A method for valuing architecture-based business transformation and measuring the value of solutions architecture

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His main interest is to develop the enterprise and solution architecture discipline, by conducting fundamental & applied research and using state-of-the-art concepts and methods to solve concrete architecture challenges.

Enterprise and Solution Architecture are key in today's business environment. It is surprising that the foundation and business case for these activities are nonexistent; the financial value for the business of these activities is largely undetermined.

To determine business value of enterprise and solution architecture, this thesis shows how to measure and quantify, in business terms, the value of enterprise architecture-based on business transformation and the value of solution architecture.

Value of Architecture

Raymond Slot

A method for valuing Enterprise Architecture based Business Transformation and Measuring the value of Solutions Architecture

RAYMOND SLOT

A method for valuing Architecture-Based Business Transformation
and
Measuring the value of Solutions Architecture

Raymond Slot
University of Amsterdam
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Een methode voor het waarderen van Architectuurgebaseerde Business Transformatie & Meten van de waarde van Project Architectuur

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor

aan de Universiteit van Amsterdam

op gezag van de Rector Magnificus

prof. dr. D.C. van den Boom

ten overstaan van een door het college voor promoties ingestelde

commissie, in het openbaar te verdedigen in de Agnietenkapel

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Copromotor:	professor dr. Guido Dedene
Overige leden:	dr. E.J. de Vries UHD
	prof. dr. H.A. Proper
	prof. dr. P. Adriaans
	prof. dr. P. Johnson
Faculteit:	Economie en Bedrijfskunde

To Vincent

ऋ॒चो अ॒क्षरे॑ पर॒मे व्यो॑म॒न्यस्मि॑न्दे॒वा अधि॒ विश्वे॑ निषे॒दुः
यस्तन्न वेद॒ किमृ॒चा क॑रिष्यति॒ य इत्तद्वि॒दुस्त इ॒मे समा॑सते

Richo Akshare Parame Vyoman
Yasmin Deva Adhi Vishve Nisheduh
Yastanna Veda Kim Richa Karishyati
Ya It Tad Vidus Ta Ime Samasate
Jai Guru Dev

“Knowledge is structured in consciousness,
the field in which reside all the impulses of intelligence
responsible for the creation of the entire universe.
He who does not know this field,
what can knowledge accomplish for him?
He who knows it is established in all possibilities in life.”
Rig Veda 1.164.39

Preface

History

When does one decide to undertake something like a PhD study? I remember when I graduated with my MSc in January ’84, that I had a notion that I would ‘ever’ get a PhD. At that point in time, I was eager to start with a job, after 7½ years university study. My first attempt came in ’85 when I drafted a research proposal. I don’t remember the subject of the proposal anymore, but it didn’t lead to a study.

Fourteen years later, I was busy in the area of business and IT architecture. At that time, there was not that much research known about the benefits and quantification of architecture. In a discussion with a number of architects, the idea came to me to choose the subject *business value of architecture* as the subject for my study. This discussion must have taken place somewhere in 1999.

This led to a research proposal, which I discussed with several professors. Rik Maes and I got together in early a 2000 and decided that this would be a good study to start at the University of Amsterdam. Guido Dedene also became involved and thanks to their support, I was able to take some steps in the following years. After testing several approaches, which were discarded for various reasons, by the end of 2003, I was out of options. I decided to stop for a few months and reflect on what I had done, while looking for other ways to achieve the desired results.

The next step came when Mathieu Hagen and I met, early 2004. I was facilitating an architecture course in *Les Fontaines*[*] and Mathieu was facilitating a Six Sigma course during the same week. Coincidentally, we sat next to each other during a dinner and he was so kind to explain Six Sigma to me. It dawned to me that this was the approach were I was looking for. This encounter led to a joint research proposal, which was honored by Tonny Wildvank and Ger Donners and because of their support, we were able to start a Six Sigma pilot study and a follow-up, full-fledged project-success study, named Arjuna. Conducting the pilot and the follow-up study took about two years and by May 2006, I had become Six Sigma Black Belt and we had the results of the Arjuna study available. With this, one piece of the puzzle was complete; I was able to determine the value of Solutions Architecture.

[*] *Les Fontaines (Chantilly, France) is an international training centre.*

The next question was how to determine the value of enterprise architecture, or – more precisely – the value of architecture-based business transformation. It was clear to me that I had to define a new way of measuring the value of architecture-based on business transformation. In the literature, several approaches for determining the value of business transformation are described. There are the purely financial methods, which use ROI and NPV approach and there are architecture-specific approaches available like CBAM[*]. However, none of these approaches was satisfactory for me. There are two reasons for this. Investments in enterprise architecture are always linked to many uncertainties and they do not incorporate this uncertainty aspect. Besides, the investment process in enterprise architecture is not an 'all or nothing' initiative. Implementing enterprise architecture takes many years and is a phased approach. Managers responsible for the implementation of enterprise architecture, adapt the planning continuously to take care for changed circumstances and to include learning experiences from previous phases. These adaptation and learning effects are also not valued in these valuation methods.

Hence, I looked around for another approach. A casual remark of a colleague put me on the track of Real Options Analysis. ROA looked promising and I used the next year to dive into this theory and to see how it could be used to value the investments in enterprise architecture. By the summer of 2007, I had worked out an approach for applying ROA to value architecture-based business transformation. At that point in time, I met with Ton Hardeman and Wouter Schmitz who allowed me to apply this approach in their company and this took place in the second half of 2007. By the end of that year all the pieces of the puzzle where available and I was able to start writing the chapters of this thesis. This writing process took about a year; I was able to finish it in the spring of 2009. Looking back, I discovered many new things in this learning adventure and I am thankful that I am able to finish it with positive results. It took a lot of time (my first planning aimed for an end date of 2005) but it is very satisfying to finish this initiative and adding some value to the field of business and IT architecture.

Acknowledgements

A research study like this cannot be conducted without the cooperation of many people. First, I would like to thank my wife for her support through all these years. Without her support, I would not have been able to finish it. My children were

[*] *Cost Benefit Analysis Method (Asundi, et al., 2001)*

young when I started, but at the end, they were aiming for a bachelor or masters degrees themselves and I thank them for their support.

I like to thank everyone who contributed to this research. Mathieu Hagen for teaching me the basics of statistics and Six Sigma and supporting the initiative enthusiastically, Tonny Wildvank, Edwin Kok and Ger Donners for supporting the first Arjuna initiative, Jouke Hopperus Buma, Nico Toussaint, Goossen Foppen and Bernard Hüdepol for pushing the Six Sigma approach, Victor van Swede for providing support with the Six Sigma data processing efforts. Ton Hardeman and Wouter Schmitz, who allthisowed me to work on this topic in their company, Max Stahlecker and Rudolf Jurgens who were very persisting in their efforts to gather the required data. For being able to conduct the project level study, my gratitude goes to: André Weber, Edgar Giessen, Frank Harmsen, Hans Schevers, Jack van Eijk, Jan Joosen, Jos Smit, Kaeso de Jager, Maickel Sweekhorst, Marco Folpmers, Mark Grimberg, Ron Tolido, Tom Vanderwiele, Wil van Hamersveld and the project managers who took the time to fill in the questionnaire. Furthermore, I like to thank the reviewers of the manuscript, who read very carefully through it and their input helped me considerably to rephrase unclear passages and correct many other omissions. Among others, I owe thanks to Bart van Riel, Maarten Kuijpers, Klaas Zondervan, Marijn Driel and Arnold van Overeem.

Summary

Enterprise and solution architecture have become key elements in today's business and IT portfolio of activities. The purpose of these initiatives is to improve business and IT alignment, which is assumed to result in more effective and efficient use of the business and IT assets of a company. Enterprise architecture is the discipline that aligns business strategy with execution. Solution architecture is the discipline that aligns the enterprise architecture with business and IT implementation projects.

The theory and especially the practice of Enterprise Business and IT architecture has been developed quite vigorously the last years. Seen as a further development of the Information Planning approach (Martin, et al., 1989) the starting point for IT architecture is often considered John Zachman's article in the IBM Systems Journal (1987). Enterprise architecture is considered the "missing link" between, on the one hand, strategy and implementation and, on the other hand, business operation and IT operation (Maes, et al., 1999). Every major organization has created an enterprise and/or a solution architecture department which is responsible for defining and implementing the respective architectures.

Considering the activities that take place in the business and IT architecture world, it is surprising that the foundation and business case for these activities are largely nonexistent. There has been very little research published on the financial value of business and IT architecture. In other words, when organizations are investing in architecture by setting-up architecture departments, recruiting architects, educating and training these architects and setting-up architecture development and governance procedures, the cost of these activities can relatively easily be determined. However, the financial value for the business of these activities is largely undetermined. With "financial value" is meant the revenue or savings (in Euro's) created by organization, which originates from the use of enterprise or solution architecture.

Research Questions

To determine business value of enterprise and solution architecture, the following research questions are addressed:

1. Can we define a suitable method for measuring and quantifying, in financial terms, the value of enterprise architecture-based business transformation?
2. Is the method usable in practice to determine the value of enterprise architecture-based business transformation?

3. Can we define a suitable method to measure and to quantify, in financial terms, the value of solution architecture?
4. Can we apply this method to determine the value of solution architecture?
5. How is the business value of IT related to the value of enterprise and solutions architecture?

Question 1. Can we define a suitable method for measuring and quantifying, in financial terms, the value of enterprise architecture-based business transformation?
Several methods are available for determining the financial value of architecture-based business transformation. One of the most simple and straightforward methods is the Net Present Value method. This method discounts expected future cash flows. However, there are several shortcomings using this method (Saha, 2004). *Real Options Analysis* (ROA) is another method for assessing the financial results of enterprise architecture. However, the standard ROA approach is not suitable for evaluating the financial results of enterprise architecture. Enterprise architecture-based business transformation initiatives have two main sources of uncertainty. Business transformation initiatives face uncertainty with regard to revenue and uncertainty with regard to cost. Also, the probability distributions of the revenue and cost uncertainty may be different. The standard ROA approach cannot accommodate these requirements. Therefore, we have adapted the standard ROA method to make it suitable for assessing the value of an enterprise architecture based business transformation initiative. Our approach can include multiple sources of uncertainty, while each source of uncertainty may have a different probability distribution.

Question 2. Is the method usable in practice to determine the value of enterprise architecture-based business transformation?
To test the ROA-based financial assessment method in practice a case study is conducted. In the case study, several architecture-based business transformation scenarios are compared. The business value (in terms of business revenue and savings) is calculated using the ROA approach.

Based upon the experiences of this case study we can conclude that Real Options Analysis is a valid approach for quantifying the value of enterprise architecture based business transformation. We also can conclude that ROA provides a better insight into the value of architecture based business transformation then other valuation methods. The reason for this is that the ROA is also able to assess the value of revenue elements which are difficult to assess with other methods.

First, ROA assesses the value of future changes in the transformation initiative. Architectural investments generally have an uncertainty about the value of future services. Because of this nature of architectural investments, it is often not clear beforehand how the investments will be applied for maximal usefulness. Future users of the architecture implementation may find novel ways to use it and to generate additional value from it. This uncertainty provides its own value, which is not recognized by other valuation methods.

Second, ROA allows for valuing infrastructural investments. Architectural investments tend to have an infrastructural character. Infrastructural investments are generally hard to value, because their benefits are spread across company and are contingent upon follow on investments. ROA can handle this uncertainty better than other methods.

Question 3. Can we define a suitable method to measure and to quantify, in financial terms, the value of solution architecture?

To understand the value of solution (or project-level) architecture we selected as a measurement method statistical analysis of projects. This method allows us to mutually compare the results of software development projects and correlate the role of solution architecture to project success. The method analyses variance in project success variables and correlates these variances with solution architecture related project input variables. Examples of success variables are: *Project Budget Overrun*, *Project Time Overrun* and *Customer Satisfaction*. Examples of project input variables are: *Presence of a Solution Architecture Design*, *Presence of Architectural Governance Procedures*, etc.

Question 4. Can we apply this method to determine the value of solution architecture?

The statistical analysis approach was tested in a survey of 49 software development projects. In the survey, we define ten solution architecture-related project input variables and correlate them with eight project success variables, by statistically analyzing the results of 49 software development projects. The table below gives an overview of the main results. Applying solution architecture product to projects is correlated with the following project success effects:

	Project Success Effect
(a)	19% decrease in project budget overrun
(b)	Increased predictability of project budget planning, which decreases the percentage of projects with large budget overruns from 38% to 13%
(c)	40% decrease in project time overrun

	Project Success Effect
(d)	Increased customer satisfaction, with 0.5 to 1 point – on a scale of 1 to 5
(e)	10% increase of results delivered
(f)	Increased technical fit of the project results

Table 1-1. Result overview value analysis for Solutions Architecture

These results demonstrate that the use of solution architecture is correlated with substantial, positive effects on project success variables. We can conclude that there are convincing indications that the use of solution architecture is correlated with a substantial improvement of several key success variables.

Question 5. How is the business value of IT related to the value of enterprise and solutions architecture?

During the last 15 years, several widely-published studies fail to identify a correlation between business performance and investments in IT. This is contrary to popular belief that IT support and businesses in improving their performance. A key question for the IT industry is therefore why this correlation cannot be measured.

We find that many IT value studies do not incorporate the role and value of architecture. Because architecture is concerned with the effectiveness and appropriate use of IT assets within an organization, this implies that these studies do not distinguish between those organizations that use IT assets appropriately and those who do not. The underlying assumption for this research is apparently that higher IT investments automatically lead to a higher impact of IT assets within the organization, which – at its turn – would automatically lead to better business performance. This assumption is clearly incorrect. When considering the business value of IT, one should not only consider the level of IT spending, but also the level of effective or appropriate use of IT assets by the organization.

Based on our research findings and relevant literature, we conclude that enterprise architecture plays a pivotal role in improving the effectiveness of the use of IT assets within a corporation, improves IT impact on business performance and, consequently, allows IT investments to have measurable effects on business performance.

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List of Definitions

1.

Business Value of Enterprise and IT Architecture

This chapter introduces the subject of the thesis, definition of the concepts, statement of the key research questions and deliverables, followed by a description of the content of the chapters of the thesis.

1.1 Introduction

The theory and especially the practice of Enterprise Business and IT architecture have been developed quite vigorously the last years. Seen as a further development of the Information Planning approach (Martin, et al., 1989) the starting point for IT architecture is often considered John Zachman's article in the IBM Systems Journal (1987). Enterprise architecture is considered the "missing link" between, on the one hand, strategy and implementation and, on the other hand, business operation and IT operation (Maes, et al., 1999). While the development of business and IT architecture methods more or less started from 1987, the approach and particularly the theory of architecture are still under development. International and national standardization organizations, such as *The Open Group* (TOGAF, 2004) and in the Netherlands Lankhorst (2005) is working on standardization of business and IT architecture and the effects of these efforts are now reaching the end users. Various IT organizations have developed their own architecture framework and use it in the market (Rijsenbrij, et al., 1999).

Considering the activities that take place in the business and IT architecture world, it is surprising that the foundation and business case for these activities are largely nonexistent. The whole field of architecture is still relatively young; main developments only started about 10 years ago. There is still little research done to quantify, in financial terms, the value of architecture.

The main subject of this thesis is to quantify financially the value of architecture-based business transformation and to measure the value of solutions architecture. Organizations invest a lot of money in architecture. These investments include, among others: training of architects, development of architectures and implementation of architecture processes within the organization. Is the spending of all this money justified? Approaches to information economics (Parker, et al., 1988; Oirsouw, et al., 1993) generally do not include the effects of business and IT architecture.

We argue that the consequence of this omission is a main reason that there is no measurable correlation between investment in IT and the business effects for the company (Strassman, 1997). Soh and Markus (1995) argue that plain investment figures, comparing the level of the investment to, for instance, revenue do not include any indication about the effectiveness of the investment. We claim the application of Enterprise Architecture improves Business-IT alignment. Furthermore, it improves the effectiveness of IT resources.

Summarizing, the subject of this thesis is linked to the effectiveness of investments in IT and the business benefits that an organization derives from investment in IT. In other words, we argue that architecture is a point of leverage, which can help management to improve the effectiveness of IT investments.

1.2 Definition of Enterprise Architecture

In order to understand the subject of architecture and the role of architecture within an organization, we will define what we mean by enterprise and solution architecture. Various definitions of business and IT architecture are in use. An overview:

1. *"The fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution."* (IEEE, 2000)

2. *"The formal description of the system, or a detailed plan of the system at component level to guide its implementation. The structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time."* (TOGAF, 2004)

3. *"Normative restriction of designer freedom"*(Dietz, 2005)

4. *"Architecture links vision, strategy and feasibility, focusing on usability, durability and effectiveness"*(IAF, 2007).

5. *"Enterprise Architecture is the practice of applying a comprehensive and rigorous method for describing a current and/or future structure and behavior for an organization's processes, information systems, personnel and organizational sub-units, so that they align with the organization's core goals and strategic direction."* (Wikipedia, 2007)

Considering these definitions, it appears that the first two are defining architecture results and the third and the fourth define the concept of architecture. Apparently, the type of definition reflects the purpose of the author of the definition. The Wikipedia definition defines architecture as a practice, addressing both the business and technical architecture. In this thesis, we will use the following definition:

Definition 1-1. Purpose of Architecture
The purpose of Enterprise and Solution Architecture is to align the current and/or future structure and behavior for an organization's processes, information systems, personnel and organizational sub-units, information systems and technical infrastructure with the organization's core goals and strategic direction.

Definition 1-2. Enterprise Architecture
Enterprise Architecture is the practice of applying a standard approach for and describing in a standard way the current and/or future structure and behavior for an organization's processes, personnel and organizational sub-units, information systems and technical infrastructure.

Note that this definition does not make a distinction between Business and IT architecture; it encompasses them both. This is how we consider the EA discipline; it should be seen as one discipline, addressing both business and IT.

1.3 Solutions Architecture

Enterprise architecture sets standards and guidelines, based on strategy, for the structuring of the organization. The Enterprise architecture is implemented by many projects, each implementing its own small part of the total design. The approach where project objectives are also determined by enterprise architecture objectives is called development under architecture. Wagter et al. (2001) formulate this as follows: "Development under architecture realizes concrete business goals within the desired time frame, at the desired quality levels and at acceptable costs. [...] When a project is developed under architecture, the project starts with a so-called Project Start Architecture [(PSA)]. A [PSA] is a translation of the overarching [enterprise] architecture principles and models to rules and guidelines tailored to the project. This provides the practical rules, standards and guidelines that are used by the project. Also, project design choices that influence other projects are described in the [PSA].” Based on this description, we define *Solution Architecture* as follows:

Definition 1-3: Solution Architecture
Solution architecture is a way of working with two main aspects:
(1) Projects incorporate enterprise architecture-based standards, rules and guidelines. The solution architecture describes the structure of the solution, the main interfaces and the interaction to the environment, to the existing application portfolio and to adjacent projects.
(2) Architecture governance processes are in place to control the progress of the projects, with regard of the implementation of the standards, rules and guidelines by the project.

The function of Solution Architecture is to link strategic business principles and objectives to actual implementation. As such, it can be considered an element of the Enterprise Architecture discipline, as the part of the EA discipline that takes care of implementations of the architecture.

1.4 Key Research Questions

The following key research questions are addressed:

1. *Can we define a suitable method for measuring and quantifying, in financial terms, the value of enterprise architecture-based business transformation?*
2. *Is the method usable in practice to determine the value of enterprise architecture-based business transformation?*
3. *Can we define a suitable method to measure and to quantify, in financial terms, the value of solution architecture?*
4. *Can we apply this method to determine the value of solution architecture?*
5. *How is the business value of IT related to the value of enterprise and solutions architecture?*

1.5 Key deliverables

The following key deliverables are defined in this thesis:

(a) *A definition framework for measuring the value of business and IT architecture*
(b) *Definition of a method to measure the value of enterprise architecture based business transformation*
(c) *Definition of a method to measure the value of solution architecture*
(d) *The results of a case study describing the value of enterprise architecture based business transformation initiatives*
(e) *The result of a case study describing the value of architecture-based business transformation*
(f) *Results and conclusions describing the relationship between the maturity of architecture and the business value of IT*

1.6 Content of the Thesis

Chapter 1 describes the key research questions and the content of the thesis. Chapter 2 defines enterprise and solution architecture, and describes the relation of architecture to other disciplines. Chapter 3 introduces the value of architecture and describes the architecture value assessment framework. Chapters 4 and 5 describe a method of measuring the value of architecture-based business transformation. Chapter 4 introduces the measurement approach. Chapter 5 describes the results of a case study, where this approach is applied. Chapters 6 and 7 describe a method of measuring the value of solutions architecture. Chapter 6 introduces the basic concepts and the measurement approach, while chapter 7 discusses the results of a study applying this approach. Chapter 8 describes the role of architecture and how this contributes to the value of IT for organizations. Chapter 9 contains a revisitation of the key research questions and overall conclusions.

Chapter	Description
1	Introduction to the subject, definition of the key concepts. description of the key research questions and key deliverables.
2	Definition of the role of architecture and positioning of architecture and relations to business transformation, strategy development and program execution.

Chapter	Description
3	Introduction to the measurement approach of the value of enterprise and solutions architecture. Introduction of the architecture value assessment framework.
4	Description of the approach for measuring the value of architecture-based business transformation.
5	Description of the case study for measuring the value of enterprise architecture based business transformation.
6	Description of the approach to measure the value of solutions architecture and the application of this approach for 49 IT software development projects.
7	Description of the results and conclusions from the solutions architecture case study.
8	Description of the role of enterprise architecture in creating IT value for organizations.
9	Revisitation of the key research questions and overall conclusions.

Additional material is contained in the appendixes.

Appendixes	Description
1	Description of the approach of using ROA for valuing enterprise architecture development over multiple years
2	An overview of business services for the financial case study
3	Raw data analysis and transformation
4	Analysis of the null-hypothesis

2.

Positioning of Business Transformation and Architecture

This chapter describes the function of enterprise architecture and the role of architecture in respectively business transformation, strategy development and program execution.

2.1 Function of Enterprise Architecture

2.1.1 Generic Model

Abcouwer, Maes and Truijens (1997) introduced a generic model for information management, based on nine squares.

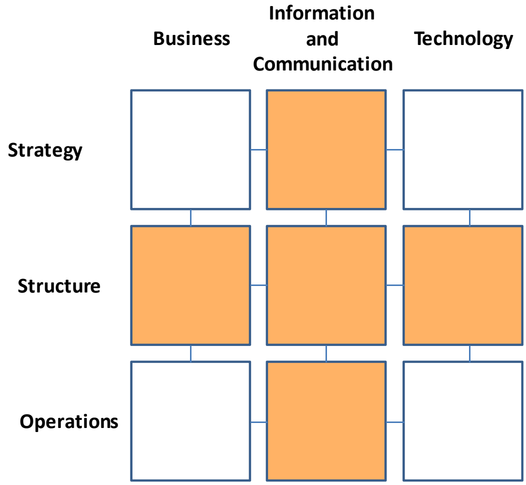

Figure 3 4. Generic model for information management

This model expands the basic model of Henderson and Venkatraman (Henderson, et al., 1992) and adds a *Structure* row and an *Information and Communication* column. In (IAF, 2007) is explained that architecture provides concepts and tools for the middle column and row. This paper uses the *Integrated Architecture Framework* to illustrate this point.

Based on this generic model, we can conclude that the main function of enterprise architecture is *to link strategy-to-operation* and *to link business-to-IT*. Strategy-to-operation means a consistent and univocal “translation” of high-level strategic directives to concrete rules, guidelines and structures that can be used by the operational process. Business-to-IT means that IT solutions support business processes optimally and, vice versa, business makes optimal use of technological possibilities.

2.1.2 Business Transformation

We define business transformation as follows:

Definition 2-1. Business Transformation
Business transformation is a management initiative to change the current situation to an envisioned future state, by changing the organization and the IT environment in order to align them with strategic goals.

Consider the following picture demonstrating the basic transformation mechanism:

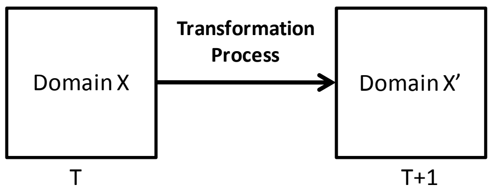

Figure 2-1. Basic transformation approach

Domain X denotes the business and IT elements of some part of an organization. At some point in time (T) the domain starts a change process which will implement some changes, resulting in *Domain X’* at some future time (T+1). Each transformation process contains these basic steps:

1. Develop a business vision of the desired situation
2. Develop a business and IT strategy to achieve the desired situation

3. Create a blueprint of the desired situation, based on the business vision and on the business and IT strategy
4. Develop transformation scenarios to realize the desired situation, based on the blueprint
5. Implement the desired situation, based on the migration strategy and the blueprint

The role of enterprise architecture in this process is:

- *A supportive role during the development of the vision and the strategy.* Architecture may highlight new (technical) possibilities, to be included in the vision and strategy.
- *A leading role during the description of the new situation.* Architecture will structure and describe the vision into more detail.
- *A cooperative role during the description of the migration path.* Definition of the migration path is done co-operatively between line management, program management and architecture.
- *A controlling role during the implementation.* Architecture will restrict the choices of the implementation in order to improve the alignment between vision and implementation.

Is it possible to execute these steps without using architecture? The answer is – of course – yes; for many years, this process has been executed without a formal architecture approach. The role of architecture is therefore *supportive*, aimed to *improve the quality* of transformation processes. Op 't Land et al. (2009) state: "The emerging instrument of enterprise architecture promises to provide management with insight and overview to harness complexity. Where classical approaches will handle problems one by one, enterprise architecture aims to deal with these issues in a coherent an integral fashion, while at the same time offering a medium to achieve a shared understanding in concept realization among all stakeholders involved and govern enterprise development based on this conceptualization. As such, enterprise architecture plays a key role in the governance of organizations and their evolution." This leads to the following statement about the function of enterprise architecture:

Definition 2-2. Function of Enterprise Architecture
Enterprise architecture is a managerial instrument intended to improve the efficiency and effectiveness of business transformation initiatives.

Management has several instruments available to support business and IT transformation, e.g. planning, budgeting, sourcing instruments. The main differences between enterprise architecture instrument and other instruments is that architecture is *content-based* – it defines blueprints, describing business processes, applications and infrastructure and that architecture has a *strategic, long-term point of view*, whereas other instruments generally emphasizes shorter time-spans.

