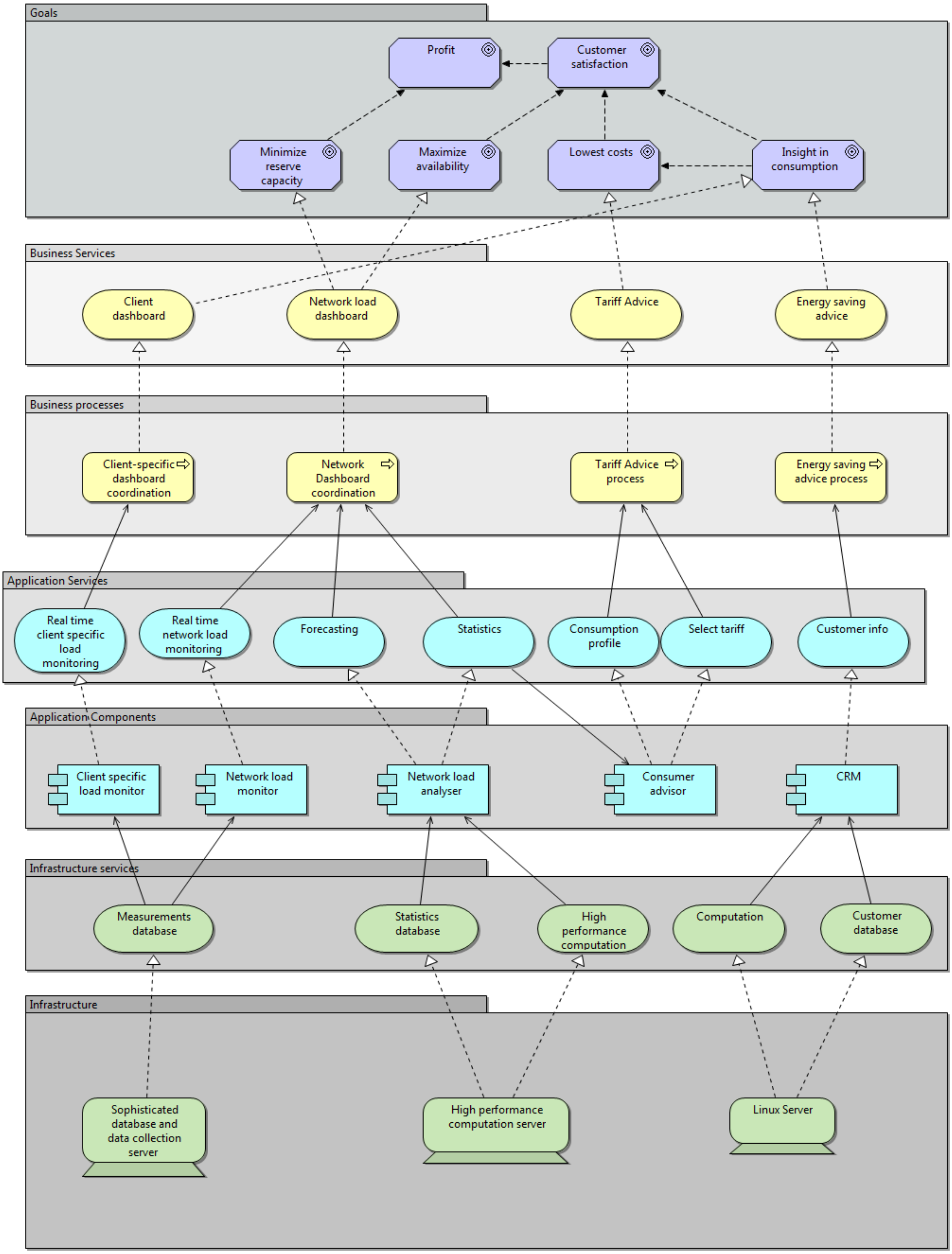

Figure 18 Architecture including investment option 1

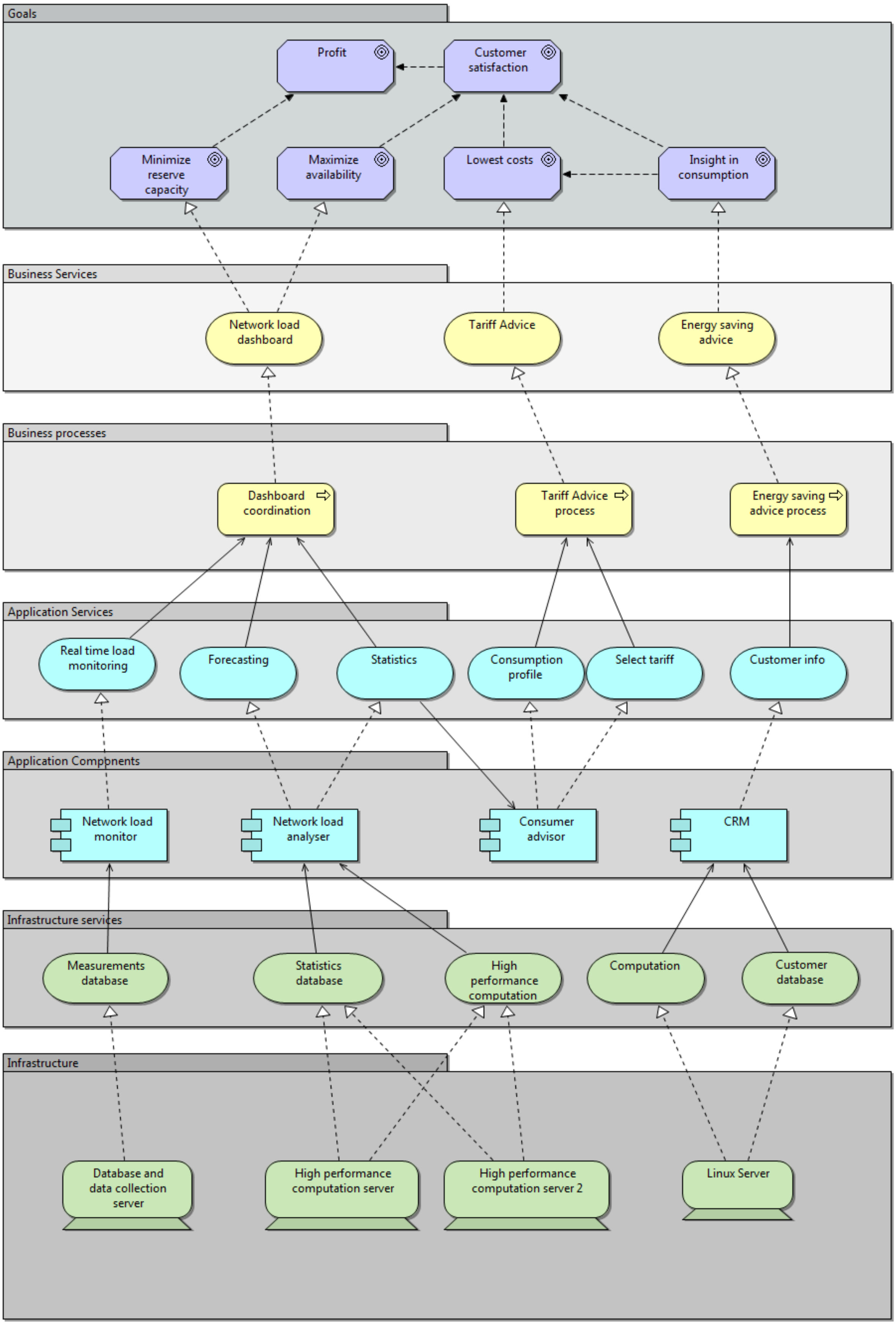

Figure 19 Architecture including investment option 2

Appendix B

Notation	Definition
V_j	Option value of project *j*
B_j	Present value of expected benefits (returns) of project *j*
C_j	Present value of the expected costs of project *j*
N()	Cumulative standard normal probability density function
σ_j^2	Variance of expected project returns of project *j*
T	Time to option expiration
r_t	Risk-free interest rate
r_d	Risk adjusted discount rate
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*)
cf_j	Net cash flows associated with project *j*

Table 2 Notations used in the Real options model(Bardhan et al., 2004)