The main goal of enterprise architecture is to improve the organizational performance by aligning organizational structure, business processes, information assets, IT assets and infrastructure to the core goals and strategic direction of the organization.

With the term “Enterprise Architecture”, we mean the whole concept of business and IT architecture and not necessarily only the architectural deliverables. When referring to the outcomes of an architecture process we will use the term “architectural design”.

Definition 2-3. Architecture Design
An architectural design describes: “The fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution.” (IEEE 1471 definition).

2.2 Positioning of Architecture to Other Disciplines

2.2.1 Relation of Architecture to Strategy

According to Johnson and Scholes (1993 p. 16), strategic management is “taking decisions about major issues facing the organization and ensuring that the strategies are put into effect.” Strategic management has three main elements: strategic analysis, strategic choice and strategy implementation. They state: “There is strategic analysis, in which the strategist seeks to understand the strategic position of the organization. There is strategic choice, which has to do with the formulation of possible courses of action, their valuation and the choice between them. And there is strategy implementation, which is concerned with the learning how the choice of strategy can be put into effect, and with managing the changes required.”

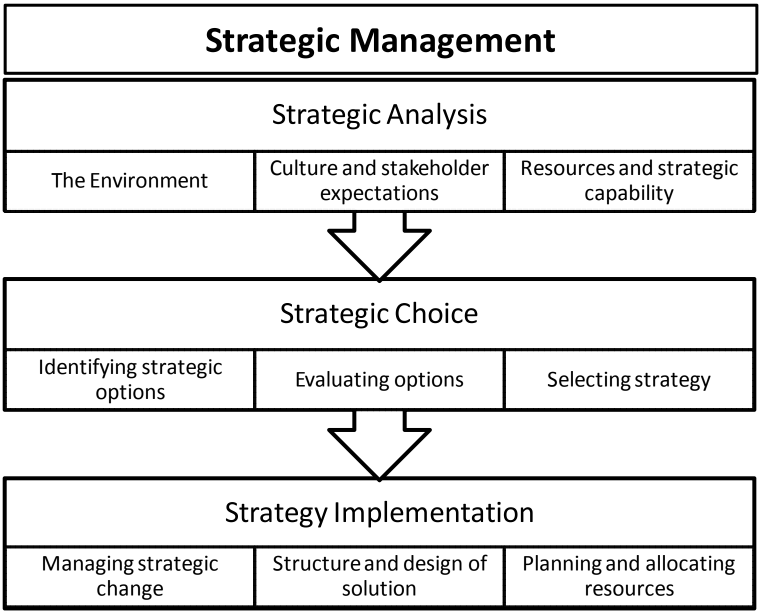

Figure 2-2. Main Elements of Strategic Management according to Johnson & Scholes

The role of architecture in these phases varies according to the type of activity. See the table below for an overview of the role of architecture in strategic management.

Strategic element	**Role of Enterprise Architecture**
Strategic Analysis	Limited. Executed by senior management.
Strategic Choice	Supportive. Architecture can have a supportive role in identifying strategic options and evaluation and the feasibility of these options.
Strategy Implementation	Leading for structuring the solution. Leading in guarding the alignment between strategy and design & implementation.

Table 2-1. Role of Enterprise Architecture in Strategic Management

The value of architecture is mainly visible in the third strategic element; *Strategy Implementation.* In this thesis on the value of architecture, we will focus on the third element.

2.2.2 Relation of Architecture to Program Execution

Program management is the process of managing multiple ongoing inter-dependent projects. Project management is responsible for keeping projects within budgets, within the agreed timelines and the allocation of resources. Architects are responsible for designing an optimal solution. Program management and architecture need to work together one from the process point of view; the other from the content point of view. There are several similarities between the role of program and project manager on one hand and enterprise architect and project architect on the other hand.

	Process Steering	Content Steering

Program Level	• **Program Management Office**
	  ○ Led by program manager
	• **Purpose**
	  ○ To manage process-related issues
	    ▪ Time, money, resources
	  ○ Align individual project process-wise
	• **Use a program charter**
		• **Architecture Design Office**
		  ○ Led by enterprise architect
		• **Purpose**
		  ○ To manage content-related issues
		    ▪ Scope, interfaces, functionality, structure
		  ○ Align individual project content-wise
		• **Use an enterprise architecture**

Project Level	• **Project plan**
	  ○ Responsible: project leader
	  ○ Needs approval from PMO
	  ○ Provides process-related directions for design and development
		• **Solutions architecture**
		  ○ Responsible: solutions architect
		  ○ Needs approval from ADO
		  ○ Provides content-related directions for design and development

Table 2-2. Comparing roles of program and project management and Architecture

3.

Business value of Enterprise Architecture

This chapter discusses the value of IT for organizations and the role of architecture in improving organizational performance. Next, it describes the value the architecture can add to the change process of an organization, at strategic, tactical and operational level. It defines an architecture value assessment framework.

3.1 The Value of IT for Organizations

Many researchers have published on the topic of the value of IT for organizations. The general conclusion is that researchers do not find evidence that IT-spendings provide economic advantages. Paul Strassman states: "It is safe to say that so far nobody has produced any evidence to support the popular myth that spending more on information technologies will boost economic performance."(Strassman, 1997). He continues: "[This] does not contradict the fact that computers frequently make decisive contributions to efficiency, competitive viability, and value creation. However, high or low spending levels for computers can be associated with both inferior [and] superior results. High-performance firms do not allocate more money to IS than low-performing firms." This conclusion is in line with what other researchers have found (Bowen, 1986).

Considering the reasons for this finding, Strassman's conclusion is that IT spendings are notoriously inefficient. He states: "The built-and-tear-down practices associated with each of the computerization investment cycles are the primary reason that we have not seen effective cost reductions and overall information processing costs in our society. Top management has become customized to short-life expectancy of their systems investments and have paid little attention to the need to preserve capital by expecting a longer useful life from it. [...] Short-term thinking about investments in software and people can produce disastrous consequences. The typical breakeven point from major innovations in an information system is anywhere from four to six years or even longer for a major restructuring of how an organization plans to operate. [...] It is a short-term view of the value of systems that ultimately leaves an organization with hundreds or even thousands of inconsistent and non-interoperable solutions. [...] If the build-and-junk approach becomes the only acceptable method for supporting business operations, it is likely to cause grief in due course." (Strassman, 1997 p. 77)

3.2 The Role of Architecture in Improving Organizational Performance

The issues raised by Strassman as the main causes for the low effectiveness of IT, are exactly the topics enterprise architecture aims to address. Strassman observes that many IT assets are built with a strong focus on the short-term. Project managers are judged on the cost and time needed for the project they run and not on, for instance, the retained value of the software they produce after four years. This last factor is, of course, much more interesting from a company perspective. Projects may produce poor results on time and within budget and deliver results that do not fit in with the business processes or may need a significant time and money to maintain during the lifetime of the system. The envisioned role of architecture is to remedy this situation.

Soh en Markus (1995) have proposed a model to link IT investments to business performance. They have identified three main processes: "the IT Conversion Process", "the IT Use Process" and "the Competitive Process". The IT Conversion Process is the process that converts IT expenditures to IT assets. The IT Use Process is the process of the usage of the IT assets, and this process will deliver IT impacts within the organization. The Competitive Process uses IT impacts to improve organizational performance / competitiveness.

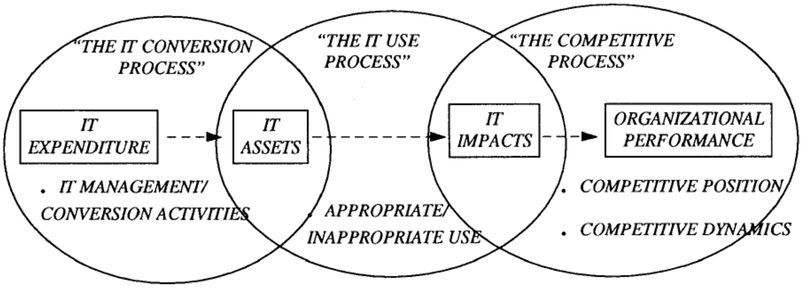

Figure 3-1. The relationship between IT expenditures and Organizational Performance (from Soh and Markus)

Linking IT expenditures directly to organizational performance ignores the effect of the intermediate steps and may be the reason why no correlation between IT expenditures and organizational performance is found. Our understanding of the role of architecture in terms of this model is: (1) to improve the quality of the outcomes of the IT conversion process and therefore improve the quality of the resulting IT assets; and, (2) to improve the impact of IT assets within the organization, by supporting the "appropriate" use of IT assets within the organization.

3.3 Value of Architecture in the Business and IT Transformation Process

Paragraph 2.1.2 describes the basic steps for a transformation process:

1. Develop a business vision of the desired situation
2. Develop a business and IT strategy to achieve the desired situation
3. Create a blueprint of the desired situation, based on the business vision and on the business and IT strategy
4. Develop transformation scenarios to realize the desired situation, based on the blueprint
5. Implement the desired situation, based on the migration strategy and the blueprint, using solution architecture

The following figure illustrates the relationships between these concepts:

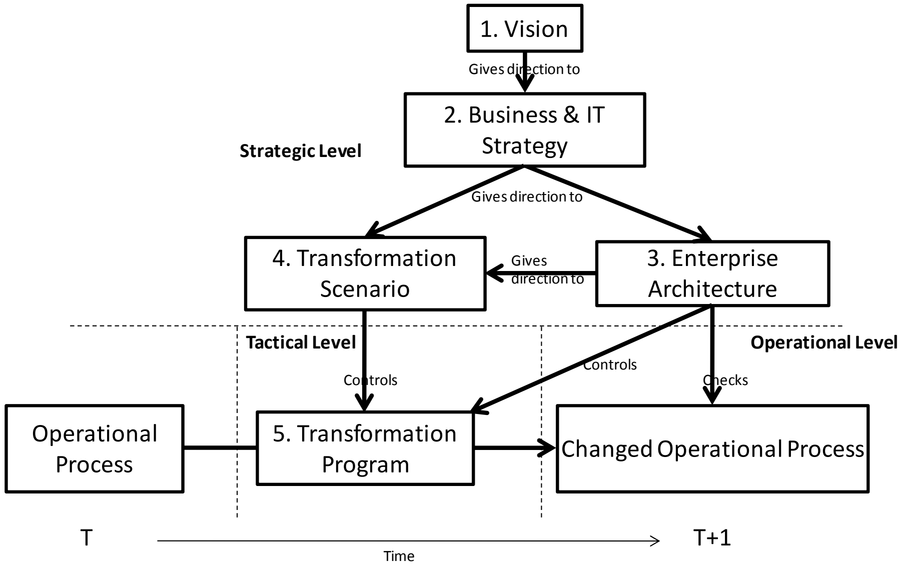

Figure 3-2. Relationship between architecture, transformation scenario, solution architecture, transformation program and operational processes

The objective of this thesis is to measure – at strategic level – the value of enterprise architecture-based business transformation and – at tactical level – the value of solution architecture. At strategic level, we measure the value of the business transformation derived from the enterprise architecture blueprint. At tactical level, we measure the value of enterprise architecture for programs and projects (the *solution architecture*). Measuring the value of architecture at operational level is not in scope for this thesis.

Based the above considerations, we define the value of architecture as follows:

Definition 3-1. Value of Architecture
The value of architecture is defined as the incremental, leveraging value delivered by architecture to the business and IT environment.

3.4 Architecture Value Assessment Framework

To understand the value of architecture we need to assess the architecture with regard to the *business value* of the architecture, the *implementation cost* and the *risks* that occur. These three aspects of architecture value can be assessed at strategic, tactical and operational level. This results in an architecture value assessment framework. This framework will be the basis for the subsequent assessments and measurements of architecture value in this thesis.

		Architecture Value Aspects		
		Business Value	**Cost**	**Risk**
Levels	**Strategic**	Insight in the value of enterprise architecture-based business transformation scenarios	Insight in the cost of enterprise architecture-based business transformation scenarios	Insight in the risk of enterprise architecture-based business transformation scenarios
	Tactical	Improving success rate of transformation programs	Decreasing the cost of transformation programs	Lowering transformation risk and increasing planning reliability of transformation programs
	Operational	Maximize the value delivered by the operational environment	Minimize the cost of the operational environment	Minimize operational risk

Table 3-1. Architecture value assessment framework

This framework allows us to refine the earlier definition of the value of architecture.

Definition 3-2. Value of architecture (extended)
The value of architecture is defined as the additional, leveraging value delivered by architecture to the business and IT environment. The value can be measured at Strategic, Tactical and Operational level. It considers the aspects of Business Value, Cost and Risk.

4.

Measuring the Value of Business Transformation

This chapter describes several approaches for measuring the value of business transformation and compares them to Real Options Analysis (ROA). It describes adaptations to the standard ROA theory, to make it suitable for valuing business transformation. The theory is illustrated by an example. The chapter closes with an overview of criteria that can be used for selecting business transformation scenarios, when using ROA.

4.1 Role of Enterprise Architecture

4.1.1 Managerial Instrument

The purpose of enterprise architecture is to help management understand the impact and ramifications of business change. As such, enterprise architecture is one of the instruments that management has available to manage the organisation. Enterprise architecture differs in two ways from other instruments:

1. Enterprise architecture is aimed to manage change, instead of managing existing operations
2. Enterprise architecture is content-oriented, instead of being process or financial oriented.

The goal of enterprise architecture is to deliver a blueprint of the new situation. The purpose of this blueprint is to increase the understanding of the new situation and to define a optimal transformation approach. By increasing the understanding of the new situation, management can check whether the new situation aligns with and complies with the business strategy and the transformation objectives. By having a clear understanding of the target, future situation, defining a transformation scenario to go from the AS-IS to the target situation becomes easier.

4.1.2 Enterprise Blueprint

There are several enterprise architecture methodologies, among which Zachman (1987) and TOGAF (2004) are best known. The purpose of these methodologies is to structure the work of an enterprise architect. These methodologies provide tools, concepts and process models to create an enterprise blueprint. The blueprint describes the strategic direction of the organization and the main organizational goals. It describes objectives, principles, scope, requirements and the structure of the desired situation. A blueprint generally includes business, information and IT architecture. The business architecture describes the services, processes and structure of the business. The information architecture defines and structures the information requirements, flow and ownership for the organization. The IT architecture describes the information systems and the infrastructure.

Blueprints may include the description of several solution alternatives. The purpose of defining solution alternatives is to find the solution that balances business value, cost and risk.

4.2 Transformation Scenarios

Architectural blueprints are implemented using transformation scenarios. For instance, the enterprise architecture may have three main solution options: (1) buy and configure a standard package; (2) build a new solution from scratch; or (3) reuse and expand an existing system. The options may vary considerably with regard to the value for the business, the consequences for business processes, investment levels, risk profiles and implementation options. A solution option with the related investment and implementation choices is called a transformation scenario. To assess the value of the architecture-based business transformation, we will assess the value of the associated transformation scenarios and compare these to the value of the null-scenario. The null scenario is a continuation of the status quo: no change. The difference in value between the transformation scenario and the null-scenario provides us with an understanding of the value of the business transformation scenario.

4.3 Architecture Valuation Methods

To understand the value of a business transformation scenario based on an architectural blueprint, we will consider some methods for assessing the value transformation scenarios.

4.3.1 Net Present Value Analysis

A simple and often used approach of assessing the value of the transformation scenario is the Net Present Value (NPV) method. NPV calculates the current value of future cash flows.

$$NPV = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i} \tag{4-1}$$

where:

$n = Number\ of\ years$
$C_i = Cash\ flow\ in\ year\ i$
$r = Annual\ interest\ rate$

See Table 4-1 for an illustration of the use of NPV. Based on architectural blueprint the transformation of an enterprise has two possible scenarios. Scenario 1 is a big-bang approach and scenario 2 is a phased approach. The scenarios have the following expected cash flows over the five years (with an interest rate of 5%):

Scenario		Expected Cash flow in Year					NPV
		0	1	2	3	4	
1. Big-bang	Revenue	€ 0	€ 4	€ 8	€ 8	€ 8	€ 6.3
	Cost	€8	€ 8	€ 1	€ 1	€ 1	
	Cash Flow	**€ -8**	**€ -4**	**€ 7**	**€ 7**	**€ 7**	
2. Phased	Revenue	€ 0	€ 2	€ 4	€ 8	€ 8	€ 2.3
	Cost	€ 3	€ 5	€ 8	€ 1	€ 1	
	Cash Flow	**€ -3**	**€ -3**	**€ -4**	**€ 7**	**€ 7**	

Table 4-1. Example Net Present Value (M€)

Calculating an NPV is simple and straightforward. The optimal selection criterion is simple: choose the scenario that provides the highest net present value, i.e. in this example the big-bang scenario. To calculate the value of the big-bang scenario, we compared the value of the scenario to the null-scenario. In this case, the null-scenario is “doing nothing” (NPV zero). Compared to the null scenario the architecture implementation provides a value of € 6.3 million.

The main disadvantage is that the approach does not give insight into the risks of a scenario. The NPV is a “single point static estimate” (Saha, 2004).

4.3.2 Decision Tree Analysis

Introduction

Decision Tree Analysis (DTA) provides an extension to the NPV method by allowing the possibility of several different outcomes of a scenario. Each outcome has an estimated probability, which allows for a weighted NPV calculation across the outcomes. We extend the example of Table 4-1, using Decision Tree Analysis.

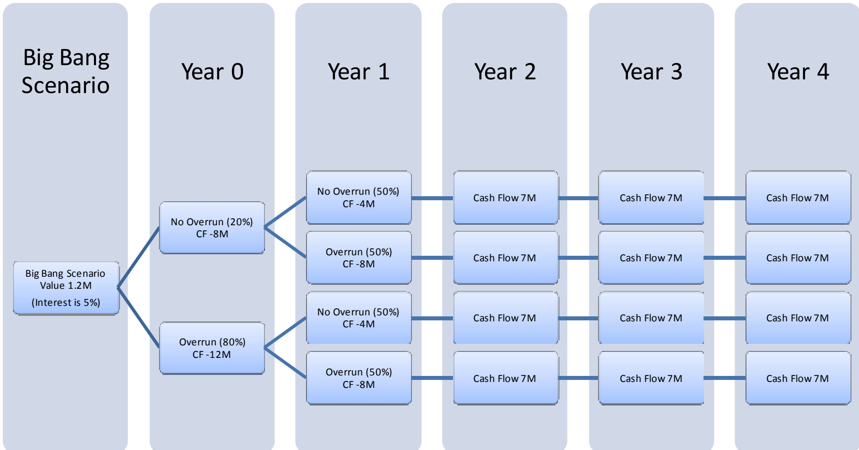

Figure 4-1. Decision Tree for Big Bang Scenario Example (M€)

In this example, the DTA analysis takes into account the possibility of overruns in year 0 and in year 1. The probability of overrun in year 0 is estimated to be 80% and the probability of overrun in year 1 is estimated to be 50%. This results in four possible outcomes; no overrun (with a probability of 10%), overrun only in year 0 (40%), overrun only in year 1 (10%) and overrun in both year 0 and year 1. For each of these four possibilities the NPV is calculated and the value of the scenario is the probability-weighted average of these four NPV's. See Table 4-2 for the resulting value of the Big-bang Scenario example.

Scenario 1. Big-Bang																				
				Year																
				0				1				2			3			4		
Possible outcomes	NPV	Resulting Prob	Resulting NPV	Profit	Cost	Cash Flow	Prob	Profit	Cost	Cash Flow	Prob	Profit	Cost	Cash Flow	Profit	Cost	Cash Flow	Profit	Cost	Cash Flow
No Overrun	€ 6,3	10%	€ 0,6	€ 0,0	€ 8,0-	€ 8,0-	20%	€ 4,0	€ 8,0-	€ 4,0-	50%	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 1st year	€ 2,3	40%	€ 0,9	€ 0,0	€ 12,0-	€ 12,0-	80%	€ 4,0	€ 8,0-	€ 4,0-	50%	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 2nd year	€ 2,5	10%	€ 0,3	€ 0,0	€ 8,0-	€ 8,0-	20%	€ 4,0	€ 12,0-	€ 8,0-	50%	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 1st and 2nd year	€ 1,5-	40%	€ 0,6-	€ 0,0	€ 12,0-	€ 12,0-	80%	€ 4,0	€ 12,0-	€ 8,0-	50%	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Value of Scenario			**€ 1,2**																	

Table 4-2. Decision tree calculations for Big Bang Scenario example (M€)

Similarly, we can calculate the DTA value of the phased scenario.

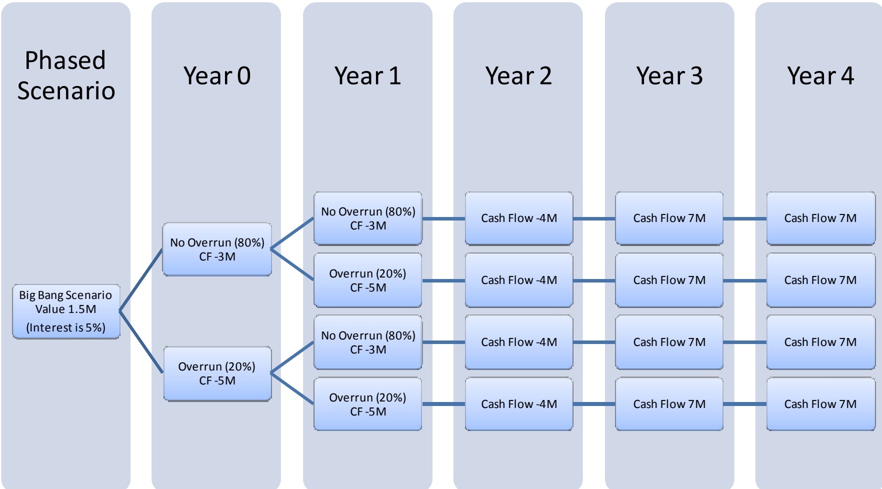

Figure 4-2. Decision Tree for Phased Scenario Example (M€)

Scenario 2. Phased																				
				Year																
				0				1				2			3			4		
Possible outcomes	NPV	Resulting Prob	Resulting NPV	Profit	Cost	Cash Flow	Prob	Profit	Cost	Cash Flow	Prob	Profit	Cost	Cash Flow	Profit	Cost	Cash Flow	Profit	Cost	Cash Flow
No Overrun	€ 2,3	64%	€ 1,5	€ 0,0	€ 3,0-	€ 3,0-	80%	€ 2,0	€ 5,0-	€ 3,0-	80%	€ 4,0	€ 8,0-	€ 4,0-	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 1st year	€ 0,3	16%	€ 0,1	€ 0,0	€ 5,0-	€ 5,0-	20%	€ 2,0	€ 5,0-	€ 3,0-	80%	€ 4,0	€ 8,0-	€ 4,0-	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 2nd year	€ 0,4	16%	€ 0,1	€ 0,0	€ 3,0-	€ 3,0-	80%	€ 2,0	€ 7,0-	€ 5,0-	20%	€ 4,0	€ 8,0-	€ 4,0-	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Overrun 1st and 2nd year	€ 1,6-	4%	€ 0,1-	€ 0,0	€ 5,0-	€ 5,0-	20%	€ 2,0	€ 7,0-	€ 5,0-	20%	€ 4,0	€ 8,0-	€ 4,0-	€ 8,0	€ 1,0-	€ 7,0	€ 8,0	€ 1,0-	€ 7,0
Value of Scenario			**€ 1,5**																	

Table 4-3. Decision tree calculations for Phased Scenario example (M€)

Based on this analysis, we can compare the expected outcome for both scenarios using NPV and Decision Tree Analysis.

Scenario	Valuation Method	
	NPV	**DTA**
Big Bang	€ 6.3M	€ 1.2M
Phased	€2.3M	€ 1.5M

Table 4-4. Expected business value of Big-Bang and Phased Scenario

Compared to the NPV approach, the scenarios value calculations are more extensive; they include a probability estimation of the possible outcomes. For the Big-Bang scenario, it is estimated that there is a probability of 80% on cost overrun from 8 to 12 million for the first year and a probability of 50% for the second year. Consequently, the value of the scenario decreases sharply from 6.3 to 1.2 million. The value of scenario 2 also decreases, but less sharply, because of better risk control.

Use of DTA

Decision Tree Analysis provides a more differentiated picture of the value of transformation scenarios and provides more insight for decision-making. The weak point in creating a decision tree analysis is the estimation of the various probabilities. Estimation of a probability is subjective and influences the resulting value considerably. This weakness can be overcome to some extent by using sensitivity analysis. Sensitivity analysis gives some insight into the consequences of choosing specific probability values. Using Decisions Tree Analysis has its advantages compared to the Net Present Value method, but the method is difficult to handle in practice because of the required assessment of probabilities.

In addition, the DTA approach describes only a limited number of discrete points (in the example above four points per scenario). This limited number of points may also prove insufficient to get a good understanding of the risks involved. Extending the number of points, to for instance 10 or 15, only exacerbates the problem of determining the associated risk for each of these points.

The selection criterion that can be applied to the scenario can be more diverse than with the Net Present Value approach. One may choose the highest NPV or one may provide, for instance, a risk-based approach to avoid negative consequences as much as possible. In the above example, one would choose the *Big-Bang* scenario, when using the criterion of maximum expected value, but one may choose the *Phased* scenario, to avoid the large negative probability of large cost in the first year.

4.4 Using Real Options to Valuate Enterprise Architecture

4.4.1 Real Option Analysis Compared with NPV and DTA

Net Present Value calculates the expected cash flow of a scenario, by identifying estimations for revenue and for cost and subtracting the cost from the revenue. The value of the scenario is determined by calculating the interest-adjusted sum of the cash flows. Decision Tree Analysis uses essentially the same approach, but instead of calculating one cash flow value, DTA calculates several cash flow values and calculates the associated probabilities. The DTA scenario value is equal to the probability-weighted average of the individual cash flows.

NPV and DTA calculate *single-point estimates* for revenue and for cost and, by subtracting them, for the cash flow. A *single-point estimate* is an estimate of one specific value. NPV calculates one revenue estimate, one cost estimate and, consequently, one cash flow estimated. DTA uses basically the same approach, but the one single estimate is replaced by multiple single-point estimates, each with its own probability.

Real Options Analysis

With Real Option Analysis (ROA), the *single point estimate* is replaced by a continuous range of possibilities described in a *Probability Distribution*. Hence, the single-point revenue estimate is replaced by a revenue probability distribution; the single-point cost estimate is replaced by a cost probability distribution and the cash flow probability distribution is calculated by merging the revenue and cost distributions in one overall distribution.

Because of the substitution of a single-point estimate by a probability distribution, Real Options Analysis accomplishes the same goal as DTA – which is incorporating possibility of multiple outcomes with associated probabilities. Compared to DTA, ROA has the following advantages:

(1) ROA delivers a continuous spectrum of possible outcomes (instead of a limited number of discrete outcomes).

(2) The probability of a specific outcome can be derived from the probability distribution (this removes a weak point of DTA; it is no longer necessary to estimate the discrete individual outcomes).

(3) Since the Real Options Analysis provides more information than the NPV or DTA approach, additional criteria for Enterprise Architecture scenario selection become eligible.

Because of these advantages, the use of ROA provides a broader insight in to the risks, value and options of Enterprise Architecture. It allows, consequently, a more precise valuation of the options for management when implementing enterprise architecture.

Real Options Analysis is a field of research, which is derived from the financial options analysis. Therefore, we will first look at financial options analysis.

4.4.2 Financial Options Analysis

Option analysis calculates the value of financial options, based on the current value and volatility of the option. A definition: "An [financial] option is a right – not an obligation – of its owner to buy or sell the underlying asset at the predetermined prize on or before a predetermined date." (Kodukula, et al., 2006).

The Black-Scholes Equation

Option analysis got an important impulse in the 1970s, when Fischer Black, Myron Scholes and Robert Merton published two articles on option pricing.(Black, et al., 1973; Merton, 1973). These articles constitute a breakthrough in financial option pricing. Their solution became known as the Black-Scholes equation. This equation calculates the future value of a financial (European*) call option based upon the current price and the volatility of the price. The formula is:

$$C = N(d_1)S_0 - N(d_2)Ae^{-r.T} \tag{4-2}$$

where:

$$\begin{aligned}
&C = Future\ value\ of\ the\ Call\ option\\
&S_0 = Current\ value\ of\ the\ asset\\
&A = Strike\ price\\
&r = Interest\ rate\\
&T = Time\ \ to\ expiration\ (in\ years)\\
&d_1 = \frac{\ln(S_0/A) + T(r + 0.5\sigma^2)}{\sigma\sqrt{T}}\\
&d_2 = d_1 - \sigma\sqrt{T}\\
&\sigma = Volatility\ of\ the\ asset -\\
&\qquad Standard\ deviation\ over\ the\ period\ of\ a\ year\\
&N(x) = \ Value\ of\ the\ cumulative\ standard\ normal\ distribution
\end{aligned}$$

The most interesting point is that no future value needs to be estimated. The only actual input is the *Current Value* and the *Standard Deviation* of the asset. Although the approach was initially developed only for financial instruments, it was suggested by Myers (1977) that the approach would also be useful for non-financial, real assets.

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* *An European option is an option that can only be exercised at the end of its life, this in contrast to an American option, which can be exercised anytime during its life.*

4.4.3 Real Option Analysis

Real Options and Enterprise Architecture

"A real option is the right – not an obligation – to take action [...] on an underlying non-financial asset" (Kodukula, et al., 2006). Applying real options analysis for enterprise architecture value assessment is interesting for several reasons. Pallab Saha writes about this: "[We view] enterprise architecture development as largely a process of decision making under uncertainty and incomplete knowledge. [.. We] assume that portion of the value of enterprise architecture initiative is in the form of embedded options (real options), which provide architects with valuable flexibility to change plans, as uncertainties are resolved over time."(Saha, 2004).

In other words, a real option is an opportunity to invest now for gaining future benefits. Architecture-based business transformation provides a framework for investment to improve business performance and gain future business benefits. Both the investment and the outcomes are subject to uncertainty and, consequently, option analysis is a viable approach of valuing the investments in enterprise architecture.

Adapting the Financial Options Approach

The Black-Scholes equation deals with one source of uncertainty, i.e. the future price of the asset. An enterprise architecture based transformation scenario has two sources of uncertainty; uncertainty about the required investments and uncertainty of the future revenue. The Black-Scholes approach will need to be adapted to include both sources of uncertainty.

Methods of Calculating Real Options

There are several calculation methods for calculating real options, among which using the Black-Scholes equation. The choice for using a specific calculation method depends on the information that is available and the validity of the method for a given application. An overview of calculation methods (see also Kodukula (2006)):

Calculation Method	Calculation Approach
Partial differential equations	• Analytical approximations • Numerical methods
Simulations	• Monte Carlo
Lattices	• Binomial • Trinomial • Quadrinomial • Multinomial
Closed form solutions	• Black-Scholes

Calculation Method	Calculation Approach
Integrals	• Probability Density Functions • Analytical approximations • Numerical methods

Table 4-5. Overview of Option Calculation Methods

These methods deliver essentially the same results, but some methods are more suitable in certain situations than others. Considering the type of analysis that we need to do and the type of the available information, the best approach for us to calculate the value of enterprise architecture scenarios is using integrals in combination with *Probability Density Functions*, because this approach allows for easy manipulation of Probability Density Functions both in analytical and numerical form, using multiple sources of uncertainty. We also use Black-Scholes when applicable, in the case of one source of uncertainty.

4.4.4 Probability Distributions

Probability Density Functions

The Real Options Approach calculates the future value of an underlying asset using a *probability distribution*. The possibility that a specific future event happens does not have to be estimated by hand – as is the case with Decision Tree Analysis – but can be derived from the probability distribution.

Probability distributions are mathematically represented by a Probability Density Function or PDF. A PDF has two main characteristics:

$$p(x) \geq 0 \qquad \forall\, x\, \in \mathcal{R} \tag{4-3}$$

$$\int_{-\infty}^{\infty} p(x)\,\mathrm{d}x = 1 \tag{4-4}$$

Equation (4-3) denotes the fact that a probability cannot be negative, while (4-4) means that the cumulative probability of an experiment described by a probability density function must be 100%.

4.4.5 Calculating the Cash Flow Probability Density Function

The Probability Density Function for Revenue

The revenue structure of organizations consists generally of a large number of small identical, independent transactions, where each transaction adds a percentage to the revenue. For example, if an organization sells books, each book will have a revenue percentage, which adds to the overall revenue. This is true for many organizations, whether they sell books, computers, insurance contracts, furniture, software, learning courses, etc. The total revenue of many organizations is build-up of small revenues of numerous small individual transactions.

Because of this revenue structure, it is possible to define the shape of the probability density functions of these organizations. Statisticians have demonstrated that the probability distribution of a sum, consisting of many small amounts, will be normally distributed. This proof is called the Central Limit Theorem (Weisstein, 2009). Based on this theorem we assume that the revenue for these types of organizations is normally distributed[*].

Normal Distribution

The normal distribution is characterized by two parameters: the mean and the standard deviation. The probability density function for the Normal distribution is:

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{4-5}$$

where:

$x = Value$
$\mu = Mean$
$\sigma = Standard\ deviation$

See Figure 4-3. Probability density function of an example Normal Distribution, with an expected value (μ or the $mean$) of 4 and a standard deviation (σ) of 1.

[*] *This approach may not be valid for organizations that make profit or create budgets in some other way. Especially governmental organizations and companies who sell a small number of large products (such as shipyards) may need another approach.*

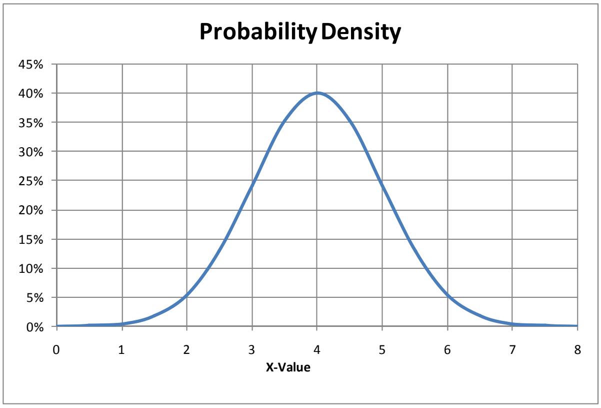


Figure 4-3. Probability density function of an example Normal Distribution

Probability functions either are graphically presented using the density function or by the cumulative probability function. The cumulative probability function is defined as:

$$cn(u) = \int_{-\infty}^{u} p(x)dx \tag{4-6}$$

Where $p(x)$ is the Probability Density Function.

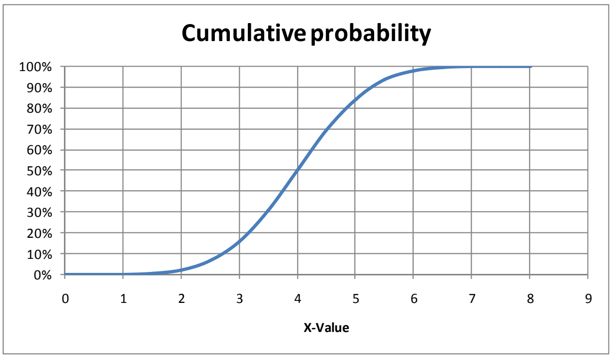


Figure 4-4. Cumulative probability function of an example Normal Distribution

Associated with a probability density function are three values, the *Expected Value*, the *Mode* and the *Median*. The *Expected Value* is the average outcome considering all experiments who obey to this distribution function. Is calculated by:

$$\int_{-\infty}^{\infty} x.p(x)dx \qquad (4\text{-}7)$$

Where $p(x)$ is the probability density function. The *Mode* is the most often occurring or the *most likely* outcome. It is calculated by solving the equation

$$p'(x) = 0 \qquad (4\text{-}8)$$

Where $p'(x)$ is the derivate $\frac{d}{dx}p(x)$ of the probability density function. The *Median* is the value where the cumulative probability is 50%. It is calculated by solving the equation

$$cn(x) = 0.5 \qquad (4\text{-}9)$$

Where $cn(x)$ is the cumulative probability function.

For the normal distribution, the expected value, the mode and the median are the same and equal to μ (in this example 4).

Probability Density Function for Cost

The *cost* of a project is the sum of the cost of the various activities that take place within a project. However, a main difference between the revenue and cost probability distributions is that the activities of a transformation program are *not independent* from each other; there are numerous interdependencies. Researchers in the field find that, consequently, the individual activities have a *multiplicative* (instead of an *additive*) effect on each other. Marasco (2004) states: “One could argue that all variance in the outcomes of software development projects is due to many small but multiplicative [...] effects.” The multiplicative effect leads to a type of probability distribution called the lognormal distribution. The *Multiplicative Central Limit Theorem* states that random factors that have multiplicative interactions, obey the lognormal distribution (Limpert, et al., 2001). Marasco writes: “Mathematically, the [probability] distribution [function of software development projects] results from phenomena that statistically obey the multiplicative central limit theorem.”

The probability density function of the lognormal distribution is:

$$cp(x) = \frac{e^{-(\ln(x-\lambda) - \mu)^2/(2\sigma^2)}}{(x-\lambda)\sigma\sqrt{2\pi}} \qquad x > \lambda$$
$$= 0 \qquad x \leq \lambda \qquad (4\text{-}10)$$

where:

$x = \ Cost\ of\ the\ Project$
$\mu = Location\ parameter$
$\sigma = Scale\ parameter$
$\lambda = Threshold\ parameter$

An example lognormal distribution, with $\mu = 0.85$, $\sigma = 0.6$ and $\lambda = 0$ is shown below:

Figure 4-5.Probability density function of an example lognormal distribution

The horizontal axis denotes the cost, while the vertical axis denotes the probability that this cost occurs.

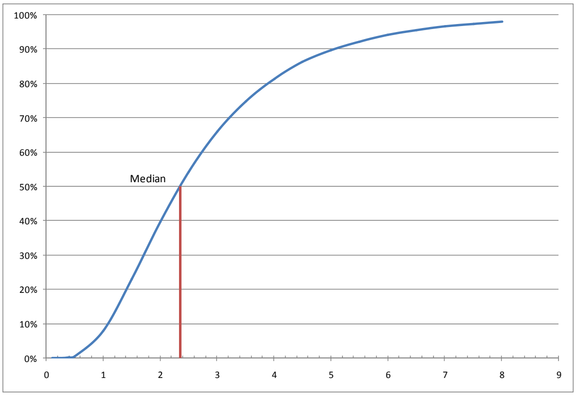


Figure 4-6. Cumulative probability function of an example lognormal distribution

There are several differences between the normal distribution and the lognormal distribution. The lognormal distribution is not symmetric, but has a tail to the right. This tail represents a small probability of high cost overruns. Because of this, the expected value, the median and the mode all differ from each other. The value of the most likely value (the mode), the expected value and the median are respectively:

$$e^{\mu-\sigma^2}+\lambda \qquad \text{Most likely value – Mode (=1.6)} \tag{4-11}$$

$$e^{\mu+\frac{\sigma^2}{2}}+\lambda \qquad \text{Expected Value (=2.8)} \tag{4-12}$$

$$e^{\mu}+\lambda \qquad \text{Median (=2.3)} \tag{4-13}$$

We find that for the lognormal distribution the *mode* is an easy to understand measure, denoting the most likely outcome. We find too, that the expected value is difficult to calculate without statistical analysis.

Convolution of Probability Density Functions

The cash flow of a business transformation effort is equal to the revenue minus the cost. To calculate the cash flow, we will need to merge the revenue and cost distributions into one combined cash flow distribution. Probability distribution functions can be merged by a mathematical operation called *convolution*. Convolution takes two probability density functions as input, and delivers a third PDF, which is the combination of the two input functions.

The convolution of two functions is given by:

$$h(u) = f \circ g = \int_{-\infty}^{\infty} f(x)g(u-x)dx \tag{4-14}$$

where:

$h(u) = f \circ g = \mathit{The\ convoluted\ Probability\ Density\ Function}$
$f(x)\ \mathit{and}\ g(x) = \mathit{Input\ Probability\ Density\ Funtions}$

Convolution has the following properties (Weisstein, 2007):

$$f \circ g = g \circ f - \mathit{Commutativity} \tag{4-15}$$

$$(f \circ g) \circ h = f \circ (g \circ h) - Associativity \quad (4\text{-}16)$$

$$f \circ (g + h) = f \circ g + f \circ h - Distributivity \quad (4\text{-}17)$$

The convolution of two normal distributions with parameters $(\mu_1, \ \sigma_1)$ and (μ_2, σ_2), provides again a normal distribution with parameters μ_c and σ_c (Weisstein, 2007), where

$$\mu_c = \mu_1 + \mu_2 \quad (4\text{-}18)$$

and

$$\sigma_c = \sqrt{{\sigma_1}^2 + {\sigma_2}^2} \quad (4\text{-}19)$$

In the general case, the *function centroids* of the convoluted functions can be added together (Weisstein, 2007).

$$\langle x(f \circ g) \rangle = \langle xf \rangle + \langle xg \rangle \quad (4\text{-}20)$$

Where the function centroid $\langle xf \rangle$ is defined as:

$$\langle xf \rangle = \frac{\int xf(x)dx}{\int f(x)dx} \quad (4\text{-}21)$$

Since $\int_{-\infty}^{\infty} f(x)dx = 1$ for a probability density function (see(4-4)) and the expected value for PDF is equal to $EV(f) = \int_{-\infty}^{\infty} xf(x)dx$, we can derive from this:

$$EV(f \circ g) = EV(f) + EV(g) \quad (4\text{-}22)$$

Where $EV(x)$ is the expected value of probability density function x. In other words, the expected value of a convoluted probability density function is equal to the sum of the expected values of the input functions.

Cash Flow Probability Distribution Function

Merging the revenue and the cost probability distribution functions will give us the probability distribution of the cash flow. First, we define cost as a negative cash flow. From (4-10) we can define the cost probability function with negative x:

$$c(x) = cp(-x) \qquad (4\text{-}23)$$

The cash flow probability density function becomes – from (4-5), (4-14) and (4-23):

$$cf(u) = \int_{-\infty}^{\infty} p(x).\,c(u-x)dx \qquad (4\text{-}24)$$

The expression (4-24) describes the convolution of the revenue and cost probability density functions, and this is equal to the cash flow function. The convolution operator is not dependent on the type of distribution that is described by the input PDF's, i.e., it works both for normal, lognormal or any other probability distribution. In our case, $p(x)$ has a normal distribution and $c(x)$ has a lognormal distribution. Consequently, $cf(u)$ describes the convolution of a normal and the lognormal probability density function. This result cannot be expressed analytically, because the convolution of a normal and a lognormal distribution cannot be expressed analytically, but the function $cf(u)$ can be calculated using numerical methods. For the previous example, the resulting probability density function of the cash flow is:

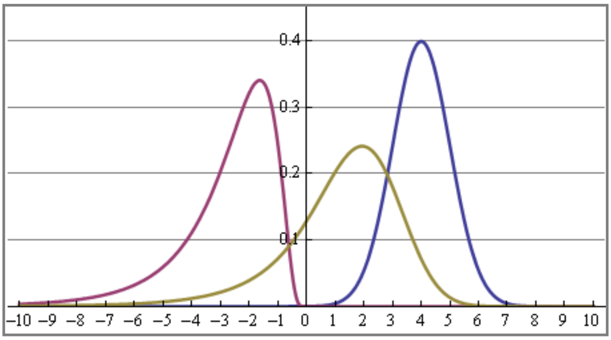


Figure 4-7. Example Probability density function of the cost (left), revenue (right) and cash flow(middle).

This figure shows $cf(x)$ (yellow, middle), which is the convolution of

(1) The revenue distribution (blue, right); a normal distribution with the expected value (μ) is 4 and the standard deviation (σ) is 1, and

(2) The cost distribution (red, left); a negative lognormal distribution with $\mu = 0.85$, $\sigma = 0.6$ and $\lambda = 0$.

The probability distribution function $cf(x)$ (4-24) describes the *combined* revenue/cost probability for the project. From this probability function, we can derive the expected value of the project, which is:

$$\int_{-\infty}^{\infty} x.cf(x)dx \ (= 1.22) \qquad (4\text{-}25)$$

This value is equal to the expected value of the revenue (4), minus the expected value of the cost (2.8). We can also derive the most likely value of this distribution. The most likely value is calculated by solving the equation:

$$cf'(x) = 0 \qquad (4\text{-}26)$$

Were $cf'(x)$ is the derivate of $cf(x)$ to x. This value is equal to 1.9.

4.5 Selecting a Preferred Scenario

4.5.1 Potential Selection Criteria

When using the Net Present Value or the Decision Tree Analysis to analyze the value of scenarios, the evident selection criterion is the maximization of value, i.e. the scenario with the highest expected value will be chosen. Because of the fact that Real Options Analysis provides more information than the Net Present Value or Decision Tree Analysis approach, other selection criteria for business transformation scenarios become possible. An overview of the possible scenario selection criteria when using ROA:

Criterion	Description	Rationale	Relation to PDF	Decision criterion	Remarks
Maximization of likely value	Maximization of the most likely (most often occurring) value	Use of most likely value is easy to explain and to understand.	The most likely value is the value where $cf'(x) = 0$.	The scenario with the highest likely value will be chosen.	The scenario with the highest likely value may not have the highest expected value.

Criterion	Description	Rationale	Relation to PDF	Decision criterion	Remarks
Maximization of expected value	Maximization of the expected (average) value	Expected value gives a more realistic picture than highest likely value.	The expected value is calculated by $\int_{-\infty}^{\infty} x.cf(x)dx$.	The scenario with the highest expected value will be chosen.	The scenario with the highest expected value, may not be the scenario with the lowest risk.
Minimization of loss	Decrease the risk of negative results	To minimize transformation risk.	The probability for a result below a specific threshold risk T is given by $\int_{-\infty}^{T} cf(x)dx$.	The scenario that minimizes the probability of a result below a specific threshold will be chosen.	This scenario may not provide the maximum business value.
Maximization of option value	Optimization of the option value.	To incorporate the value of future uncertainty.	The option value is given by $\int_{0}^{\infty} x.cf(x)dx$.	The scenario with the highest option value will be chosen.	Option value incorporates the value of the uncertainty in future cash flows.

Table 4-6. Selection criteria for business transformation scenarios

As is demonstrated in Table 4-6, the available options to assess the value for enterprise architecture business transformation scenarios are more varied when using the Real Options Approach, compared to the Net Present Value or the Decision Tree Analysis. In the following paragraphs, we will describe these transformation scenario selection criteria in more detail.

4.5.2 Maximization of Expected and Likely Value

Maximization of value is, clearly, the main objective of starting a business transformation program. Obviously, maximization of *Expected Value* is therefore a meaningful strategy to pursue. However, determining the expected value of a business transformation program is not straightforward. The analysis described in the paragraph *Relationship of the Probability Density Function to the Planned Cost (page* 55) suggests that it is difficult for managers to calculate the *Expected Cost* of a business transformation program and use the *Most Likely Cost* instead. Consequently, manages tend to calculate with the *Likely Value* instead of the *Expected Value* of a transformation program. When using Real Options Analysis, both the *Most Likely* and the *Expected Cost* of a business transformation program are calculated and this gives a better understanding of the results of the transformation.

4.5.3 Minimization of Loss

Minimization of risk means that the probability of negative outcomes is minimized. For instance, if management decides that the minimum revenue of a business transformation project should be € 1 million, we can calculate the probability that the revenue is below this threshold value. In our example, the probability of having an outcome that is less than one million is equal to $\int_{-\infty}^{1} cf(x)dx$. See the figure below for the cumulative probability function of $cf(x)$.

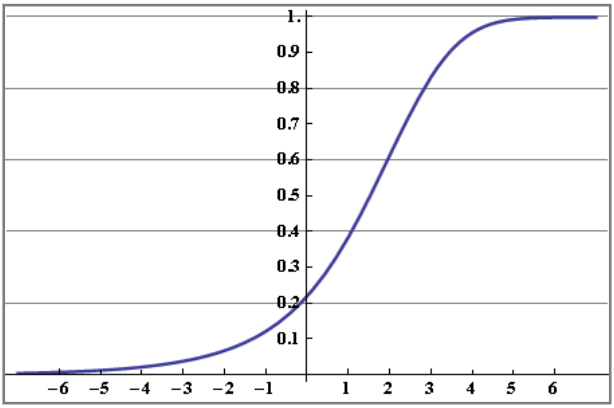


Figure 4-8. Cumulative probability function of cf(x)

From Figure 4-8 can be derived that the probability that the outcome is less than 1 is 38.5%. Hence, although the expected value of the business transformation in this example could be acceptable (which is 1.22 – see (4-25)), the probability of 38.5% of having an outcome less than € 1, may lead to a decision not to execute this business transformation scenario.

4.5.4 Maximization of Option Value

Financial value of Management Flexibility

During the execution of an enterprise architecture implementation program, the knowledge of the program management – about the expected outcomes, the feasibility of the results, the costs, the expected revenues, etc. – increases. When running the program, intermediate results become available and these results will be used to improve the probability of a positive outcome of the program. For instance, management may abandon projects, start new ones, increase or decrease the scope of projects, outsource the development of projects to a third party, etc.

This flexibility has its own financial value, because it allows management to use opportunities, which are not apparent at the start of the program. This *additional* value created by the flexibility of the management during the execution of the implementation of the enterprise architecture is not calculated by either NPV or DTA, but it can be calculated when using ROA. It is called the *Option Value.* The option value describes financially the freedom of choice that management has during the implementation of an Enterprise Architecture implementation program.

Kodukula and Papudesu state: “Whereas [DTA] is a deterministic model, ROA accounts for the change in the underlying asset value due to uncertainty over the life of a project. [...] There can be a range of possible outcomes of the life of a project, with the uncertainty increasing as a function of time. As a result, the range of the asset value would take the shape of a curve, called the ‘cone of uncertainty’. ROA accounts for this whole range of uncertainty using stochastic processes and calculates a ‘composite’ option value for a project, considering only those outcomes that are favorable [...] and ignoring those that are not. [...] This assumes that the decision-makers will always take the value-maximizing decision at each point in the project lifecycle.” (Kodukula, et al., 2006 pp. 56-57). The ‘cone of uncertainty’ that Kodukula describes is the cash flow probability distribution, which is described by the probability density function of Figure 4-7.

Calculation of the Option Value

Mathematically, the option value is determined by calculating the *partial, positive expected value* of the probability density function. In the example of § 4.4.5, this value becomes:

$$\int_0^{\infty} x.cf(x)dx\ (= 1.59\ ) \qquad (\ 4\text{-}27\ )$$

Note that this Option Value is larger than the Expected Value of 1.22 (see (4-25)). The difference between the option value and the expected value illustrates the freedom and flexibility that management has to steer the investment in the desired direction. Kodukula and Papudesu comment on this: “Real Options Analysis is most valuable when [...] management has significant flexibility to change the course of the project in a favorable direction and is willing to exercise the options.” In our example, the flexibility that management has to improve the outcome of the investment is equal to $1.59 - 1.22 = 0.37$.

4.6 Applicability of this ROA model

In the approach and examples of this chapter, we have chosen a normal distribution for describing the benefits and a lognormal distribution for the costs. These choices for specific distribution types, depends upon the underlying characteristics of the business, which determine the probabilities distributions for revenue and cost.

However, the ROA calculation model itself is independent of the underlying distribution types. The model is applicable in any situation, as long as the revenue and costs can be described in terms of probability density functions. This is because the convolution expression (4-24) is valid for any probability density function, regardless of type. Thus, when the method is applied to calculate the value of a business transformation initiative, any suitable continuous probability density function can be selected to describe the revenue and cost distributions.

Consequently, the approach described in this chapter can be characterized as a general ROA calculation method for determining the financial value of architecture-based business transformation and it is applicable for all circumstances where the benefits and the costs of an investment can be described in terms of probability density functions.

5.

Case Study Report:

Valuing Business Transformation

using Real Options Analysis

Using a standard ROA implementation process, we will apply Real Options Analysis to a real-life situation and calculate the business value for the business transformation scenarios. The first step describes the situation and the objectives, step two implements the option valuation model and step three describes the results. Next, we review the whole process and describe the benefits of Real Options Analysis with regard to factors whose value is difficult to assess in more traditional valuation methods. The chapter finishes with a comparison with other business transformation valuation methods, a discussion of critical arguments on using ROA and overall conclusions.

5.1 Approach

In their book *Real Options: Managing Strategic Investment in an Uncertain World*, Amram and Kulatilaka (1999) describe an approach to apply real options in practical situations. They advise the following four-step solution process:

(1) Frame the application
(2) Implement the option valuation model
(3) Review the results
(4) Redesign?

When applying *Real Options Analysis* to practical situations, Amram and Kulatilaka comment: “While an option in the financial contract is clearly identified, the option in the real options application is sometimes much harder to spot. In the real options approach there is much more need to think through the application frame, making sure that it covers the right issues and achieves the right balance between a simplicity that preserves intuition and richness that delivers realistic and useful results. As a result, implementation of the real options approach requires the integration of a fair amount of detailed material, from the construction of inputs to number crunching."

They emphasize adequate content knowledge, combined with a balance between simplicity and richness. Content knowledge is important to frame the problem. When framing the problem one has to consider, among others, relevant decision points, options to be calculated and relevant timeframes for the sequencing of decisions. Content knowledge is required to identify these items.

Simplicity allows intuition to validate the results, or, in other words, to use the statistical instruments for supporting human decision-making capabilities. Too much complexity may obscure the underlying rationales and make them unavailable for human analysis. We will apply these guidelines when working out the case.

5.2 Case study

The applicability of real Options Analysis for the implementation of Enterprise Architecture will be illustrated using this case study. The case study was conducted in the second half of 2007. The purpose of the case study was to help management to understand the value, costs and risks of implementing enterprise architecture.

5.2.1 Description

A large Dutch financial institution has formed a domain named *Input Handling*. The objective of this domain is to receive and handle all customer-related, non-interactive input. The types of documents that the domain handles are various. Examples are *Proofs of Identity*, *Contracts*, *Letters*, documents from the *Chamber of Commerce*, etc. Basically, when the domain receives a document, it checks the authenticity of the document, it scans and stores it and makes the electronic image accessible for a target business process. The paper original may be archived or disposed. The *Input Handling* domain is not responsible for further processing of the scanned document; this is done by the target process. For instance, documents of the business processes *Mortgages*, *Savings* or *Insurances* are scanned and processed by *Input Handling.* Currently, only paper documents are handled. In the future, other forms of input documents may be included, such as e-mail and Internet forms. Interactive channels, such as telephone or chat, are out of scope, because they are handled by the customer contact centre.

5.2.2 Current situation

The institution distinguishes between individual scanning and bulk scanning. Individual scanning is used at branch offices, where employees have direct contact with a customer and may scan, for instance, a proof of identity document. Individual scanning in branch offices is at present only of limited value. Only a few branches have a scanner and branch employees use it to scan documents to the network drive of their computer. In most cases, the scanned documents are printed and the paper copy is used in the business process. Branch offices that do not have a scanner just make a photocopy of the document and this copy is used for further processing. In the actual situation, it may happen that customers are asked to provide – within a short time span – the same documents several times, because earlier scans cannot be retraced. This is, of course, undesirable. The desired situation is to enable individual scanning in branch offices, combined with central storage and accessibility of the scanned document, across branch offices and across channels.

Bulk scanning is used for documents, which are sent by mail to a central address in the Netherlands. The central scan room scans the documents, and either archives the document or makes it available for further processing within a business process. A problem with the current solution is the retraceability of the documents from the archive by the business processes. Depending on the amount and type of the meta-information that is stored with the document, retraceability of the scanned documents within the business processes varies between 40 and 100%. In addition, reusability of the scanned documents across business processes is limited and only a few business processes are enabled to receive a scanned document directly. For the majority of the business processes, documents are scanned to the electronic archive and retrieved for operational usage from the archive.

5.2.3 Key-figures

See Table 5-1 below for some key figures about the scanning processes.

Item	Volume
Number of documents in the Electronic Archive	2.3 billion documents
Annual increase of the Electronic Archive	400 million documents
Number of documents bulk scanned annually	6.9 million documents
Different types of documents bulk scanned	1061 document types
Percentage of bulk scanned documents directly entered into the electronic archive	87 per cent
Number of paper sheets used annually in branch offices	54.5 million sheets
Expected annual number of documents scanned individually	10 million documents

Table 5-1. Key figures of the scanning process

5.2.4 Business architecture

To bring focus in the development of the *Input Handling* domain, the domain owner has requested the development of the business architecture. The purpose of this business architecture is to provide a clear vision on a generic approach for input handling, future-proof and in accordance with the business vision and strategy. It is also important that it can easily fit in the current business process and application landscape of the institution. See Figure 5-1 for an overview of this architecture.

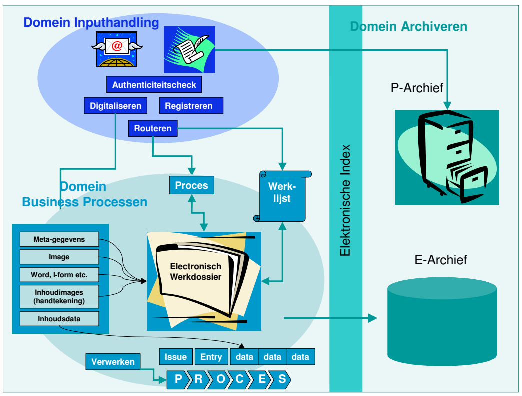


Figure 5-1. Overview of the business architecture for the domain Input Handling (picture courtesy of the case study institution)

At the upper left corner of Figure 5-1 the business functionality of the domain *Input Handling* is described. The domain has to execute the following functions:

(1) Authenticity check (Authenticiteitscheck) of the incoming document
(2) Registration (Registreren) of the document
(3) Digitization (Digitaliseren) of the document
(4) Complement the scanned image with metadata (Meta-gegevens)
(5) Routing (Routeren) of the document to an target environment

The original paper document is either discarded or moved to the paper archive (P-Archief). The electronic document is either routed to a process (Proces), to a task list (Werklijst) or to the electronic archive (E-Archief). The architecture describes the required business behavior of the solution; it does not describe the technical solution. The architecture covers the existing and foreseen future business requirements, is independent of a specific technology or the specific procedures of a particular business process and, hence, generally applicable. The business architecture is approved by the domain owner and chosen as the preferred direction for the development of the domain.

Because of the required scan volumes and the complexity of linking the scan processes to various target environments, it is found that the approach for realizing the business architecture is not trivial. Before starting the implementation, a good understanding of benefits, costs, options and risks was necessary.

5.3 Implementation Scenarios

There are two possible implementation scenarios for the implementation of this business architecture. The first one is doing the implementation in-house; the second one is to source the development of the architecture out to a contractor. Therefore, together with null scenario, we compare three business transformation implementation scenarios:

1. ***Null Scenario*** – the current, actual situation will not be changed. No implementation of the business architecture will take place.
2. ***Standard Scenario*** – the business architecture will be implemented in-house, with internal procedures and approaches.
3. ***Contract Scenario*** – the implementation of the business architecture will be outsourced to a contractor, based on a fixed-price contract. This means that the risk for budget overrun is carried by the contractor.

We will compare the benefits, costs and risks of the Standard Scenario and the Contract Scenario to the Null Scenario, using Real Options Analysis. The benefits these scenarios are calculated as a delta to the Null Scenario (the current situation).

The timeframe for implementing these scenarios is three years. In the next paragraphs, we will illustrate the use of applying Real Options Analysis for the full scenario, without (yet) considering the intermediary phases. ROA can also be used to calculate the value of individual phases and combined it in one overall scenario value. This phased approach is worked out in appendix 1 (page 128).

5.4 Solution Process

The solution process of Amram and Kulatilaka is used for our case study for applying Real Options Analysis in an Enterprise Architecture environment. An overview of the four main steps of the solution process:

Step 1. Framing the Application

The purpose of the first step *Framing the application*, is to structure the application in mathematical terms. Financial benefits and costs and the related probability distributions will be determined.

Step 2. Implement the Option Valuation Model

The purpose of the second step is to establish and value the options. In this step, we will calculate the option value of the Contract and the Standard Scenario.

Step 3. Review the Results

In this step, the results from the previous step are reviewed and various strategies for decision-making[*] can be considered. Based on the decision-making strategy, recommendations can be given for the optimal implementation strategy.

Step 4. Redesign?

Based on the reviewing of the results, a redesign may be possible. Example questions to consider in this step are: Can the set of investment alternatives be expanded? Can the investment strategy be reconfigured or redesigned to increase value? Are their options that can be added by staging or modularity?

[*] *See for the various decision-making strategies § 4.5 (page 29).*

5.5 Step 1. Framing the Application

The purpose of the first step, *Framing the application*, is to identify transformation scenarios and identify for each scenario the benefits, costs and risks. We will first consider the benefits, then the costs and based on the resulting cash-flow probability density distribution, we can derive the associated implementation risks of the scenarios.

5.5.1 Benefits

Architecture facilitates the execution of strategy. Strategic objectives of the domain *Input Handling* are[*]:

1. Maximize business value for sponsors[†]
2. Optimize strategic alignment with overall business goals like customer intimacy and satisfaction and operational excellence.

There are two types of benefits for implementing the business architecture: (1) benefits that maximize the business value for sponsors; i.e., revenue increase because of higher customer intimacy or improved commercial opportunities, and (2) benefits because of improved operational excellence; i.e., lower operational costs or reduced operational risks.

Effects on the Business

Implementing the business architecture has several types of effects on the business. To understand these effects, an expert panel was created, consisting of the domain owner and specialists in the area of business operations and digitization. With the expert panel a workshop was conducted, where a first solution outline was drafted, which was refined in several rounds. The following two main effects are identified:

- Improved quality of information
- More efficient and faster information handling

These main effects translate to the benefits described in Table 5-2.

[*] *From an internal strategy document of the financial institution, November 2007.*

[†] *With "sponsors" are meant the internal clients of the domain input handling; i.e., the departments that make use of the services of the domain.*

Benefit	Explanation
Quality improvement of the information used within business processes	Part of the (customer) information is currently stored at various places on paper and some is already available electronically. When all the information will be available electronically at one central storage location, the quality of the information within the processes will improve, because there will be one common source of information. For instance, in the current situation it may happen that different employees of the institution base their decisions on different versions of the same document.
Quality improvement information provisioning to the customer	The supply of information to the customer will improve because of the general quality improvement of information within the processes.
Documents need to be provided only once by customers	Some documents, like extractions from the Chamber of Commerce, or identification documents, may be asked several times from the same customer, because the copy is kept on paper controlled by one employee. With the new system, documents are scanned once, stored centrally, and can be reused across business processes.
Shorter elapsed time for process handling, because of elimination of transport of physical paper documents	Many of the business processes are executed at various locations throughout the Netherlands. If the business process stops at one location and needs to continue at another location, then the paper documents are transported between locations. Transport of documents to another location takes one or two days. In a typical business process, several locations are involved and, therefore, execution of a business process may need up to 10 days for just the transport of paper documents. This delay is eliminated when using only electronic documents.
Improved customer satisfaction	Because of shorter processing times, improved quality of information and less need to issue the same documents several times, customer satisfaction is expected to rise.
Ability to facilitate one Electronic Customer File	Implementation of the business architecture provides basic building blocks for creating a central electronic customer file. This is a long-term goal associated with the current business architecture.

Table 5-2. Overview of benefits that improved customer intimacy and commercial opportunities

Effects on the Efficiency of Internal Operations

The expert panel approach was used also to understand the effects of the business architecture on operational efficiency. Replacing paper with electronic documents improves the efficiency of business processes. The main effects are: less searching for documents, better availability of documents across channels, decrease of process cycle times and increased manageability of the information within a process. Furthermore, several existing ad hoc procedures for document handling can be removed and will be replaced by one standard way of working.

Benefit	Explanation
Improved document handling	It is expected that the time it takes to handle paper documents (i.e., printing, copying, scanning, archiving) will decrease.
Less use of paper	The use of paper for copying and printing will decrease.
Transport reduction	The effort needed for transporting documents will decrease.
Less documents stored in the Central Paper Archive	Is expected that more documents will be destroyed after scanning and, therefore, that the effort it takes to run the central paper archive will be less.
Linking output documents to input documents (e.g. contracts)	Many incoming paper documents are printed by the institution first, then sent to a customer, who has to sign or approve the document, and then sent back to the institution. The main example of this type of document is a contract. Part of the functionality described in the business architecture is to mark these types of documents before they are sent to the customer, so that they can be identified easily when received back.
Up-to-date customer info	In the past, the institution has conducted several initiatives to improve the quality and consistency of their customer data, to comply to legal requirements. The expectation is that the quality of the customer info improves, so that these projects for customer file reparation are unnecessary anymore.

Table 5-3. Overview of benefits that improve operational excellence

5.5.2 Quantification of Benefits

Benefit Drivers

To understand the value of the architecture implementation scenario, the benefits described in the previous paragraphs were quantified in financial terms. When determining the benefits, special attention was given to the quantification of the operational efficiency benefits, because they were much easier to quantify, than customer intimacy or commercial opportunity benefits. For each of the benefits described in Table 5-3, several activities were undertaken to understand the impact on the size of the benefits. For instance, for the benefit *Less use of paper*, the total cost of paper purchases for copiers and printers was requested. Based on the total cost, an estimation was made of the impact of the benefit and the resulting financial consequences. Comparable activities were undertaken to estimate the financial impact of the other benefits.

Because of uncertainties in estimating the size of the benefits, the quantification of the individual benefits was described in terms of a lower and an upper estimate. For each of the benefits described in this table we were able to quantify the expected benefits and an estimation of the probability that this benefit would be realized.

#	Benefit	Estimated Savings		Rationale
		Lower estimate	Upper estimate	
1	**Improved Document handling**	€4M	€5M	Efficiency of the document handling will be improved, i.e. accessing information, the speed of finding specific documents will be increased, etc. The estimation is that the time needed to handle paper decreases with 30 to 50%.
2	**Less use of paper**	€ 500K	€ 2M	Less cost of paper, copier maintenance, etc.
3	**Transport reduction**	€ 2.5M	€ 3.5M	The estimation that the paper transport between various locations can be reduced by 30 to 50%.
4	**Less documents stored in the Central Paper Archive**	€ 0.75M	€ 1.25M	The estimation is that the number of paper documents that are archived will decrease, in the long term, with 25 to 50%.
5	**Linking output documents to input documents (e.g. contracts)**	€ 400K	€ 600K	Many documents that the financial institution receives are documents that are sent earlier, an example being financial contracts. By providing the printed documents with an unique identification code, which is recognized during scanning, handling of these documents can be improved.
6	**Up-to-date customer info**	€ 800K	€ 1.2M	Digitization of information leads to efficiency improvements of the information management for customer files. For instance, it is expected that customer file repair will not be necessarily any more.

Table 5-4. Estimation of individual benefits of implementing the business architecture

These estimations were based upon and validated with the volumetrics described in Table 5-1.

Probability Density Function for Benefits

To describe these figures in mathematical terms, we will apply two assumptions.

1. The probability of the benefits is normally distributed (see § 4.4, page 24).*

* *Because of motivation described in § 4.4, we selected a normal distribution. The characteristics of the expected savings did not give indication that another distribution type would be more appropriate. Also note that the validity of the calculation method is not dependent on the selected distribution type (see § 4.6).*

2. The a priori probability that the actual savings are indeed within the bounds specified – as the results of the discussion in the expert panel and the outcome of the underlying research – is 75%*.

Based on these assumptions, we are able to create a probability density functions that describe the benefits. If the probability is 75% that the actual outcome is between the lower and the higher estimate, this means in mathematical terms that:

$$\int_{le}^{he} N(x,\mu,\sigma)dx = 0.75 \qquad (5\text{-}1)$$

where:

$x = Savings$
$\sigma = Standard\ Deviation$
$\mu = Mean$
$N(x,\mu,\sigma) = Normal\ Probability\ Distribution\ Function$
$le = Lower\ Estimate$
$he = Higher\ Estimate$

Based on this calculation the value of the Standard Deviation can be calculated. This leads us to the following figures:

Benefit	Lower Estimate	Higher Estimate	Expected value	Standard Dev.	Variance
1	4	5	4.5	0.4351	0.1893
2	0.5	2	1.25	0.6526	0.4250
3	2.5	3.5	3	0.4346	0.1889
4	0.75	1.25	1	0.2174	0.0473
5	0.4	0.6	0.5	0.0870	0.0076
6	0.8	1.2	1	0.1738	0.0302
Total			**11.3**	**0.942**	**0.8891**

Table 5-5. Expected value (EV) and standard deviation for benefit savings (EV in € x 10^6)

This table shows the expected value and standard deviation values for the identified benefits (Lower, Upper and EV in $\times$ € 1.000.000). The total Expected Value and Variance is calculated by the sum of the individual Expected Values and Variances.

* *We will challenge this value later on and conduct a sensitivity analysis to understand the effect of this value on the final result (See page 55.)*

The total Standard Deviation is calculated as the square root of the total Variance. This is because the expected value of the convolution of several normal distribution functions is the sum of the individual expected values. The standard deviation of the convolution is the square root of the sum of the variances (see (4-18) and (4-19)). The following probability density function describes the combined benefits.

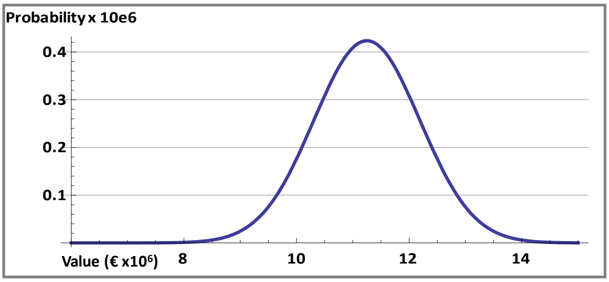


Figure 5-2. Probability distribution function for expected benefits

5.5.3 Quantification of Costs

Cost drivers

The cost of the architecture can be determined by calculating the cost of the implementation and operation of the various elements of the business architecture. The following cost elements are identified.

<table>
<thead>
<tr><th>Type of cost</th><th>Factor</th><th>Cost</th></tr>
</thead>
<tbody>
<tr><td rowspan="3">Development cost (one-time investment)</td><td>The cost of implementation of the architecture functionality</td><td>Based on the business architecture, twenty Business Services where identified. A Business Service describes a discrete part of the functionality of the total business architecture. See for the description of the Business Services
Appendix: An Overview of Business Services for the Financial Case Study (page 144). The cost of implementing the business services was calculated, by splitting up the business services into general categories, which describe the complexity of implementing the service. Three categories are used: Simple, Medium and Complex.
<table>
<tr><th>Category</th><th># Services</th></tr>
<tr><td>Simple</td><td>9</td></tr>
<tr><td>Medium</td><td>9</td></tr>
<tr><td>Complex</td><td>2</td></tr>
</table>
The cost of building a simple, medium or complex service is estimated to be respectively € 50.000, € 100.000 or € 200.000. The categorization of the services and the estimated cost per category is based on the judgment of an expert panel. Total cost is therefore € 1.750.000. (= 9 × 50K + 9 × 100K + 2 × 200K)</td></tr>
<tr><td>Cost of fitting the architecture within the existing environment</td><td>The cost of fitting the architecture within an existing environment is € 450.000. This estimation is based on the judgment of an expert panel.</td></tr>
<tr><td>Cost for implementing the architecture within the sponsor's business process</td><td>The cost of connecting the business architecture to the business processes of a sponsor is estimated to be € 150.000. Six business sponsors will implement the architecture within their processes. The connecting cost will be therefore € 900.000.</td></tr>
<tr><td>Annual maintenance cost</td><td>Operational costs to maintain the architecture</td><td>The cost of operating the implemented business architecture (including license costs, etc.) is estimated to be € 2.000.000 annually.</td></tr>
</tbody>
</table>

Table 5-6. Cost of implementing the business architecture

PDF Parameters

As we have seen (on page 31) the probability density function for cost follows a lognormal distribution. The lognormal distribution is characterized by three parameters: the location, scale and threshold parameters. We need to estimate the value of these three parameters, based on past performance of this institution, with regard to budget overrun of IT projects. We were able to analyze 70 IT projects. The actual cost of the project was compared with the planned cost. The actual cost of the project was taken from the financial administrative systems. The planned cost of the project was taken from the initial, formal project-budget request document. See the results in the figure below.

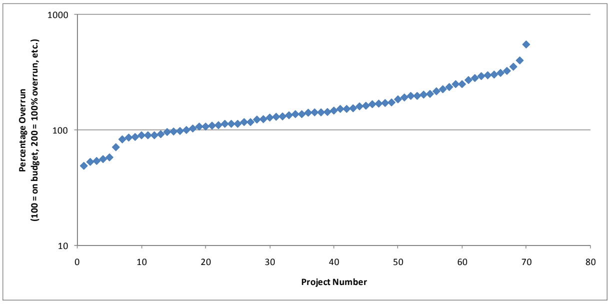


Figure 5-3. Overview of budget overrun for 70 IT projects

Figure 5-3 depicts 70 project results using a logarithmic scale. A project score of 100 means that the project has finished on budget. Scores above one hundred means that the project has overrun. For instance, a project score of 120 means that it has 20% overrun. A score below 100 means that the project has underrun: the initial budget was higher than the actual costs. We can analyze these figures to find out the corresponding probability distribution. Using Minitab®, we found out that these results follow a 3-parameter lognormal distribution.

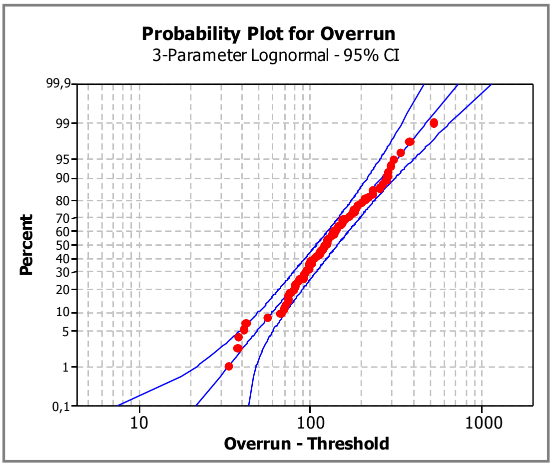


Figure 5-4. Lognormal analysis for project budget overrun

This analysis compares the frequency of the actual figures with a theoretical distribution, while trying to minimize the error between the theoretical value and the actual frequency. A red dot describes the results of one individual project. The middle line is the "ideal" lognormal distribution and the higher and the lower lines denote the 95% confidence intervals.

The parameters of the corresponding lognormal distribution are:

Location	4.8	**Planned Cost**	Set to 100
Scale	0.57	**Most often occurring (Mode)**	103
Threshold	15.3	**Expected Cost**	158

Table 5-7. Parameters project overrun lognormal distribution

These parameters give rise to the probability distribution function depicted in Figure 5-5, where the planned cost of implementing the business architecture is set to 100. From the distribution follows that the most likely (most often occurring) overrun is 3%, while the average overrun is 58%.

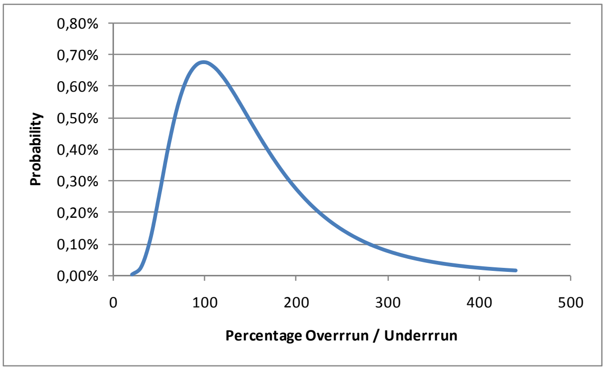


Figure 5-5. Lognormal distribution for project budget overrun

Relationship of the Probability Density Function to the Planned Cost

It is interesting to note that the planned cost is virtually the same to the most likely occurring actual cost – the mode. The planned cost is 100, while the mode is 103. This demonstrates that the planning for the cost of projects is based upon the most likely outcome of the project, instead on the average cost of projects. Indeed, the general understanding of project management within this institution was that the average project cost was substantially higher than the planned cost, although exact figures on this were not available. Based upon the analysis of the previous paragraph we can conclude that the average overrun is 58%.

Probability Density Function for Cost

Figure 5-5 depicts the general characteristics of projects within this financial institution. To apply these figures to our case we will need to convert these generic results to the actual figures. This means that the norm value of 100 will be replaced by the planned cost for this project. The planned costs for implementing the business architecture are (based on Table 5-6):

The cost of implementation of the architecture functionality	€ 1.750.000
Cost of fitting the architecture within the existing environment	€ 450.000.
Cost for implementing the architecture within the sponsor's business process	€ 900.000.
Total	**€ 3.100.000**

Table 5-8. Total implementation cost for realizing the business architecture

Scaling the probability density function of Figure 5-5, to a value where 100 equals € 3.1, gives a probability density function with the following parameters:

Location	1.36	**Mode**	€ 3.3M
Scale	0.57	**Expected Value**	€ 5.1M
Threshold	0.47	**Median**	€ 4.4M

Table 5-9. Parameters of the lognormal distribution for development cost

These parameters give rise to a lognormal probability distribution function that is shown in Figure 5-6.

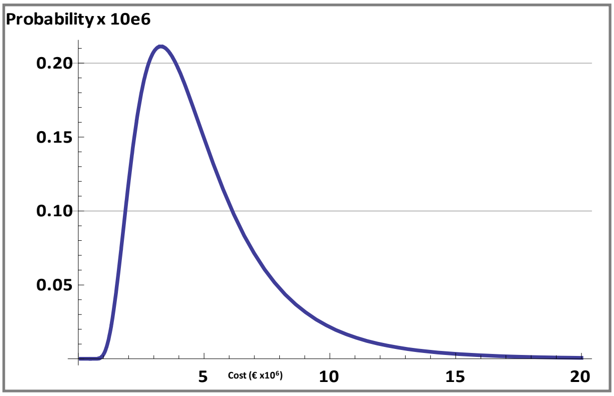


Figure 5-6. Probability density function describing the cost of the business architecture

This figure shows the probability density function of the actual cost for implementing the business architecture within this financial institution, based on an analysis of overruns and under runs of 70 projects.

Operational Cost

The annual, operational cost of the solution is € 2M (see Table 5-6). The operational cost has to be subtracted from the expected benefits. Consequently, the expected benefits decrease from € 11.3M to € 9.3M.

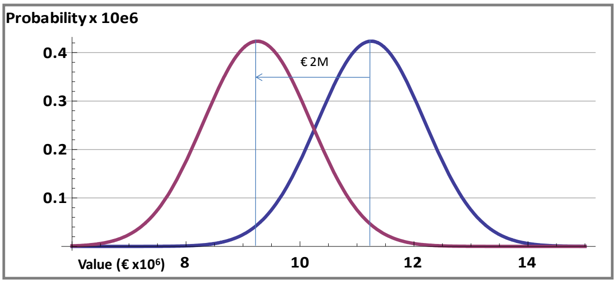


Figure 5-7. Probability distribution for expected benefits after operational costs.

5.5.4 Standard Scenario – Cash Flow Probability Functions

At this point, we have developed a probability density function for both the benefits and the costs. This means that we have an understanding of the probability for a certain actual outcome with regard to the benefits and to the costs. To determine the relationship between costs, benefits for implementing the business architecture, the revenue and cost probability density function are combined, using the approach for convolution of two probability distribution functions as described in

(4-14). This convolution provides a probability density function describing the cash flow.

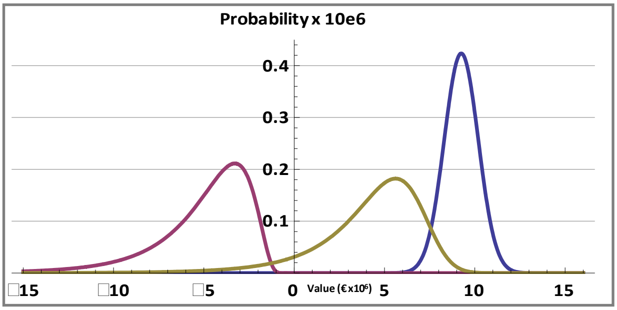


Figure 5-8. PDF's of cost, cash flow and revenue of the Business Architecture

The left probability density function (red) describes the cost. The right function (blue) describes the expected benefits. The middle function (yellow) is the convolution of these two functions and describes the resulting cash flow probability density function, for the standard scenario. The cash flow function in cumulative format is shown below.

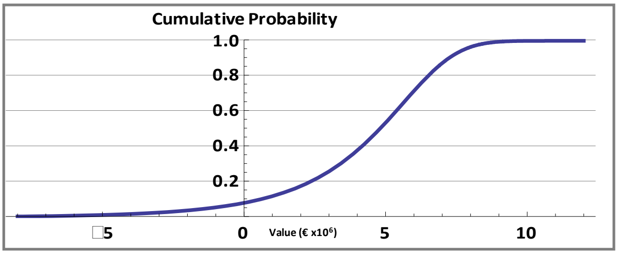


Figure 5-9. Cumulative probability function of the cash flow

From this cash flow function, we can derive some key-figures:

Figure	Value
Expected Value	€ 4.3M
Median – 50% Value	€ 4.8M
Mode – Most likely outcome	€ 5.6M (18%)
Probability of Negative outcome	8%
Probability of high revenue (>€6M)	29%

Table 5-10. Key-figures of the cash flow

The expected revenue of implementing the business architecture is € 4.3M. We can conclude that implementing the business architecture will most probably be a revenueable initiative; the probability of a positive outcome is 92%. However, the expected value of € 4.3M is € 1.3M less than the most likely outcome of € 5.6M. If we assume that management calculates the benefit of the program based on the most likely cost (as is discussed on page 55), then the resulting value of the implementation of the business architecture will be less than expected.

5.5.5 Sensitivity Analysis

The results of Table 5-10 are based on the assumption that the probability of the actual benefits to be within the estimates described in Table 5-4 is 75%. This 75% is a rather arbitrary choice. To understand the impact of this choice, we will revisit our results, based on different assumptions. This gives an indication of the sensitivity of the results to the assumption. To challenge the assumptions we will recalculate the benefit probability density function, using the value of respectively 75%, 50% and 25% as probability values for the confidence of the bandwidths described in Table 5-4. The benefit probability function (as described in Figure 5-2) becomes for these three values:

Key-figure		Value		
	Confidence estimates	25%	50%	75%
Expected value		€ 11.3	€ 11.3	€ 11.3
Standard Deviation		3.401	1.606	0.943

Table 5-11. Sensitivity analysis key figures for benefits

When the confidence of the estimates decreases, then the standard deviation of the probability density function increases. Increase of the standard deviation means that the possible outcome spread out. This is illustrated in the figure below.

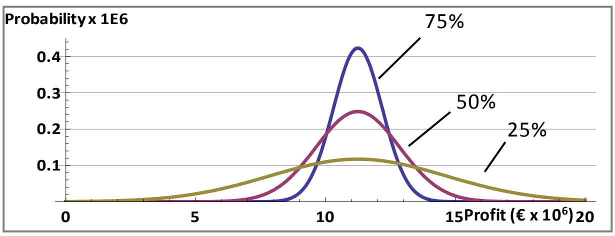


Figure 5-10. Sensitivity analyses for benefits

Figure 5-10 shows three probability density functions for benefits, the first one based on 75% confidence, the second one based on 50% confidence and the third one based on 25% confidence. Each successive function is more 'flat', reflecting the increasing uncertainty of the outcome.

To understand the effect of the flattening of the benefit probability density function on the cash flow function, these benefit functions are convoluted with the cost function (Figure 5-6). This results in the following cash flow functions:

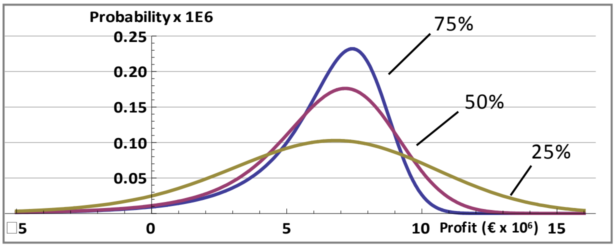


Figure 5-11. Results of sensitivity analysis for the cash flow function

An overview of the key-figures for the cash flow functions:

Key-figure	Value		
Cash Flow Function:	25%	50%	75%
Expected Value	€ 6.3M	€ 6.4M	€ 6.4 M
Median – 50% Value	€ 6.6M	€ 6.7M	€ 6.9M
Mode – Most likely outcome	€6.8M	€7.1M	€ 7.4M
Probability of Negative outcome	5%	2%	2%
Probability of high revenue (>€8M)	34%	28%	24%

Table 5-12. Sensitivity analysis Key-figures for the cash flow

When inspecting these figures we find that the Expected Value hardly changes. At the lower end (the probability of a negative outcome), the changes are also limited: the probability of a negative outcome only increases slightly from 2 to 5%, and then only for the 25% confidence level. At the high end (probability of an outcome above € 8M) the differences are more explicit: the probability of a high outcome increases from 24%, via 28% to 34%; an increase of 10%, while the lower end changes only 3%. We can say that the effect of the assumption on the confidence level of the bandwidths of Table 5-4 is limited. Specifically, the differences between the 75% estimate and a 50% estimate is limited. If anything, an increase in uncertainty about the expected benefits has a positive, beneficiary net effect on the financial outcome. The finding that an increase of uncertainty increases the value of a real option is a common finding for researchers working with real options (Amram, et al., 1999). Because of the fact that the effect of the choice of confidence level is limited and the resulting cash flow functions are not very sensitive to the assumptions, we have chosen to continue our calculations with the 75% confidence level.

5.6 Step 2. Implement the Option Valuation Model

The risk of cost overrun in developing the enterprise architecture is substantial. For instance, if we look at Figure 5-6, which describes the cost for implementing the business architecture, the planned cost is € 3.1M, the most likely cost (the mode) is € 3.4M, but the expected cost is € 4.9M, which is equal to 58% overrun. The probability of more than 100% overrun – the probability that the cost increases from the planned value of € 3.1M to more than € 6.2 – is almost 20%, 1 out of 5. From these figures, it is evident that risk mitigation of the cost has a significant impact on the total profitability of the program. To limit the risk of the development, part of the risks of developing the architecture can be passed-on to an external developer.

The option to contract allows the financial institution to contract out the development of the enterprise architecture, against a fixed-price. The fixed price can be seen as in insurance premium against high overrun. In effect, this eliminates the cost uncertainty; only the revenue remains. For instance, if the contractor decides to undertake development of the business architecture for a fixed-price of € 4M, this creates a new cash flow probability density function.

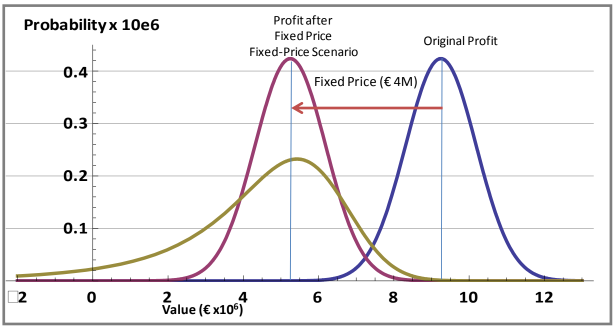


Figure 5-12. Comparing cash flows with and without contracting option. Example for fixed price of € 4M.

The right (blue) graph describes the revenue function, which is also described in Figure 5-7. The left (red) probability density function describes the probability density function for the *Contract Scenario*. The Contract PDF is equal to the original revenue PDF, shifted to the left over four units, because the fixed-price example of developing the business architecture is € 4M. The lower (yellow) PDF describes the standard scenario.

The key question is of course, which choice is the best one? Is it better for the financial institution to go for fixed-price (red, upper left) or to go for standard development (yellow, lower)? Clearly, the answer to this question depends on the investment strategy of the financial institution. Table 4-6 mentions four feasible strategies. These are:

1. Maximization of likely value
2. Maximization of expected value
3. Minimization of loss
4. Maximization of option value

We will discuss the application of these strategies in the following paragraphs.

5.6.1 Maximization of Likely and Expected Value

Analysis

The likely value of the standard PDF is € 5.6M, while the expected value is € 4.3 (according to Table 5-10). For the revenue PDF, the expected value and the likely value are both equal to € 11.3M (see Table 5-5). Therefore, the likely and the expected value of the Contract PDF is equal to € 11.3 minus the operational costs (€ 2M) minus the value of the fixed-price. See the Figure below.

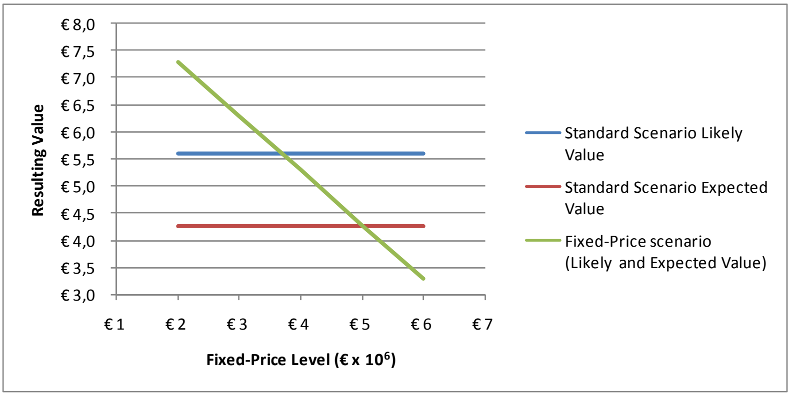


Figure 5-13. Likely and Expected Value of the Standard and the Contract Scenario

Conclusion

When opting for the strategy of maximization of *Likely Value*, the Contract variant is p referable when the price is below € 3.7M. In practice, this strategy is mostly used, because planned and most likely values are virtually the same (see the paragraph *Relationship of the Probability Density Function to the Planned Cost page,* 55). However, this is not a very sensible strategy, because the likely value does not say much about the expected value and it does not consider the risks of negative outcome. Other strategies may be more suitable.

When opting for the strategy of maximization of *Expected Value*, the Contract variant is preferable when the price is below € 5.0M.

5.6.2 Minimization of Loss

Analysis

Management may set a lower limit for the expected outcome of the cash flow of the implementation of the business architecture. The objective of this selection strategy is to minimize the probability that the cash flow resulting from the implementation of the business architecture is below this lower limit. The probability that the standard PDF delivers a result below a specific threshold is equal to:

$$S_p = \int_{-\infty}^{T} p_s(x)dx \qquad (5\text{-}2)$$

where:

$$p_s = \ Probability\ Density\ Function\ of\ the\ standard\ cash\ flow$$
$$T \ = Threshold\ value$$
$$S_p = Prob.\ of\ outcome\ below\ T, for\ the\ standard\ PDF$$

Figure 5-9 demonstrates this function graphically.

For the Contract PDF, the probability that the cash flow outcome is below the threshold is equal to:

$$F_p = \int_{-\infty}^{T} p_p(x + A)dx \qquad (5\text{-}3)$$

Where

$$p_p = \ Probability\ Density\ Function\ of\ the\ profit$$

$$T = Threshold\ value$$
$$A = Fixed\ Price\ value$$
$$F_p = Prob.of\ outcome\ below\ T, for\ the\ fixed\ price\ PDF$$

The strategy is to minimize the probability that the outcome will be below the threshold. This indicates that the Contract solution will be chosen if the probability of an outcome below the threshold for this solution is smaller than for the standard solution. Mathematically, this means that $F_p < S_p$. If the standard probability is smaller ($S_p < F_p$) then the standard solution will be chosen. Figure 5-14 shows the values of S_p and F_p as a function of A and T.

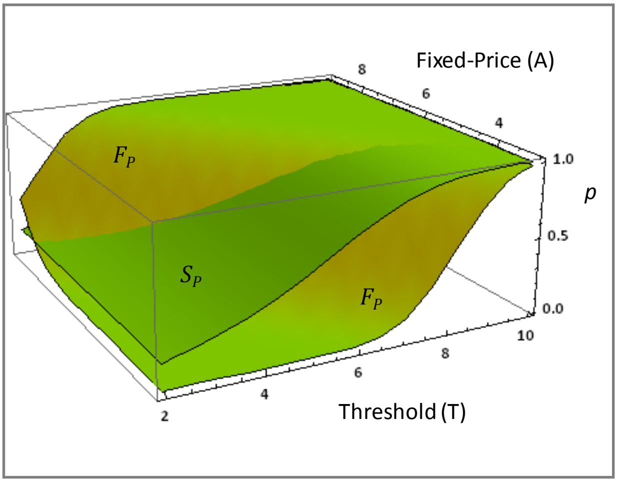


Figure 5-14. Values of $\boldsymbol{S_p}$ and $\boldsymbol{F_p}$ as function of $\boldsymbol{A}$ and $\boldsymbol{T}$.

The intersection line between S_p and F_p is shown in Figure 5-15.

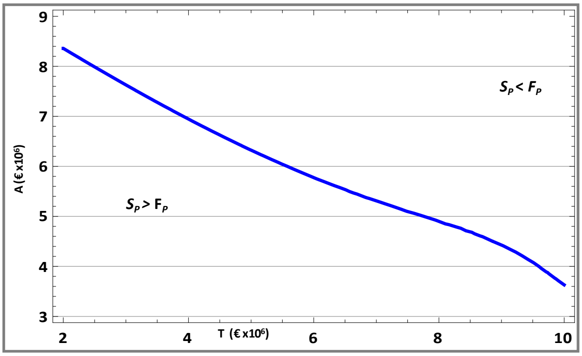


Figure 5-15. Intersection line between $\boldsymbol{S_p}$ and $\boldsymbol{F_p}$.

The horizontal axis of Figure 5-15 denotes the threshold value T and the vertical axis denotes the value of the fixed-price value A (in € x 10^6). In the area *below* the blue line, the probability that Contract Scenario delivers an outcome below the threshold, is smaller than for the Standard Scenario.

Conclusion

Below the blue line, it is favorable to select the Contract Scenario. Vice versa, above the blue line it is favorable to select the Standard Scenario. For instance, assuming the fixed-price (A) to be € 6M, then selecting the Contract Scenario is favorable when the threshold value is below € 5.6M.

5.6.3 Maximization of Option Value

Analysis for the Contract Scenario

The option value incorporates the additional value created by the uncertainty about future outcomes (see § 4.5.4, page 38). The value of the option is calculated by the Black-Scholes formula given by (4-2). This formula is repeated here:

$$O = N(d_1)S_0 - N(d_2)Ae^{-r.T} \qquad (5\text{-}4)$$

The following table gives an overview of the Black-Scholes parameters within the context of our case.

Para-meter	Explanation	Usage of the parameter in the context of our case	Value
S_0	Current value of the asset	The current value of the asset is not known, because the asset will be created by the project. Therefore, we only can use the estimated future value of the asset, which is given by Table 5-5. We subtract the operational cost.	€ 9.3M
A	Cost of fixed-price	This is the cost of the fixed-price project.	(variable)
r	Interest rate	The standard interest rates used for investment decisions within the financial institution is 10%.	10%
T	Time to expiration (in years)	The planned time for realization of the architecture is three years.	3
σ	Volatility of the asset	The volatility over three year of the assets is based on the calculation of Table 5-5.	0.94

Table 5-13. Usage and value of Black-Scholes parameters

Filling in the parameter values of this table into the Black-Scholes equation, we find the relationship between the option value and the fixed-price cost.

$$O = 4.65\left(1 + Erf(3.5 - 1.3\ln(A))\right) - .37A\left(1 + Erf(3.1 - 1.3\ln(\mathrm{A}))\right) \qquad (5\text{-}5)$$

where:

$O = Option\ Value$

$A = Fixed\ Price\ value$

$Erf(x) = Error\ Function = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}dt$

This gives the following relationship between the option value and the fixed-price value.

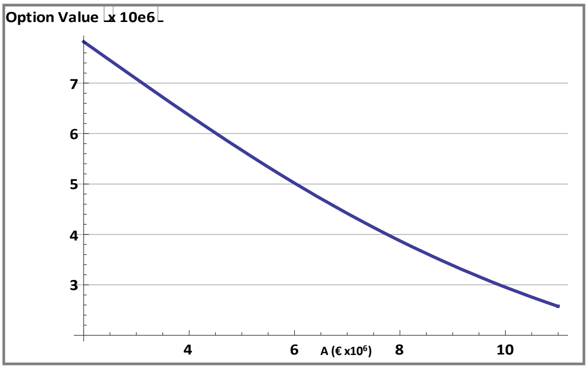


Figure 5-16. Relationship between option value and fixed-price

The horizontal axis denotes the value of the fixed-price, while the vertical axis denotes the value of the option. For instance, if the fixed-price is € 4M, then the resulting option value is € 6.4M.

Analysis of the Standard Scenario

The option value of the standard scenario cannot be calculated with Black-Scholes, because it deals with two sources of uncertainty, i.e., uncertainty with regard to the cost and uncertainty with regard to the revenue. To calculate the Option Value, we use formula (4-27), with the cash-flow probability density function of the standard solution (as is shown in Figure 5-8).

Figure	Value
Expected Value	€ 4.3M
Option Value	€ 4.4M
Median – 50% Value	€ 4.8M
Mode – Most likely outcome	€ 5.6M
Probability of Negative outcome	8%
Probability of high revenue (>€6M)	29%

Table 5-14. Key figures of cash flow function including Option Value

Table 5-14 is a copy of Table 5-10, but includes the Option Value. We find that the option value of the standard scenario is almost identical to the expected value. The reason for this is that the probability of a negative outcome is relatively small; approximately 8% (see Table 5-10 and Figure 5-9). A small probability of negative outcome means that Real Option Analysis has not significant added value, compared to NPV.

5.7 Step 3. Review the Results

And so, what is the best option; to contract or not to contract? Figure 5-17 gives a summary of the findings:

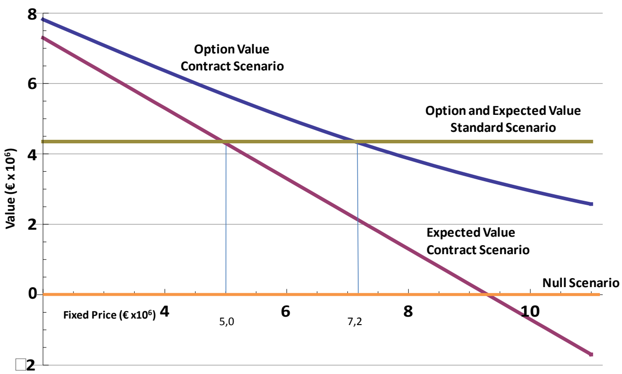


Figure 5-17. Comparison of standard option versus the contract option

Figure 5-17 is a combination of Figure 5-13 and Figure 5-16. We compare the *Expected Value* of the Standard Scenario to the *Expected* and the *Option Value* of the Contract Scenario. (For the Standard Scenario, the *Expected Value* is virtually identical to the *Option Value*, so these are treated together). These scenarios are compared to the Null Scenario (do nothing; continue the status quo).

The conclusion is, that the *Option Value* of the Contract Scenario is significant higher than the *Expected Value* of the Contract Scenario and that the difference between them increases if the fixed-price increases. This is understandable, because the *Option Value* is equal to the partial, positive *Expected Value*. In other words, the *Option Value* only considers the positive outcome of the *Expected Value* and ignores the negative outcomes. When the fixed-price increases, then the *Expected Value* becomes more negative and, consequently, the difference between the *Option Value* and the *Expected Value* of the Contract Scenario increases.

Based upon this analysis, it is advisable to choose for the Contract Scenario, if the total contracting cost is € 7.2M or less, otherwise the Standard Scenario would be advisable. If we compare this result with the analysis of § 5.6.2, which minimizes the probability of a negative outcome, then we see that the Contract Scenario for a cost of € 7.2M is also viable on the condition that the threshold value is set to € 5.3M or lower.

5.8 Step 4. Redesign?

In Step 4, the analysis is considered holistically, within the complete context of the question and the proposed solution. It allows the owner of the problem to take another angle or go for a different solution direction. For instance, in this case we considered only one type of contract option, namely the fixed-price contract. In the analysis, also other types of contracts might be included, such as: time and material with ceiling, or a shared risk approach between the contractee and the contractor. All these options have their own value that can be calculated separately.

5.9 Comparison with Other Valuation Approaches

Various methods for valuing architectural and IT investments have been developed. We will discuss a number of these methods and compare it to the Real Option Analysis approach that has been discussed in this thesis.

5.9.1 SAAM

Software Architecture Analysis Method was developed to analyze the properties of software architectures (Kazman, et al., 1994). The approach considers three perspectives for understanding and describing software architectures---functionality, structure and allocation. SAAM, therefore, is an approach to value qualitatively the various properties of software architecture and does not aim to quantify the business benefits of the software. In this respect, the purpose of the method is quite different from the Real Options Analysis that was described in this thesis.

5.9.2 ATAM

Kazman, Klein and Clements (2000) developed ATAM: *Architecture Trade-Off Analysis Method*. The purpose for ATAM is: “[...] to assess the consequences of architectural decisions in light of quality attribute requirements.” ATAM , therefore, is an approach to value qualitatively the various architectural decisions that can be made during the development of an Enterprise Architecture. It does not aim to quantify the benefits of architectural decisions, but to improve and demonstrate the alignment of architectural quality attributes with the objectives of the users of the enterprise architecture. The method is aimed at increasing the *fit for purpose* of the resulting architecture.

5.9.3 CBAM

The purpose of the Cost Benefit Analysis Method (CBAM -- (Moore, et al., 2003; Asundi, et al., 2001; Kazman, et al., 2002)) is to structure the decision-making process for implementing an enterprise architecture, in order to maximize the benefits that the architecture provides, while minimizing cost. CBAM analyses architectural decisions from the perspective of cost, benefit, schedule and risk. As such, it is comparable in purpose and perspectives to the Real Options Analysis that was described in this thesis. CBAM does not use ROA for this analysis, but a combination of scenario thinking and *utility levels*. A *utility level* valuates various qualities of the final solution with regard to the objectives of the users of the architecture. The utility levels are defined qualitatively by expert users or management. This method does not incorporate the value of future decision-making and as such, it is an approach, which depends on subjective estimations by key users. The reliance on the opinion of expert users and senior management makes the approach difficult to apply. The advantage of the method is that it makes the intuition and understanding of the value of the architecture explicit and traceable.

5.9.4 Other ROA approaches

There is a sizeable literature on using option valuation for IT investments. Dos Santos (1991) was one of the first authors to value IT investments using Real Options Analysis. More recently see Hilhorst (2004) and (2005). In the 2004 study, a combination of *Multiattribute Decision Analysis* (MADA) and Real Option Analysis was used, to incorporate both financial and non-financial elements in the decision-making process. The reason for including ROA is because to “include risk as a measure of uncertainty with respect to specific consequences of an investment, adds to the reliability of the outcome of the decision." The reason for using the combination of ROA and MADA is to address one of the major arguments against using ROA, that is "its lack of transparency for decision-makers. Using real Options Analysis in the multi-attribute approach gives a better insight in different implementation scenarios." (Hilhorst, et al., 2004).

5.9.5 Critics on Using ROA for IT Investment Evaluation

De Jong, Ribbers and Van der Zee (1999) assert that real Options Analysis is not a useful instrument to value IT investments. Their three main objections are:

(1) *It is difficult to estimate the input values* (the Variance and Net Present Value) *for subsequent projects*
(2) *ROA -- in its closed Black-Scholes form -- is too simplistic, because too many assumptions are being made*
(3) *This form is too complex to communicate to management*.

Indeed, estimation of input values is a critical activity when performing Real Option Analysis. However, this activity is critical for any valuation method, be it ROA, Decision Tree Analysis or other methods. We have tried to overcome this objection by splitting up the analysis in the two main components (i.e., revenue and cost expectations) and measuring separately the expected value and variance for each of the components. For the cost component, we were able to measure the actual variance, which gives us confidence that this value is correct.

We support the statement that the basic Black-Scholes formula is too simplistic for many situations. That is why we adapted the basic method by calculating separately the revenue and cost probability distributions.

It might be that the basic Black-Scholes formula is too complex to communicate. After all, the formula is more or less a 'black box' with a number of input parameters that delivers an output value, which is not necessarily intuitively related to the input parameters. However, we find that the adaptations that we have added to the basic approach (that is calculating separate revenue and cost probability distributions and combining them) are easily explained to management. Management is experienced to think in revenue and cost factors, and instead of having one revenue and cost estimation value, this approach builds on this thinking in describing revenue and for cost distributions. Combining the revenue and cost distributions in one overall distribution is very much comparable to the process that is performed with single revenue and cost factors.

6.

Value of Solutions Architecture

In the previous chapters, we found that Real Options Analysis is a suitable instrument to assess the value enterprise architecture based business transformation. The analysis in this chapter, describes an approach for measuring the value of solution architecture at project level. The assertion is that the use of solution architecture increases the success rate of projects and that it is an essential discipline, next to other well-known project-level disciplines, such as Project Management, Analysis and Design, Software Development and Testing. This chapter describes what is meant by success rate of projects and describes an approach for measuring the effect of Solutions Architecture on projects, using the Six Sigma approach. Next, it describes a case study and describes how it is set-up and conducted.

6.1 Role of Architecture at Tactical Level

6.1.1 Introduction

The tactical aspect of architecture concerns the use of architecture during the *implementation process* of the business transformation. Transformation projects are the vehicle to change business and IT. In this chapter, we will look at the role of project-level (or solutions) architecture and study its value for software development projects.

6.1.2 Success of IT projects

Methods and Techniques for Software Development

In the literature, we find many publications on the topics that are linked to Software Development projects. Many books and articles are published on the topics of Project Management, Analysis & Design, Software Development and Testing. References for project management are Kerzner (2003) and PRINCE[*] 2 (Office of Government Commerce, 2008). For Analysis & Design and Software Development and Testing, various methods are published. Among them: RUP[†] (Barnes, 2007) and DSDM[‡] (2008) are well known. In addition, CMMI[§] (SEI, 2006) defines stages and maturity levels for (software) development processes.

Definitions
Project management is the discipline of planning, organizing and managing resources to bring about the successful completion of specific project goals and objectives.
Analysis and design is the process to analyze the requirements for the software and create a design that fulfils the requirements. **Analysis** is the process where business people and IT people need to work out a common frame of reference and a shared understanding of the requirements of a software system. **Design** is the process of planning and solution structuring for a software system.
Software Development is a systematic approach to the development, operation and maintenance of software.
Software testing is the process of checking software, to verify that it satisfies its requirements and to detect errors. Software testing is an empirical investigation conducted to provide stakeholders with information about the quality of the product or service under test, with respect to the context in which it is intended to operate.

Table 6-1. Definitions of main software project development activities

6.2 Role of architecture in software development

6.2.1 Success Rate of Projects

None of the approaches described in the previous paragraph, recognizes explicitly the role of enterprise architecture and the connection from enterprise architecture to project-level architecture, although DSDM has published a paper on the relationship between TOGAF (2004) and DSDM (DSDM and TOGAF, 2003).

According to Piselo (2003), about one third of custom software development projects fail, about half of the projects is late, over budget, or has reduced functionality and only one sixth of the projects is delivered on time, within budget and according to specification. Considering the lack of attention of the major software

[*] PRojects IN Controlled Environments
[†] Rational Unified Process
[‡] Dynamic Systems Development Method
[§] Capability Maturity Model Integration

development methodologies for architecture, one could assert that this is one of the reasons for this poor performance. We assert that:

IT Software Development Projects are 'more successful' when they are 'Developed under Architecture'.

In order to be able to test this assertion, we have to define more precisely what we mean by a *more successful* project. For a description of *Developed under Architecture,* see Definition 1-3 (page 4).

6.2.2 Factors influencing project success

An IT project can be considered as a process with a number of inputs (called project variables) and outputs (success variables). The approach to measure project and success variables we have chosen is derived from Wohlin (2003). He states: "If $pv_1, pv_2 \ldots pv_i \ldots pv_k$, are the project variables and $sv_1, sv_2 \ldots sv_i \ldots sv_k$, are the success variables, then the objective is to identify which project variables are good estimators for which success variables. Project variables describe key drivers and characteristics of the software project and can be measured (or estimated) before the project starts [or during project execution]. Success variables are measured when the project is completed." Figure 6-1 illustrates this.

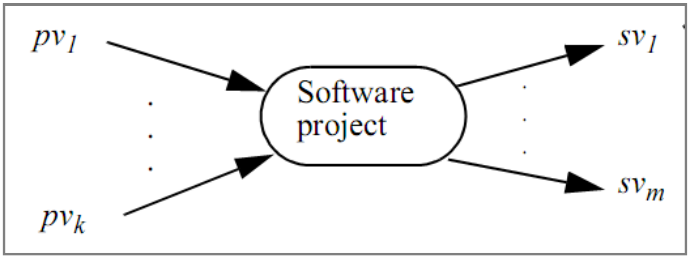


Figure 6-1. Project and success variables (from Wohlin)

Examples of project variables are: *quality of the requirements*, *experience of the project manager*, *quality of the project architecture*, etc. An example of a success of variable is: *the match between functional requirements and delivered functionality*.

Based on this model, we use the following definition for the success of projects, related to architecture:

Definition 6-1. Architecture-related success of projects
Projects are 'more successful' if we can identify architecture-related project variables, which are positively correlated with one or more success variables.

6.2.3 Project variables

Project variable model

For his master thesis, Rudolf Jurgens developed a project variable model (Jurgens, 2008). He identifies about 80 project variables. The project variables include architecture variables and non-architectural variables. The following approach was used to create the list with project variables:

1. Define first draft of project variables
2. Validate this first draft with the expert panel, consisting of project managers, quality managers, software engineers and architects
3. Refine and extend the list to create the second draft based on the input from the expert panel
4. Validate the second draft again with the expert panel
5. Based on the feedback of the expert panel, define the definitive list with project variables

Table 6-2 describes the project variables that are related to architecture.

Nr	Architectural Project Variable	Rationale for inclusion
1	Involvement of an architect in the technical budget calculation for the project	The technical budget is the budget for which the project should be built. Setting a technical prize includes considering various (technical) factors and price drivers, which is the expertise of the architect.
2	The general experience of the architect, who creates the project architecture, as reflected in the certification level of the architect.	Experienced architects have more insight and oversight then less experienced architects.
3	The certification level of the architect, should match the complexity of the project.	Projects come in different size. Therefore, projects that are more complex should be executed to the more experienced architects.
4	The specific experience of the architect on the subject of the project.	It is probably advantageous for an architect to have experience with the specific topics of the project.
5	Quality of the project architecture	The project architecture is the guideline for the project.
6	Quality customer's domain architecture	The customer's domain architecture provides guidelines for the project architecture.

Nr	Architectural Project Variable	Rationale for inclusion
7	Quality of the customers enterprise architecture	The customer's enterprise architecture provides guidelines for the underlying domain and project architecture.
8	Quality of the customers architecture governance process	A high-quality architecture governance process helps the project to make the right decisions.
9	Presence of a controlling architect during the execution of the project	A controlling architect checks whether the project keeps itself to the project architecture.
10	Compliancy testing between architecture and project during execution	If the compliancy is checked of project deliverables and the project as picture, then, any discrepancies between the two are known

Table 6-2. Overview of architecture-related project variables

6.2.4 Success variables

Project success dimensions

According to Wideman (2008), project success has the following dimensions:

1. Internal Project Objectives (efficiency during the project)
2. Benefit to Customer (effectiveness in the short term)
3. Direct Contribution (in the medium term)
4. Future Opportunity (in the long term)

He gives the following key questions and success variables for each of these dimensions.

Dimension	Key-questions	Success variable
1. Internal	• How successful was the project team in meeting its schedule objectives? • How successful was the project team in meeting its budget objectives? • How successful was the project team in managing any other resource constraints?	• Meeting schedule • Within budget • Other resource constraints met
2. Benefit to Customer	• Did the product meet its specified requirements of functional performance and technical standards? • What was the project's impact on the customer, and what did the customer gain? • Does the customer actually use the prod-	• Meeting functional performance • Meeting technical specifications & standards • Favorable impact on customer, customer's gain • Fulfilling customer's needs • Solving a customer's problem

Dimension	Key-questions	Success variable
	uct, and are they satisfied with it? • Does the project's product fulfill the customer's needs, and/or solve the problem?	• Customer is using product • Customer expresses satisfaction
3. Direct Contribution	• Has the new or modified product become an immediate business and/or commercial success, has it enhanced immediate revenue and profits? • Has it created a larger market share?	• Immediate business and/or commercial success • Immediate revenue and profits enhanced • Larger market share generated
4. Future Opportunity	• Has the project created new opportunities for the future, has it contributed to positioning the organization consistent with its vision, goals? • Has it created a new market or new product potential, or assisted in developing a new technology? • Has it contributed additional capabilities or competencies to the organization?	• Will create new opportunities for future • Will position customer competitively • Will create new market • Will assist in developing new technology • Has, or will, add capabilities and competencies

Table 6-3. Dimensions, Key-Questions and Factors for Project Success (According to Wideman)

Success variables within the scope of the study

Not all of the success variables mentioned by Wideman were available for our survey. The success variables that we would like to measure were matched with the information that was available during an interview with the project manager. The combination of the list of Wideman and the list with available information, led to the following list of six success variables.

No	Variable	Definition
A	**Budget**	Percentage underrun or overrun for the project. We compare the actual project cost to the original project planning. Scope changes during the execution of the project were taken into account.
B	**Time**	Percentage underrun or overrun for the project time. We compare the actual timeframe with the original, planned timeframe. Scope changes during the execution of the project were taken into account.
C	**Customer Satisfaction**	Customer's satisfaction assessment of project execution and result.
D	**Percentage Delivered**	The percentage of the intended results that are actually delivered by the project.
E	**Functional Fit**	The match between the planned and delivered functionality; is the functionality delivered by the project in accordance with the planned functionality?

No	Variable	Definition
F	**Technical Fit**	The match between the planned and delivered non-functional characteristics; is the security, availability, performance, etc. of the delivered project result in accordance with the planned characteristics?

Table 6-4. Overview of available success variables

6.3 Measurement set-up

6.3.1 Introduction

To test the value of architecture for projects, we conducted a measurement were we studied 49 software development projects. The objective of the study is to find statistically significant correlations between architecture and related input variables and success variables. The chosen measurement approach is based on Six Sigma.

6.3.2 Six Sigma

Six Sigma is "a disciplined, data-driven approach and methodology for improving process quality in any type of process -- from manufacturing to transactional and from product to service" (iSixSigma, 2007).

DMAIC Improvement Model

Six Sigma describes two different improvement process models: DMAIC* and DFSS†. The choice between them, depends on the objective of the Six Sigma study. For us, DMAIC is the most suitable process to use. An overview of the DMAIC phases:

Phase	Objective	Activities	Results
1. Define	• Define the context scope and objectives of the study	• Define null hypothesis	• Context and measurement objectives • Testable null-hypothesis
2. Measure	• Obtain process information	• Check availability of process information • Measure and collect process information	• Measured process information
3. Analyze	• Analyze measured process information • Create recommendations for improvement	• Clean the data • Analyze data using hypothesis testing • Setup recommendations for improvement	• Confirmed or falsified null-hypothesis • Recommendations for improvement

* *Define, Measure, Analyze, Improve, Control*

† *Design For Six Sigma*

Phase	Objective	Activities	Results
4. Improve	• Carry out the improvement recommendations	• Implement recommendations	• Improved process
5. Control	• Check whether recommendations have effect • Prevent reverting to the old situation	• Set up process limits • Monitor process limits	• Institutionalized improved process

Table 6-5. Six Sigma DMAIC process

We use the phases 1, 2 and 3 in this study.

Process capability level

Six Sigma describes a standard method for allocating quality levels to processes. The purpose of allocating a quality level to a process is to understand how well the process functions and to understand if process improvement measures are effective. This quality level (Six Sigma uses the term capability level) is a number from 0 to 6, 6 being the highest quality. The capability level is determined by the number of *Defects per Million Opportunities* (DPMO) produced by the process. See Table 6-6*.

Sigma Level	Yield	DPMO
0.5	16%	841,345
1	31%	691,462
1.5	50%	500,000
2	69%	308,538
2.5	84%	158,655
3	93%	66,807
3.5	98%	22,750
4	99%	6,210
4.5	99.9%	1,350
5	99.98%	233
5.5	99.997%	32
6	99.9997%	3.4

Table 6-6. The Six Sigma Process Quality Table

Yield denotes the percentage of process runs that provide results without defects. The *DPMO* column shows this number in terms of defects per million opportunities. If we define a software development project as one opportunity and define a defect as a delivery over budget, over time or with reduced functionality, then – according

* *This table is derived from the standard normal distribution, shifted over 1.5σ.*

to Piselo (2003) – the custom software development process has sigma level of 0.5, because the study indicates that only about 16% of the projects deliver according to plan. The highest capability level gives the method its name.

6.3.3 Hypothesis Testing

Introduction

Correlations between project and success variables are identified using statistical tests. A statistical test calculates a probability value (p-value) which represents the probability that the null-hypothesis (H_0) is correct. H_0 states that the tested variables are *not* correlated. If the p-value of the test is below the threshold value – also named the significance level – then we cannot accept the null-hypothesis. If we reject the null hypothesis, then we accept the alternative hypothesis, e.g. that the variables *are* correlated.

Choice of Threshold Value and the α/β Risks

The threshold value we have chosen for rejecting the null-hypothesis is 5%. In other words, a test is significant when the resulting p-value is 5% or lower. The significance level of 5% is a commonly used value for hypothesis testing. By choosing this threshold value, we accept a 5% probability that we mistakenly accept the alternate hypothesis. This is called the *α-risk*, or the *Type I* risk. Conversely, there is also a *β-risk* or *Type II* risk. This is the probability that the alternative hypothesis is not accepted, while it is correct. See for a discussion on these risks Marco Folpmers (2002).

Statistical tests

For hypothesis testing, several statistical tests are available; we will discuss the applicable tests.

Test	Description
ANOVA	ANOVA stands for Analysis of Variance. ANOVA tests "whether the data from [several] populations, formed by the treatment options from a single factor, [...] indicated the population means are different."(Benbow, et al., 2005) 'Treatment options from a single factor' means that the tested project variable must have several *discrete values*, and the total population of success variables is split up in sub populations according to the values of the tested project variable. ANOVA tests if the means of these sub populations are significantly different. Thus, the input variables for ANOVA must be discrete while the output variable must be a continuous, numerical variable. Other requirements for the ANOVA test are (Benbow, et al., 2005): • Independence of cases – individual projects need to be independent • Normality – the success variable has a normal distribution • Equal variances – the variance of data in groups should be the same

Test	Description
	Another requirement for hypothesis testing is that the samples (i.e. the individual projects) are selected at random from the total population. See for more information on this (Pyzdek, 2003).
Linear regression	For linear regression, the independent variable must be numerical and dependent variable must be numerical and continuous. A requirement for the test is that the remaining errors are assumed to follow a normal distribution, with a means of zero and a constant standard deviation. Errors must not be linked to the dependent variable (Pyzdek, 2003).
Kruskal-Wallis	The ANOVA requirement that the success variable needs to be normal distributed, can be relaxed by using a nonparametric test. In general, tests that require a normal distribution are preferred above nonparametric tests because normal based tests have more power(Pyzdek, 2003). However, if the data distribution is not normal and cannot be transformed to normal distribution then nonparametric tests are useful. In this case, we used the Kruskal-Wallis test (Kruskal, et al., 1952). The data requirements for Kruskal-Wallis are identical to ANOVA: the input variables must be discrete while the output variable must be a continuous, numerical variable. A requirement for the test is that the distribution of the samples is identical. The exact type of distribution does not matter (Pyzdek, 2003).
Bartlett	Bartlett's (Snedecor, et al., 1989) test, tests whether the variances in the sub populations are significant different. This test is specifically used for testing the time and the budget success variables, in order to understand whether architectural project variables have a significant influence on the reliability of the planning. The data requirements for this test are equal to ANOVA.

Table 6-7. Overview of statistical tests for hypothesis testing

As can be seen from the description, the type of test that is applicable in a specific situation depends on the testing context. Based upon the specific requirements for each test, we defined the following guidelines for selecting statistical tests when testing for differences in *Expected Value*:

1. If the success variable is continuous and normal distributed (or is transformed to normal distribution), and the project variable is discrete then use the ANOVA test.
2. If the success variable is continuous, but the distribution of the variable is not known and the project variable is numerical then use regression analysis.
3. If the success variable is numerical but the distribution is unknown and the project variable is discrete then use Kruskal-Wallace.

When we test for differences in *Variance*, Bartlett is used.

Minimum Sample Size

One main factor for determining the reliability of a hypothesis test is the *sample size*. The *sample size* is the number of responses allocated to one answer of a project variable. Project variables have generally three possible answers. (The questionnaire is multiple-choice and asks the interviewee to choose from the answer 1, 2 or 3.) The survey size used for testing is 49 projects. When analyzing the results for a project variable, the 49 projects are split up in three samples, according to the three answers. Consequently, the average sample size is about (49 / 3 ≈) 16 projects. Individual samples may be smaller, because the projects might be unevenly distributed over the samples or projects may not have answered this question.

The null-hypothesis tests assume that the sample mean is an indication for the population mean. The reliability of the sample mean compared to the population mean is given by a Confidence Interval (CI). The upper and lower limits for the CI are determined by the size and the standard deviation of the sample and the required confidence level. There is an inverse relationship between the sample size and the size of the confidence interval. The larger the sample size, the smaller becomes the confidence interval and vice versa. For reliable hypothesis testing, it is imperative that the sample size is not too small, because the results of the hypothesis testing become unreliable. The following analysis determines the minimum sample size.

The confidence interval is defined as (Pyzdek, 2003):

$$\mu = \bar{X} \pm s\frac{t_{(\alpha/2,n-1)}}{\sqrt{n}} \qquad (6\text{-}1)$$

where:

$\mu = Population\ mean$

$\bar{X} = Sample\ mean$

$t_{(\alpha/2,n-1)} = t\ distribution\ value, for\ p = \alpha/2\ and\ df = n-1$

$\alpha = \alpha\ risk = 5\%\ .This\ provides\ a\ 95\%\ Confidence\ Level.$

$s = Sample\ standard\ deviation$

$df = Degrees\ of\ Freedom$

$n = Sample\ size$

The value of the *Confidence Interval Multiplier* M_{ci} ($t_{(\alpha/2,n-1)}/\sqrt{n}$) determines the reliability of the sample mean with regard to the population mean as function of s, the sample standard deviation. Formula (6-1) states that there is an $(1-\alpha)$ probability that the population mean is between $\bar{X} - \text{s} \times M_{ci}$ and $\bar{X} + \text{s} \times M_{ci}$. See Figure 6-2 for an overview of the value of the Confidence Interval Multiplier M_{ci} as function of the sample size.

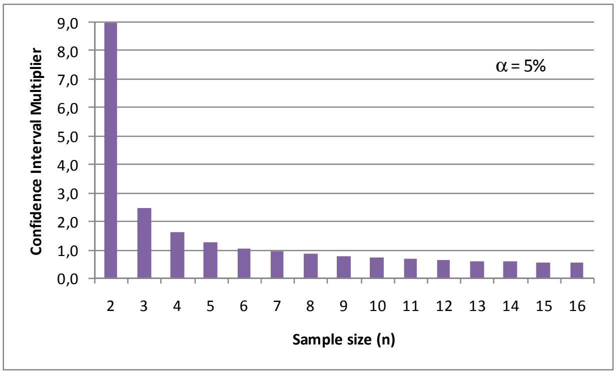


Figure 6-2. Value of the Confidence Interval Multiplier for various sample sizes

As can be seen, the value of M_{ci} increases rapidly for small values of n. Therefore, it becomes impossible to obtain a reliable estimate of the population mean μ for small n. To prevent incorrect conclusions, we choose 6 as the lower limit for the sample size. This gives a 95% probability that the population mean is within the range defined by plus or minus one sigma of the sample mean. Consequently, test results that are based on sample size of 5 or smaller are discarded or transformed.

6.4 Description of the Project Study

6.4.1 Description of the Projects

The study was conducted at a Dutch commercial IT service provider, where projects from various customer organizations were examined. Forty-nine projects were included in the study. These were all IT projects, were specification-based tailor-made (bespoke) software is developed. The software is mainly developed for companies from the financial sector, but also from industry and government. The type of projects encompasses (among others) transformation projects[*], merger and acquisition projects[†], single function integration projects[‡] and lifetime extension projects[§].

[*] *Cross functional projects, such as CRM implementations*
[†] *Rationalization or consolidation projects, shared service centre*
[‡] *New general ledger or HRM system*
[§] *Web enabling of legacy systems, application integration*

Project Selection

See below for an overview of the project selection criteria. Only projects that comply with these criteria are included in the study.

Nr.	Criterion	Rationale
1	Software development projects only.	No pure package or infrastructure implementations, to prevent comparing different types of projects with different characteristics.
2	The architect and/or the project manager must still be available for an interview.	To collect information of the project that is not accessible otherwise.
3	Minimum planned cost of € 100.000 at start of the project, no more than € 10 million.	Exclude very large projects and very small projects. These projects may need a different approach.
4	Start of project execution no longer than three years ago.	To ensure data quality. Information is collected through interviews. Interviewees cannot remember relevant details if the project started too long ago.
5	Project must be finished or in the last phase.	The results of the project must be available.

Table 6-8. Project selection criteria

Project size

The average project size is about € 700K, while the median size is about € 450K. See Table 6-9 for an overview of the key figures of the projects within the survey scope.

Characteristic	Value
Number of projects	49
Average project size	€ 695.000
Minimum project size	€ 50.800
First quartile	€ 125.000
Median	€ 349.000
Third quartile	€ 939.000
Maximum project size	€ 2.500.000

Table 6-9. Key figures of the size of the surveyed projects

6.4.2 Testing the Null-Hypothesis

H_0 Statements

Based upon the definition of the success variables (see Table 6-4) the following H_0 statements are formulated.

No	H_0 statement
I	Application of enterprise architecture is not significantly correlated with the expected value of the actual project budget (as percentage of the planned budget).
II	Application of enterprise architecture is not significantly correlated with the variance of the actual project budget (as percentage of the planned budget).
III	Application of enterprise architecture is not significantly correlated with the expected value of the actual project timeframe (as percentage of the original timeframe).
IV	Application of enterprise architecture is not significantly correlated with the variance of the actual project timeframe (as percentage of the original timeframe).
V	Application of enterprise architecture is not significantly correlated with the expected value of customer satisfaction.
VI	Application of enterprise architecture is not significantly correlated with the expected value of the percentage delivered.
VII	Application of enterprise architecture is not significantly correlated with the expected value of the functional fit.
VIII	Application of enterprise architecture is not significantly correlated with the expected value of the technical fit.

Table 6-10. Null-hypothesis statements

With the term *Application of enterprise architecture*, we refer to the application of enterprise architecture for projects as reflected in the ten architecture-related project variables (see Table 6-2).

Remarks

1. Note that the null-hypothesis states that the project and success variables are *not* correlated. Rejection of the null hypothesis implies acceptance of the alternate hypothesis, i.e. that the variables are correlated.

2. The analysis identifies *correlations* between project and success variables and not *causal relationships*, because the type of statistical analysis used, is not able to identify causal relationships. However, by analyzing these correlations, we are often able to give meaning to the correlation and describe a causal mechanism that may be underlying the correlation.

3. For both the budget and time success variables, we have defined two null-hypothesis statements. The budget and time success variables are tested both with regard to the expected value (statements I and III) and the standard deviation (statements II and IV). The other success variables are tested only for expected value. The reason to test budget and time for standard deviation is that architecture may be correlated with an increase of reliability of the planned budget and time. A lower value of the standard deviation indicates less variance in the outcomes of the actual projects and thus a higher reliability of the planned figures.

Choice of Statistical Tests

We will test each H_0 statement with each of the ten project variables. Based upon the guidelines for choosing a statistical test (see § 6.3.3 page 79), the following tests will be used to validate each of the H_0 statements.

H_0 Statement	Statistical Test	Rationale for using this test
I	ANOVA	Success variable is continuous and can be transformed to normal distribution.
II	Bartlett	Success variable is continuous and can be transformed to normal distribution. Test for equal variances.
III	ANOVA	Success variable is continuous and can be transformed to normal distribution.
IV	Bartlett	Success variable is continuous and can be transformed to normal distribution. Test for equal variances.
V	Linear regression	Success variable and project variables are continuous, but success variable is not normal distributed.
VI	Linear regression	Success variable and project variables are continuous, but success variable is not normal distributed.
VII	Kruskal-Wallis	Success variable can be interpreted as continuous, distribution of the success variable is unknown and project variable is discrete.
VIII	Kruskal-Wallis	Success variable can be interpreted as continuous, distribution of the success variable is unknown and project variable is discrete.

Table 6-11. Choice of Statistical Tests

6.4.3 Measurement setup

Interviews

The approach we have chosen to collect the required information is by means of interviews with the project manager. For the measurement setup, the following steps were carried out:

1. Select the projects that are eligible to be included in the study. (See Table 6-8). Identify for each project the project manager, which was responsible for the project.
2. Create a questionnaire for the interviews, containing questions on the success and project variables (see for the questionnaire page 148).
3. Then, for each project, plan and conduct interview with the project manager.

Reliability of the Information

One of our major points of attention is the reliability of the information that is collected using the interviews. From a Six Sigma perspective, special attention is given to the repeatability and the reproducibility of the information (Pyzdek, 2003). The purpose of these reliability measures is to ensure that the information from the project is reproduced faithfully and correctly within the questionnaire answers. To minimize ambiguities in the answering of the questions, we took the following measures:

1. Carefully formulating the questions and answers, to make them as unambiguous as possible. We set up a initial test questionnaire, used this questionnaire several times, and then defined the final questionnaire based on the experiences of the test interviews.
2. Setting up guidelines how to interpret the questions, especially in situations where the answers were not clear-cut and using these experiences.
3. Analyze the answers for strange patterns or outliers, which could indicate misinterpretations or ambiguous questions. Use these experiences to revise the instructions for the interviewers or/and to adapt the formulation of the question and answers
4. Working with a selected group of interviewers, who were all trained in interpreting the answers to questions as univocally as possible and we organized discussions about the interpretation of questions.
5. Validate the answers of the interviewees where possible by independent means. Some answers could be validated by information from financial systems, others by crosschecking it with other people who work on the same project.

This procedure delivered 49 filled-in questionnaires.

6.5 Project Study Approach

6.5.1 Analyze Setup

The objective of the analyze phase is to analyze the measured information for correlations between project and success variables. To analyze the measured information for correlations, we have to execute the following steps:

Step 1. Analyze and clean the raw data for outliers and inconsistencies. Transform the information to achieve a normal distribution. Select the statistical tests that can be used for the analysis.

Step 2. Null-hypothesis testing. Each of the H_0 statements is either validated or rejected.

Step 3. Findings, interpretation of the findings and conclusions

6.5.2 Analysis Step 1. Raw Data Analysis and Transformation

Raw data from the interviews and from the information systems may contain errors or anomalies introduced by the measurement system or from other error sources. The objective of the raw data analysis step is to prevent that these errors and anomalies disturb the correlation analyses later on, because – of course – this will lead to erroneous conclusions. Therefore, the first activity in the analysis phase is the cleaning of the raw data.

Several analysis methods (ANOVA, Bartlett) require the data to have a normal distribution. As is mentioned in Table 6-7, tests that use normal distributed data are more powerful than nonparametric tests and are therefore preferable. Therefore, part of this step is to analyze whether non-normal distributed data can be transformed to normal distribution. See the appendix (page 148) for a detailed description of this step.

6.5.3 Analysis step 2. Null-hypothesis Testing

In the second step, the null-hypothesis statements are tested for significance with each of the project variables. See the appendix (page 158) for a detailed description of this step.

6.5.4 Analysis Step 3. Findings, Interpretation and Conclusions

Findings, interpretation of the findings and conclusions of the Project Study are discussed in the next chapter.

7.

Results of the Solution Architecture Case Study

This chapter discusses the results of the null-hypothesis (H_0) tests. Each of the project variables is tested against every H_0 statement. This provides understanding of the correlations between the project and success variables. Of the 80 possible correlations, 19 proved to be significant. For each of the identified correlations, the size of the effect, an interpretation of the underlying mechanism for the correlation and the consequences of the correlation are given. In addition, the limitations of the analysis are discussed, together with a comparison of findings by other researchers. The chapter ends with overall conclusions.

7.1 Significant Correlations

Table 7-1 shows a summary of null hypothesis testing results. In the previous chapter, ten architecture-related project variables were identified and eight H_0 statements were defined. Each of the project variables is tested against every statement; this gives 80 possible correlations. Of these 80 correlations, 19 correlations proved to be significant. The table below shows the corresponding p-values of the significant correlations. A correlation is significant if the statistical test delivers a probability value (p-value) that is equal or smaller than the chosen significance level of 5%. For the significant correlations, the H_0 statement is rejected, which means that the outcome of the statistical test indicates that the project variable and the success variable are correlated.

Project Variables		H_0 Statement I	II	III	IV	V	VI	VII	VIII
		EV Project Budget	Var. Project Budget	EV Project Time	Var. Project Time	Customer Satisfac-tion	Percentage Delivered	Functional Fit	Technical Fit
1	Technical Calculation	-	0.2%	-	-	-	-	-	-
2	Certification Architect	-	-	-	-	-	-	-	-
3	Certification w.r.t. Project	-	-	-	-	0.0%	-	-	-
4	Specific Experience Architect	-	-	-	-	5.0%	1.5%	-	-
5	Project Architecture	-	2.4%	0.2%	-	0.8%	0.2%	-	0.3%
6	Domain Architecture	-	-	3.6%	-	1.9%	0.6%	-	-
7	Enterprise Architecture	-	-	1.8%	3.5%	0.1%	2.6%	-	-
8	Architecture Governance	0.3%	-	-	-	-	1.8%	-	-
9	Controlling Architect	-	-	-	-	-	-	-	-
10	Architecture Compliancy	-	-	1.0%	-	-	-	-	-

Table 7-1. Overview of p-values of the significant correlations

The table shows the resulting p-values for testing a project variable against the H_0 statements. For those correlations that are found to be significant, the resulting p-values of the H_0 tests are shown in the table. For example, project variable 7 (Quality of the Enterprise Architecture) correlates significantly with the H_0 statements III, IV, V and VI, with a p-value of respectively 1.8%, 3.5%, 0.1% and 2.6%. Because of these correlations, the H_0 statement is rejected. A dash means that the relationship between the project variable and the H_0 statement is not significant (e.g. the p-value from the test is larger than the significant level of 5%) and, consequently, the H_0 statement cannot be rejected.

We find that most of the H_0 statements are correlated to project variables. In the following paragraphs we will discuss the correlations that are identified and the real also discuss some correlations which might be expected but are not found in our survey. Especially, we will have a look at project variable 2 and H_0 statement VII, because for this variable and statement we did not find correlations.

7.2 Description method

In the following paragraphs, the significant correlations are interpreted and explained. The following structure will be used to describe the finding and the interpretation.

1. *Statement* – The formulation of the H_0 statement
2. *Findings* – The actual findings of the analysis
3. *Conclusion* – Conclusions that can be drawn from the findings
4. *Significance* – Significance level. This level is equal or below the significant threshold of 5%
5. *Interpretation* – Interpretation of the findings and the conclusion, which may provide additional reasoning or foundations for the conclusion
6. *Consequences* – The size of the effect is explained, in terms of the effect on the success variable.

7.3 Overview of the results

7.3.1 H_0 statement I – Expected value of Budget Overrun

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the expected value of the actual project budget (as percentage of the planned budget).*
Finding	Project variable 8 (*Quality of the customer's architecture governance process*) tests significant. The other variables are non-significant. H_0 statement I is rejected.
Conclusion	The presence of an architecture governance process (either fully functional or limited in scope and responsibilities) is significantly correlated with a lower expected value of budget overrun, compared to a situation where there is no architecture governance process in the customer's organization present. The difference in expected value is 19% (3% versus 22%).
Significance	P = 0.3%
Interpretation	The presence of an architecture governance process implies that the organization is working with architecture and, therefore, is using project architectures and higher-level architectures. The reverse situation is not necessarily the case; an organization may be defining project architectures without having an architecture governance process. This finding shows that the presence of an architectural governance process has its own additional value.
Consequences	The average project size is € 700.000. A decrease in the overrun with 19% will save on average € 130K per project, or about € 6M for the 49 projects that we have examined. If we set the upper limit for budget overrun on 20% (i.e., any project with 20% or more overrun is defective) then the Six Sigma process capability (see § 6.3.2) of the custom software development process is 1.6 if projects

	are run without architecture governance and 2.7 for projects with governance.

Table 7-2. Results for expected value of Budget Overrun

7.3.2 H_0 Statement II – Variance of Budget Overrun

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the variance of the actual project budget (as percentage of the planned budget).*
Finding	Project variable 1 (*Presence of architect during calculation of the technical price*) and project variable 5 (*Quality of the project architecture*) tests significant. The other variables are non-significant. H_0 statement II is rejected.
Conclusion	The presence of an architect during the calculation of the technical price is significantly correlated with a lower variance of the actual project budget, compared to a situation when there is no architect present during technical price calculation. The difference in the standard deviation is 21 (13 versus 34). The presence of a high-quality project architecture is significantly correlated with a lower variance of the actual project budget, compared to a situation when there is only a medium or poor quality or no project architecture present. The difference in the standard deviation is 18 (13 versus 31).
Significance	P = 0.8% (variable 1). P = 2.4% (variable 5)
Interpretation	Presence of an architect during the calculation of the planned cost and the quality of the project architecture is correlated with an increase of the reliability of the cost planning significantly. Reduction of variance is a major goal of the Six Sigma methodology (Pyzdek, 2003). When process variance is reduced, then the process becomes more predictable and overrun decreases. A major problem for custom software development process is the lack of predictability of the actual cost. Both project variables *Presence of an architect during the calculation of the technical price* and *High-quality project architecture* are correlated with a significant improved reliability of the project budget planning.
Consequences	Piselo (2003) states that only 16% of custom software development projects deliver according to plan, or – in other words – the sigma level of software development projects is 0.5 (see Table 6-6). Reduction of the process variance improves the process quality. For instance, we can calculate from Figure 4-7 that only 13% of the projects of answer 1 have more than 20% overrun, versus 38% of answer 2. In Six Sigma terms, this improves the process quality one full level, from 1.8 to 2.8 for the success variable *Budget Overrun* (see § 6.2.3, page 74).

Table 7-3. Results for variance of Budget Overrun

7.3.3 H_0 statement III – Expected Value of Project Timeframe

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the expected value of the actual project timeframe (as percentage of the original timeframe).*
Finding	Project variables 5, 6, 7 and 10 (*Quality of the project architecture, Quality of the domain architecture, Quality of the enterprise architecture* and *Architecture*

	compliancy testing) test significant. The other variables are non-significant. H_0 statement II is rejected.
Conclusion	Application of Enterprise Architecture is correlated with a significant decrease in time overrun for projects. Four of the 10 project variables test significant, which makes the project timeframe one of the success variables that correlates with multiple aspects of the use of architecture. The presence of a high-quality project architecture correlates with a decrease in time overrun of the project, compared to a situation where there is a medium or poor quality project architecture present. The difference in overrun is 55% (71% overrun versus 16% overrun). The presence of a high-quality domain architecture correlates with a decrease in time overrun of the project, compared with situation where there is medium or poor quality domain architecture present. The difference in overrun is 44% (49% versus 5% overrun). The presence of a high-quality enterprise architecture correlates with a decrease in time overrun of the project, compared with situation where there is medium or poor quality enterprise architecture present. The difference in overrun is 46% (51% versus 5%). The presence of informal architecture compliance testing procedure correlates with a decrease in time overrun of the project, compared to the situation where there was no compliancy testing between architecture design and implementation. The difference in overrun is 56% (66% versus 10%).
Significance	P = 1.9% (variable 5) P = 3.6% (variable 6) P = 1.8% (variable 7) P = 1.0% (variable 10)
Interpretation	It is interesting to note that 4 of the 10 project variables correlate with the success variable. Probably, the same effect is measured multiple times, but from different angles. For instance, presence of enterprise architecture and the presence of the domain architecture denote probably the same type of architectural maturity of the customer's organization and both project variables may be an indication for a common underlying cause. Further indication of this is that variable 6 and variable 7 have almost the same expected values for time overrun. To understand this result more fully, it is necessary to analyze the interaction between project variables. However, the survey size is too limited to perform this type of analysis (see page 102). Consequently, we have to limit ourselves to the supposition that interaction between project variables plays a major role in this result, without being able to quantify this interaction. Overall, we can conclude that application of enterprise and architecture is correlated with a substantial decrease in project overrun.
Consequences	The average actual project timeframe for the projects that we have examined is one year – which includes on average 40% overrun. Consequently, application of architecture is correlated with a decrease of average project time of about four months.

Table 7-4. Results for expected value of Project Timeframe

7.3.4 H_0 statement IV – Variance of Project Timeframe

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the variance of the actual project timeframe (as percentage of the original time-frame).*
Finding	Project variable 8 (*Quality of the enterprise architecture*) tests significant. The other variables are non-significant. H_0 statement IV is rejected.
Conclusion	The presence of a high-quality enterprise architecture correlates significantly with a decrease of variance in the actual project timeframe, compared to a situation where there is medium or low quality enterprise architecture or no EA. The difference in the standard deviation is 108 (115 versus 7).
Significance	P = 3.5%
Interpretation	The interpretation of this result is not very clear, because the difference in the standard deviation is quite large and we did not identify a mechanism – linked to enterprise architecture – that could be responsible for this large effect. In addition, the question is why no correlation is found for domain and project architecture. The p-value for domain architecture is 11%, which could indicate a trend. However, the p-value for project architecture is 74%, which is nowhere significant. Furthermore, the sample size for answer 1 is rather small (only 8). Because of these interpretation difficulties, we suspect that this result may be spurious and further research may be needed.

Table 7-5. Results for variance of Project Timeframe

7.3.5 H_0 statement V – Customer Satisfaction

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the expected value of customer satisfaction.*
Finding	Project variables 3, 4, 5, 6 and 7 (*Match of certification level of the architect to the level of the project*, *Specific experience of the architect*, *Quality of the project architecture, Quality of the domain architecture* and *Quality of the enterprise architecture*) test significant. Project variables 2 and 8 (*Certification level of the architect* and *Quality of the customer's architecture governance process*) are close. H_0 statement V is rejected.
Conclusion	Application of Enterprise Architecture is correlated with a significant increase in customer satisfaction. Five of the ten project variables test significant, which makes customer satisfaction one of the success variables that correlates with multiple aspects of the use of architecture. Matching the level of the architect with the level of the requirement correlates significantly with an increase of customer satisfaction, compared to a situation where the certification level of the architect was under project level. The difference is an OTACE score of 4.1 versus 2.8 (on a scale of 1 to 5 – a score of 3.5 or higher is considered satisfactory). This project variable explains 51% of the total variance in the OTACE score. Broad experience of the architect with the type of engagement correlates significantly with an increase of customer satisfaction, compared to a situation

where the architect has only some experience with the type of engagement. The difference is an OTACE score of 4.0 versus 3.6. This project variable explains 8.5% of the variance in the OTACE score.

The presence of a high-quality project architecture correlates significantly with an increase of customer satisfaction, compared to a medium or low quality or no project architecture. The difference is an OTACE score of 4.1 versus 3.5. This project variable explains 16.8% of the total variance of the OTACE score.

The quality domain architecture correlates significantly with an increase of customer satisfaction. The OTACE score is 4.2, 3.8 and 3.4 for respectively a high-quality, medium quality or low quality domain architecture. This project variable explains 12.5% of the total variance of the OTACE score.

The quality of the enterprise architecture correlates significantly with an increase of customer satisfaction. The OTACE score is 4.4, 3.9 and 3.4 for respectively a high-quality, medium quality or low quality enterprise architecture. This project variable explains 24.3% of the total variance of the OTACE score.

Significance

P = 0.0% (variable 3)
P = 5.0% (variable 4)
P = 0.8% (variable 5)
P = 1.9% (variable 6)
P = 0.1% (variable 7)

Interpretation

Our supposition is that Customer satisfaction is the outcome of the comparison between the expectation of the customer and the actual results of the project. If the outcome of the project is only mediocre, but customer expectation is low, then the outcome of the project may still exceed customer expectation, and, therefore, customer satisfaction can be high. Customer satisfaction is the perceived discrepancy between expectation and realized results.

To understand the effect of perceived realized results to the customer, we analyzed the relationship between budget and time overrun with customer satisfaction. We find that budget overrun is not correlated with customer satisfaction

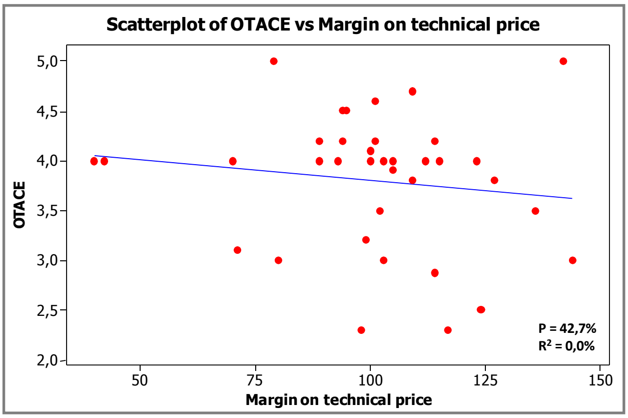


Figure 7-1. Customer satisfaction as function of budget overrun

A p-value of 42.7% does not indicate a correlation. This lack of correlation can be explained, when we realize that budget overrun is not necessarily a problem for the customer. In the case of a fixed-price construction, the IT service provider is fully responsible for the budget overrun. In this situation budget overrun may be causing an increase of customer satisfaction, because the customer receives the required functionality, while the overrun costs are paid by the provider. Budget overrun can be correlated with both high or with low customer satisfaction, and is therefore not related to the perceived value of the project for the customer. See below for similar analysis of time overrun and customer satisfaction.

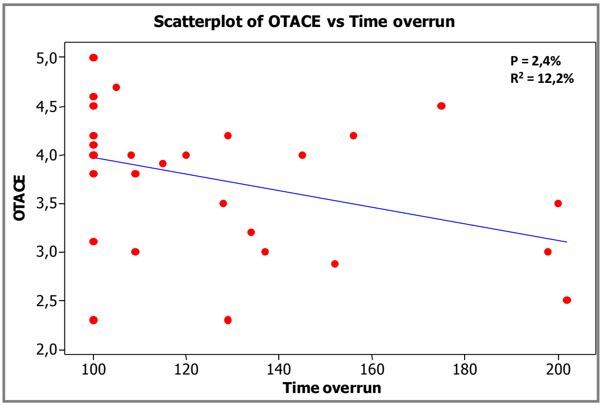


Figure 7-2. Customer satisfaction as function of time overrun

We find that this correlation is significant and is described in the following formula:

$$OTACE = 4.84 - 0.0086 * Time\ overrun \qquad (7\text{-}1)$$

Increasing time overrun decreases customer satisfaction. Contrary to budget overrun, time overrun is always directly experienced by the customer. When a project encounters obstacles that delays it, then the customer is forced to adapt business project schedules, adapt the resource planning, adapt interdependencies with other projects, etc.

A further indication that time overrun and customer satisfaction are correlated is also given by the correlations with the project variables 5, 6 and 7 (respectively quality of the project, domain and enterprise architectures) and customer satisfaction, because these three project variables also correlate with the expected value of the project timeframe (success variable 3).

The finding that time overrun and customer satisfaction are correlated, confirms the supposition at the beginning of this paragraph that customer satisfaction is related to the actual outcome of the project. Can we also find correlations that customer satisfaction is correlated to the expectation of the customer? Interes-

	tingly, project variable 3 (*Match of certification level of the architect to the level of the project)* does not correlate to budget or time overrun – but correlates with customer satisfaction. Our interpretation is that an architect, whose level is matched with the level of the project, manages the expectations of the customer in such a way that it improves customer satisfaction, while less experienced architects do not have this ability. Therefore, the correlation between customer satisfaction and both time overrun and certification level of the architect (project variable 3) supports our supposition. We can conclude that there are indications that customer satisfaction is influenced by the ability of the architect to manage expectations of the customer and by the time overrun of the project.
Consequences	Customer satisfaction is the result of the comparison of customer expectation and actual outcome of the project. The subjective elements of the customer satisfaction are co-determined by the experience of the architect. If the experience of the architect is too low compared to the level required by the project, then we find that this is correlated with the lower customer satisfaction. The difference is 0.4 point, on a scale from 1 to 5. The objective elements of customer satisfaction are co-represented by the time overrun. The effect is a 0.2 point decrease in customer satisfaction for every 20% overrun.

Table 7-6. Results for customer satisfaction

7.3.6 H_0 statement VI – Percentage Delivered

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the expected value of the percentage delivered.*
Finding	Project variables 4, 5, 6, 7 and 8 (*Specific experience of the architect*, *Quality of the project architecture, Quality of the domain architecture, Quality of the enterprise architecture* and *Quality of the customer's architecture governance process*) test significant. H_0 statement VI is rejected.
Conclusion	Application of Enterprise Architecture is correlated with a significant increase in percentage delivered. Five of the ten project variables test significant, which makes percentage delivered one of the success variables that correlates with multiple aspects of the use of architecture. Broad experience of the architect with the type of engagement correlates significantly with an increase of percentage delivered compared to a situation where the architect has only some experience with the type of engagement. The difference is 8% (92% versus 100%). This project variable explains 11.6 % of the variance in the percentage delivered. An increase in the quality of the project architecture correlates significantly with an increase of percentage delivered. The difference is between low quality and high-quality project architecture is 12%. Respectively 100% , 95% and 88% for high, medium and low quality project architectures. This project variable explains 16.9% of total variance of the percentage delivered. An increase in the quality of domain architecture correlates significantly with an increase of percentage delivered. The difference between low quality and high-quality domain architecture is 13% (92% versus 105%). This project

	variable explains 13.8% of the total variance of the percentage delivered. An increase in the quality of enterprise architecture correlates significantly with an increase of percentage delivered. The difference between low quality and high-quality enterprise architecture is 9% (49% versus 103%). This project variable explains 8.6% of the total variance of percentage delivered. Improved architecture governance correlates significantly with an increase of percentage delivered. The difference between no governance and formal governance is 10% (94% versus 104%). This project variable explains 10.2% of the total variance of percentage delivered.
Significance	P = 1.5% (variable 4) P = 0.2% (variable 5) P = 0.6% (variable 6) P = 2.6% (variable 7) P = 1.8% (variable 8)
Interpretation	Five of the ten project variables correlate with the success variable percentage delivered. It can well be that the same underlying_effect is measured multiple times, but from different angles. For instance, presence of enterprise architecture and the presence of the domain architecture may be linked by the architectural maturity of the customer's organization. To understand this result more fully, it is necessary to analyze the interaction between project variables (however, see page 102). We can conclude that application of enterprise and architecture is correlated with a substantial increase in percentage delivered.
Consequences	Analyzing the differences in percentage delivered for the five project variables, we can conclude that application of enterprise architecture is correlated with an increase of the percentage delivered of the project with approximately 10%.

Table 7-7. Results for Percentage Delivered

7.3.7 H_0 statement VII – Functional Fit

H_0 Statement	*Application of enterprise architecture is not significantly correlated with the expected value of the functional fit.*
Finding	None of the variables tests significant. H0 Statement VII is not rejected.
Conclusion	The functional fit delivered by projects, is not correlated with application of enterprise architecture.
Interpretation	This result can be explained by considering the mechanisms of IT project development. It is the business decides on the functionality of the project; i.e., business answers the *What* question. IT is responsible for building the solution; in other words, IT is responsible for the *How* question. It is therefore understandable that architecture is correlated with the quality of the transformation (as indicated by the other success variables), but not with delivered business functionality.

Table 7-8. Results for Functional Fit

7.3.8 H$_0$ statement VIII – Technical Fit

H$_0$ Statement	*Application of enterprise architecture is not significantly correlated with the expected value of the technical fit.*
Finding	Project variable 5 (*Quality of the project architecture*) tests significant. H$_0$ statement VIII is rejected.
Conclusion	An increase in the quality of the project architecture correlates significantly with an increase of technical fit.
Significance	P = 0.3%
Interpretation	This result is in line with the interpretation for statement VII. Architecture is correlated with the quality of the transformation, which includes the technical fit (performance, security, availability, etc.).

Table 7-9. Results for Technical Fit

7.3.9 Project variables without significant correlations

In our survey, there are two project variables (Variable 2: Certification of the Architect, Variable 9: Controlling Architect) for which no significant correlations were found. We will discuss this lack of results and try to find an explanation for it.

Project Variable 2. Certification of the Architect

Architect can be certified at four levels:

Level 1 – Architect
Level 2 – Senior Architect
Level 3 – Enterprise Architect
Level 4 – Global Architect

Architects are certified to provide visibility to the customer about the capability and experience level of the architect and to award the architect for his or her ability in the architecture craftsmanship. The reason for including this variable into the survey, was the assumption that more experienced architects provide a better architecture processes and deliverables, which – consequently – would provide better results for the projects. However, no such relation was found.

When investigating this lack of result, it was found that many experienced architects (who would be eligible for some higher architecture certification level) actually were not certified at their experience level. Because of this, the certification level of architect became meaningless in relation to project results, because the certification level is not clearly linked to the experience of the architect. Therefore, it is not surprising that we did not find correlation between Certification of the Architect and project success.

Project variable 9. Controlling Architect

With the term *Controlling Architect* a solution architect is meant which is present during the execution of the project and his or her as main role is to control whether the actual implementation of the project is executed according to the design described in the solution architecture. If discrepancies occur between the actual implementation and the design, then the role of the controlling architect is to signal this discrepancy. He will discuss this with the project manager and the enterprise architect. If there is no solution found at this level, then the discrepancy can be escalated to respectively the program manager, the steering committee or the business sponsor. As a solution, the discrepancy may permanently or temporarily be allowed or, when the decision is negative, the project manager may finally be required to change the actual implementation according to the solution architecture. When we included this project variable into the survey, our assumption was that the presence of a Controlling Architect would have measurable impact on project success.

This variable is closely related to project variable 8 and 10 (*Architecture Governance Process* and *Architecture Compliancy*). Variable 8 asks whether an escalation process is in place and variable 10 asks whether there is an architecture compliancy process in place. Variable 8 and 10 are significant for three H_0 statements. Variable 8 is correlated with a decrease in *Project Overrun* and an increase in *Percentage Delivered*, while Variable 10 is correlated with a decrease in project time overrun. So why do we not find a similar correlation with project variable 9?

There are multiple implementation solutions available for implementing the architecture governance and compliance processes. Using a controlling architect is one of the possible implementation choices. When investigating this issue, it was found that various organisations had different implementation mechanisms in place for implementing architecture governance and compliance processes. Sometimes, the concept of a Controlling Architect is used, but also in many situations other solutions are used.

As a consequence, the project variable became meaningless because the presence of a controlling architect as such was not a determining factor for the success of the project.

7.4 Limitations of the Analysis

7.4.1 The role of Second-Order Effects

Table 7-1 demonstrates that multiple project variables may correlate with the same success variable. For example, H_0 statement III (Expected value of project time-frame) is correlated with the project variables 5, 6, 7 and 10 (*Quality of the project architecture*, *Quality of the domain architecture*, *Quality of the enterprise architecture* and *Architecture compliancy testing*). These variables are correlated with respectively 55%, 44%, 46% and 56% lower time overrun. Can we conclude from these figures that the project variable *Quality of the project architecture* (project variable 5) on its own is responsible for 55% decrease in time overrun? The answer is no, because there are multiple variables or combinations of variables responsible for the decrease in time overrun. See the example below.

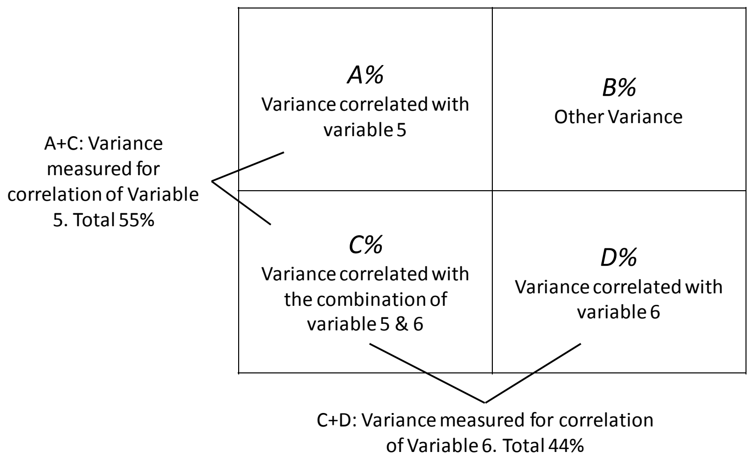


Figure 7-3. Analysis of Variance for Project Timeframe using Two Project Variables

Figure 7-3 shows a breakdown of the variance for the success variable *Project Time-frame* for the project variables 5 and 6. The total variance is split out into four components: variance that can be explained by the combination of variable 5 and 6, variance that can be explained by variable 5, variance that can be explained by variable 6 and remaining variance that cannot be explained by either 5 or 6. From our measurements, we know that A and C together is equal to 55% and that C and D together is equal to 44%. However, we are not able to determine the variance that results from the interaction between the two variables, which is represented by the value of C. In other words, we can determine the total variance for variable 5 or the total variance for variable 6, but we cannot determine the combined effect of both variables, because this is equal to the measured variance of variable 5 (55%) plus the measured variance for variable 6 (44%) minus the combined effect (C%) which is unknown. In reality, we are not dealing with two variables, but with multiple variables, and the number of second-order interactions between n variables increases quadratic with increasing n. (The number of second-order interactions between n variables is equal to $n(n-1)/2$.) On top of this, there are third-order interactions, fourth-order interactions, etc.

7.4.2 Measuring Second-Order Effects

In the paragraph *Minimum Sample Size* (page 81) is shown that the average sample size is approximately 16 projects. When testing simultaneously two project variables with a H_0 statement, then the average sample size becomes 49 / 3^2 = 5.4 projects. However, the minimum sample size is 6 projects (see page 82), which means that the average sample size is less than the minimum sample size. In addition, variance in sample sizes means that some samples will be very small. For instance, a breakdown of the results of project variable 5 (Compliancy Testing) and project variable 10 (Project Architecture) gives the following results:

		5. Compliancy Testing Answer			**Total**
		1	**2**	**3**	
10. Project Architecture Answer	**1**	3	13	8	**24**
	2	1	3	11	**15**
	3	0	0	6	**6**
Total		**4**	**16**	**25**	**45**

Table 7-10. Sample sizes breakdown for project variables 5 and 10[*]

Since five of the nine samples in this analysis are smaller than the minimum sample size, the results are unreliable. The size of the survey does not allow a test of two (or more) project variables simultaneously. The conclusion is that we are not able to measure second order (or higher order) effects. To test a H_0 statement simulta-

[*] *Four of the 49 project did not answer this question, therefore the number of projects in this analysis is 45.*

neously for two project variables – with the same average sample size of 15 – we need a survey size of 135 projects.

7.4.3 Consequences of this Limitation

The consequence of only being able to measure first-order effects is that we have to be careful when interpreting results. When drawing conclusions for a project variable, then we have to take into account that we are measuring not only a single variable, but we are measuring the effect of this variable combined with the interaction of this variable with other variables.

As a result, we cannot exactly determine which project variables are correlated with an effect. In the example of the previous paragraph, we cannot say that variable 5 is responsible for 55% decrease of time overrun. We can only say that variable 5, *in combination with the variables it interacts with*, delivers a combined effect of 55%. However, we do not know the variables it interacts with and we do not know the size of this interaction.

In addition, we are not allowed to combine the results or draw conclusions from the combination of project variables. For example, in the above example we cannot say that a combination of project variable 5 and variable 6, delivers a specific result, or that variable 5 without variable 6 will deliver a different result. The project variables that we have measured are not independent from each other and influence each other in ways we are not able to determine.

However, we must also realize that measuring (only) the first-order effects does not imply that these results are not reliable or not real. The results are real and can be trusted; the limitation of the measurement is that we are not able to determine the exact, individual correlation of project variables with a success variable. We need to keep this limitation in mind when discussing the results.

7.5 Results Summary

7.5.1 Main Results

Table 7-11 below gives an overview of the main results. Use of solution architecture is correlated with the following effects:

	Statement	Paragraph
(a)	19% decrease in project budget overrun	7.3.1
(b)	Increased predictability of project budget planning, which decreases the percentage of projects with large budget overruns from 38% to 13%	7.3.2
(c)	40% decrease in project time overrun	7.3.3
(d)	Increased customer satisfaction, with 0.5 to 1 point – on a scale of 1 to 5	7.3.5
(e)	10% increase of results delivered	7.3.6
(f)	Increased technical fit of the project results	7.3.8

Table 7-11. Overview of Main Results

These results demonstrate that using solution architecture is correlated with substantial, positive effects on project success variables. For instance, result (b) means that the percentage of projects with large overrun is decreased by 25%. This difference is substantial and this scale of improvement justifies the application of development of projects under architecture. The average project size in the survey is € 700.000. Result (b) indicates that the use of solution architecture is correlated with a saving of approximately € 140.000 for one out of four projects. On an average project portfolio, this will save annually millions of Euros. Comparable considerations can be identified for the other main results.

Of course, there is a cost associated with building up and maintaining the architecture processes and capability. These costs need to be balanced with the savings. Still, cost is only one of the aspects when taking the choice to implement an architecture function. There are other factors that are also positively influenced by architecture, which are not directly related to financial cost considerations, but are also important for the success of IT within an organization, such as increased customer satisfaction and decreased project time overrun.

7.5.2 Survey Conclusion

We can state that – for the projects part of our survey – solution architecture has a positive influence on project results. It is interesting to note that all the significant correlations between project and success variables are positive; e.g., use of solution architecture is correlated with decrease in project budget overrun, increase in planning reliability, decrease in project time overrun, etc. A 'better' value of an architecture-related project variable correlates with a 'better' outcome of the success variable, *for all identified significant correlations*. We did not identify positive-negative correlations, where a 'better' value of an architecture-related project variable is correlated with a 'worse' value of a success variable.

This positive-positive trend gives an intuitive confirmation that the use of architecture is beneficial for projects; use of architecture does not counteract project objectives.

7.6 Relation to Other Research

7.6.1 Effect of Project Variables on Project Success

The finding that project variables can have correlations with multiple H_0 statements is interesting. When tallying the number of H_0 statements that correlate significant with a project variable we find:

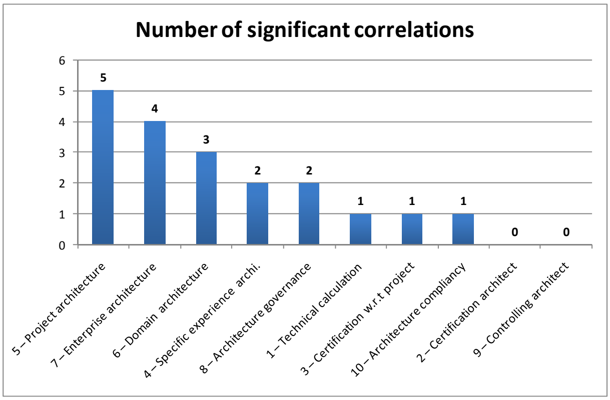


Figure 7-4. Number of significant H_0 statement correlations for each project variable

Project variable 5 (*Quality of the project architecture*) has the highest score and correlates with the H_0 statements II, III, V, VI and VIII (*Reliability of project budget planning, Project time overrun, Customer satisfaction, Percentage delivered* and T*echnical fit of the project results*).

The fact that one project variable is correlated with five different success variables, implies that this project variable must describe some essential key-element of project success.

7.6.2 Comparison to Standish CHAOS Reports

Top Ten Success Factors

The Standish group (1999; 2001) has published top 10 of project success factors. The 2001 version of the report mentions the following main success factors:

	Factor
1.	Executive support
2.	User involvement
3.	Experienced project manager
4.	Clear business objectives
5.	Minimized scope
6.	Standard software infrastructure
7.	Firm basic requirements
8.	Formal methodology
9.	Reliable estimates
10.	Other (Small milestones; Proper planning; Competent staff; Ownership)

Table 7-12. Overview project success factors (Standish report 2001)

Contrary to our findings, this list does not contain any design or architecture factor. An explanation for this is that at the time of this research (1995-2000), enterprise architecture was not widely used or known. The value of enterprise architecture was not a topic for IT executives, project managers or project staff and was obviously not identified by the Standish researchers. We feel that architecture should be on this list, because our research shows that architecture is a major project success factor.

Other researchers do value the constructive role of enterprise architecture. For example, the US National Research Council states in a review on FBI's Trilogy Information Technology Modernization Program that "if the FBI's IT modernization program is to succeed, the FBI's top leadership [...] must make the creation and communication of a complete enterprise architecture a top priority." (McGroddy, et al., 2004 p. 49). This statement acknowledges the value of enterprise architecture for system development initiatives and is in line with our conclusions.

Project Size

One of the other conclusions from the original Standish Chaos report (1999) is that the success rate and the size of the project are linked. The lower the project cost, the higher the success rate. They provide the following figures:

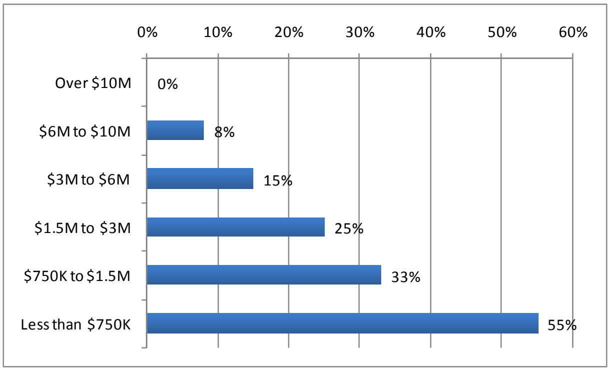


Figure 7-5. Project success rates (Standish Chaos Report, 1999).

If we correlate in our research the size of the project with the budget overrun, we find the following result:

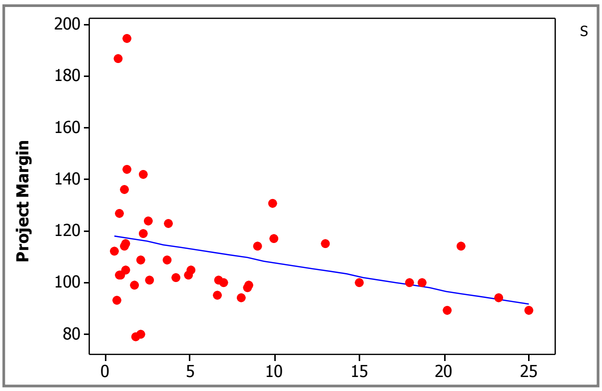


Figure 7-6. Correlation between project cost and margin

The vertical axis describes the percentagewise budget overrun or underrun. The horizontal axis describes the total cost of the IT project (x 10^5) in Euro's. Key figures of this correlation are:

Figure	Value
p	0.035
r^2	8.4%
Correlation formula	*Project Margin* = 118.6 – $1.1.10^{-5}$ * *Project Cost*

Table 7-13. Key figures for the linear correlation between project cost and margin

The correlation that we find between project cost and project margin is that projects become *more* successful with increasing projects size. This is a contradiction to the findings of the Standish report, because they find their projects become *less* successful with increasing project size. The figures are not exactly comparable, because Standish defines project success as a combination of on time, on budget and with sufficient functionality. Our correlation only considers cost overrun. Still, the trend is clearly contradictory.

In discussion with project and risk managers about the reason for our finding, the following explanations are given:

1. For small projects the initial planning effort in determining the project cost, is much smaller than for large projects. As a consequence, the project cost estimations for small projects are less reliable and the complexity of the project may be underestimated.
2. For small projects, it is very difficult to overcome a project setback within the existing budget. If a small two-month project has a setback which delays the project for one month, than the budget overrun in absolute terms may be small, but percentagewise the overrun is 50%. For large projects, this type of small setbacks can be absorbed within the existing project budget and the risk margins.
3. For large projects you have the time to rethink (part of) the solution and learn from lessons earlier in the project. For small projects, if you are halfway through the project and then find out that the original solution needs adjustment, there is no time or budget to redesign.

These arguments provide an explanation for finding that increasing project size correlates with higher project success.

Conclusion

If we try to explain the discrepancy between our results and the findings from the Standish report with our results, then we must realize that our survey projects is limited to a project size of € 2.5M, while the Standish report examines projects up to and over $ 10M. This may explain the difference. The arguments above describe the reasons why small projects (< € 1M) have high overruns; the arguments are not relevant for projects above € 2.5M. It is possible that the decreasing trend that we have identified will revert to an increasing trend for larger projects.

7.7 Applicability of the Results

The study that we conducted was carried out in a rather uniform context; the context of a commercial IT service provider. Are the conclusions from the current context also applicable in other contexts? To answer this question, we will look at some characteristics of the study and of results and see how this would fit in other contexts.

In § 5.5.3 (page 52) the probability density function for budget overrun for a Dutch financial institution is calculated (See Figure 5-5). We found that the cost overrun follows a lognormal distribution. On page 148 the probability density function for the budget overrun for the IT service provider is calculated. In this case, we found also a lognormal distribution but the parameters of the lognormal distribution differ substantially.

Parameter	Financial Institution	IT service provider
Threshold	15.3	64.9
Location	4.8	3.74
Scale	0.57	0.44
Mode	103	100
Mean	158	111
Median	137	107

Table 7-14. Comparison parameters lognormal distribution for budget overrun

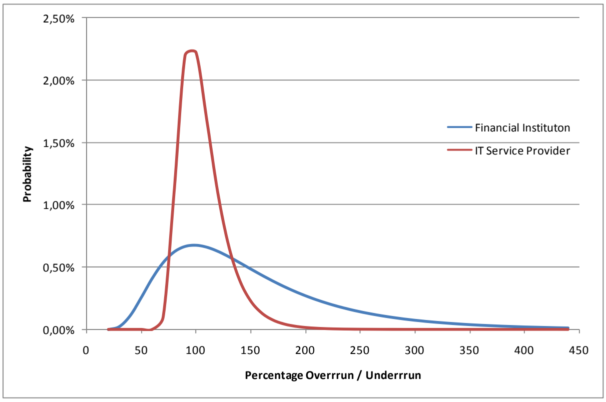


Figure 7-7. Comparison of normal distribution budget overrun

As can be seen in Table 7-14 and Figure 7-7, there are substantial differences in project budget overrun. The modes (most often occurring values) are virtually the same (100 versus 103), but the average budget overrun is in the situation of the Financial Institution considerable higher than for the IT service provider (58% versus 11%).

The conclusion from this comparison is that there are significant differences between various organizations, with regard to the variance in project budget outcomes and the resulting average budget overrun. Based upon this difference, it seems plausible that the figures we found for the architecture benefits (see Table 7-11) will be different too.

8.

Architecture and Business Performance

In the previous chapters, we discussed the value of architecture from a case study perspective. The necessary activities and conditions for the maximization of the value of enterprise architecture from an organizational perspective where only mentioned briefly. The purpose of this chapter is to define the relationship between the value of architecture as we have defined in our case studies, to the value of architecture for a corporation from an organizational perspective. We will discuss the necessary conditions that need to be filled in for architecture to be effective and valuable within the context of the organization.

8.1 Objectives of Enterprise Architecture

The purpose of the enterprise architecture discipline is to improve the organizational performance by aligning organizational structure, business processes, information success, IT assets and infrastructure to the core goals and strategic direction of the organization. Architecture is used at strategic level for planning purposes, at tactical level to improve the quality of transformation at an operational level to improve operational characteristics.

In the previous chapters, we discussed the value of enterprise architecture at the strategic and tactical levels. At strategic level, we defined a valuation method to quantify the value of enterprise architecture in business terms. This valuation method was illustrated using a case study. In the study, the value of the architecture-based business transformation was calculated. At tactical level, the value of solution architecture for IT projects was demonstrated. It was shown that several key project success variables benefit from development under architecture.

8.2 Enterprise Architecture from Organizational Perspective

Considering the role and purpose of enterprise architecture, we stated in Chapter 2: "Enterprise architecture is a managerial instrument intended to improve the efficiency, effectiveness of business transformation initiatives." (Definition 2-2, page 10). Based upon the findings and conclusions of the previous chapters about the value of architecture, can we say that enterprise architecture indeed improves efficiency, effectiveness and agility of the organization? For business and IT architecture to be effective, several conditions need to be filled in. In this chapter, we will investigate what these conditions are. We will identify the main factors that allow architecture to be effective within an organizational context.

8.3 Maturity of the Enterprise Architecture

8.3.1 Foundation for Business Execution

One of the tasks of senior management is to manage the coherence and cohesion between all the various initiatives that are going on within the organization. The objective is that various initiatives strengthen and reinforce each other, so that the organization of the business and IT processes and systems develop to a higher level of maturity. The management of an organization needs to consider the cohesion between the various programs, to bring the organization as a whole – across the company – at a higher maturity level.

The purpose of the enterprise architecture discipline is, according to Ross, Weill and Roberson (2006), to create "a foundation for business execution". They define this foundation as "the digitized business processes and the IT infrastructure that automate the company's core capabilities." They state: "As with human development, a company's foundation for execution evolves – usually beginning with a few basic infrastructural services (e.g., employee hiring and recruiting, purchasing, desktop support, and telecommunications), then encompassing basic transaction processes (sales, accounts payable), and eventually including unique and distinguishing business capabilities. Building a foundation doesn't focus only on competitive distinctive capabilities – it also requires rationalizing and digitizing the mundane, everyday processes that the company has to get right to stay in business." (p. 4).

Ross et al. state that building this foundation for execution makes the company more flexible and better able to react on external influences. "Paradoxically, digitizing core business processes makes the individual processes less flexible while making a company more agile. To return to the human analogy, great athletes will have muscles, reflexes, and skills that are not easily changed. But these capabilities give athletes a tremendous ability to react, improvise, and innovate in their chosen sport. Similarly, digitizing business processes requires making clear decisions about what capabilities are needed to succeed. And once these new processes are installed, they free up management attention from fighting fires on lower-value activities, giving them more time to focus on how to increase profits and growth. Digitized processes also provide better information on customers and product sales, providing ideas for new products and services. The foundation for execution provides a platform for innovation."(p. 5)

In short, they argue that the discipline of enterprise architecture should lead to company-wide foundation for business execution. They argue that this foundation improves the quality of basic business processes and procedures and which has the effect that basic, day-to-day tasks require less management attention. When an organization has this foundation for execution in place, then it becomes more flexible and innovative, because the basics are in place and management can focus on improving value.

8.3.2 Enterprise Architecture Maturity Stages

A foundation for execution is not built overnight. It requires long-term planning to align short-term initiatives to this strategic goal. Ross et al. describe several stages in which a foundation for execution is realized. Their research shows that organizations that have built a foundation for execution have experienced comparable development stages. They describe the following four enterprise architecture maturity stages:

Stage	Name	Description	Characteristic	Main challenge
1	**Business Silos**	Delivering solutions for local business problems and opportunities	Automate specific business processes, justified on the basis of cost reductions	Manage complexity of disparate systems
2	**Standardized Technology**	Uniform technology standards are used throughout the company	Limited number of applications and platforms, justified on the basis of our traditions and risk control	Manage complexity of disparate business processes
3	**Optimized Core**	Enterprise-wide view on applications and data	Standardized core business processes and IT applications. Shared use of enterprise data.	Central control over distributed business processes.
4	**Business Modularity**	Strategic business agility through customized or reusable modules.	Seamless linkage between business processes. Individual processes are built on the optimized core, communicate through standardized interfaces with other processes and extend them with their own functionality.	Balance central core functionality with accessibility of individual modules.

Table 8-1. Stages of enterprise architecture maturity according to Ross et al.

With his knowledge, we are able to extend Definition 2-2 and reformulate it as follows:

Definition 8-1. Function of Enterprise Architecture (extended)
Enterprise architecture is a managerial instrument, intended to improve the efficiency, effectiveness of business transformation initiatives. The long-term goal of enterprise architecture is to improve the architecture maturity of the organization to achieve Strategic Business Agility.

Thus, from a business transformation perspective, the role of enterprise architecture is to ensure that a current business transformation initiative is successful. From an organizational perspective, enterprise architecture has an additional responsibility that the current initiative contributes to the long-term goal of building a foundation for execution.

8.4 Enterprise Architecture Effectiveness

Enterprise architects will need to discuss with the organisation's CIO the long-term goal of creating a foundation for execution and incorporate this goal in the business and IT strategy. The research in our thesis shows that solution architecture has a positive effect on transformation projects. This finding reinforces the message of Ross et al. by demonstrating that architecture contributes to the efficiency and effectiveness of an organisation. In their book, they describe the business benefits for organisations that achieve higher enterprise architecture maturity levels.

They state: "Companies with a foundation for execution [...] report 17% greater strategic effectiveness than other companies – a metric positively correlated with profitability. These companies also report higher operational efficiency (31%), customer intimacy (33%), product leadership (34%), and strategic agility (29%) than companies that had not developed the foundation for execution." (p. 26). Furthermore, they report that (p. 94 ff):

- The IT budget of Stage 2 and Stage 3 organisations are on average respectively 15% and 25% lower than Stage 1 organisations
- Improved IT responsiveness, because of faster development times
- Improved risk management, which consists of
  - Less business risk
  - Less security breaches
  - Higher disaster tolerance
- Improved managerial satisfaction, for senior management and business unit management

- Improved strategic business impacts, because of improved
  - Operational excellence
  - Customer intimacy
  - Product leadership
  - Strategic agility

The effects described by Ross et. al. and the positive effects they report are in line with the type of effects that we have measured.

8.5 A Vision on the Future of IT

A major difference between Information Technology and other technologies is the very intimate interaction between businesses and IT. IT changes in day-to-day operation of many organisations, it allows business models, which were unthinkable just 10 years ago and holds the promise to automate and digitise mundane business processes. There is no indication that this automation of the business world is going to stop somewhere in the near future. On the contrary, there are indications that computers step out of their traditional environments and are going to conquer other domains by means of robotics, cybernetics, etc. Unmanned subway carriages are becoming mainstream, many companies experiment with driverless cars and the Japanese are working on household robots. Many of these science-fiction fantasies from the 1950s finally promise to become real, just because of the developments in raw computing power and material sciences. Moore's law is still holding and the question is how to reap full benefits of these developments.

Building up an effective IT landscape and a 'foundation for execution', linking IT usage effectively to standardised business processes and creating an agile company is not a trivial process. Just like many mediaeval towns made a mess of their city planning and constructed all kinds of buildings seemingly random across their territory – nowadays many organisations extend their application landscape seemingly at random without an overall plan. Organisation can implement or build isolated application silos that create short-term advantages, but way of development creates long-term chaos and inflexibility, which hampers the development of the organisation.

Many organisations are working with 20 or 30-year-old legacy systems that create risks and liabilities, because the platform cannot be supported anymore. This gives the organisation an opportunity to start building a foundation for execution, while replacing the legacy systems. The knowledge of the benefits, role and function of enterprise architecture has increased considerably over the last years. We have a much better understanding of the impact of building individual systems on the total application architecture of an organisation and the long-term effects on flexibility and agility, compared to twenty years ago. Organisations cannot afford anymore to linger in the 'Business Silos' stage of Ross et al. Enterprise architecture has become a 'mainstream' activity, supporting management to improve the quality and the efficiency of the organisation and, as this and other research demonstrates, it is a meaningful addition to the traditional management disciplines.

9. Conclusions and Summary

This chapter reconsiders the key research questions which were stated in Chapter 1 and considers the results and conclusions that can be drawn from the research described in this thesis and provides an overall summary.

9.1 Research Questions

In chapter 1, the following key research questions were stated:

1. *Can we define a suitable method for measuring and quantifying, in financial terms, the value of enterprise architecture-based business transformation?*
2. *Is the method usable in practice to determine the value of enterprise architecture-based business transformation?*
3. *Can we define a suitable method to measure and to quantify, in financial terms, the value of solution architecture?*
4. *Can we apply this method to determine the value of solution architecture?*
5. *How is the business value of IT related to the value of enterprise and solutions architecture?*

9.2 Research Questions 1 and 2

In Chapter 4 we presented an approach to adapt the standard Black-Scholes approach for Real Options Analysis, to incorporate two sources of uncertainty into the analysis. Chapter 5 demonstrates the applicability of Real Options Analysis for enterprise architecture, using a case example. Using Real Options Analysis, we analyzed the expected cash flow from this investment, considering potential benefits and potential costs. Real Options Analysis has the advantage of providing a much broader insight into the consequences of investing in business architecture compared to other analysis methods such as net present value and decision tree analysis. We find that the option value, which comes out of the real options analysis, provides higher value estimation than other analysis methods, because it incorporates the additional value that management has to steer and control the implementation of the architecture.

9.2.1 Real Options Analysis and Uncertainty

ROA is most useful when the Net Present Value of an architectural investment is neither very negative nor very positive and there is considerable uncertainty in the possible outcome. Management can use this uncertainty to steer the investment in the desired direction. More uncertainty means more value, because more uncertainty translates in more room to maneuver for management, and this translates in an increased value of the option. This argumentation assumes that the decision-makers will always take the value-maximizing decision at each point in the Enterprise Architecture investment lifecycle. To illustrate the value of high uncertainty, Kodukula and Padudesu (2006) provide the following graph:

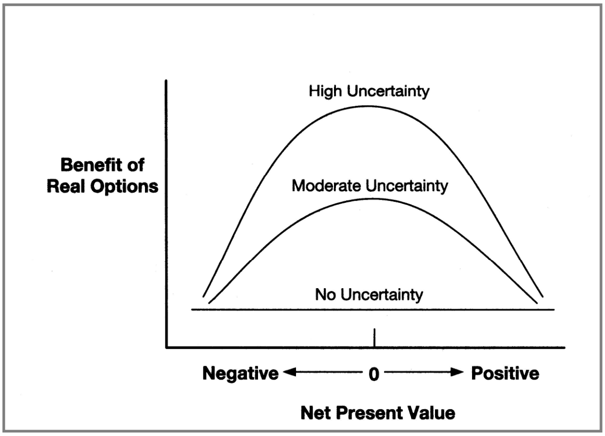


Figure 9-1. Benefits of real options analysis (Kodukula, et al., 2006).

The draft can be illustrated with the case that was discussed in the previous paragraphs. The standard scenario has a high, positive net present value of € 6.39M (see Table 5-10), with a small probability (2%) of negative outcome. As a result, the expected value and the option value are almost the same (see Table 5-14) and the benefit of calculating the option value is limited. In the case of the Contract Scenario, the Net Present Value of the scenario decreases and even turns negative when the Fixed-Price increases. Because of this, we find that the value of Real Options Analysis differs significant from the NPV, which exemplifies the additional space decision-makers have.

9.2.2 Valuing Infrastructural Investments

In the case example for the domain *Input Handling*, the architecture has strong infrastructural characteristics. The architecture lays the foundation for improving business process efficiency and improving business agility. Based on this foundation, business can add various services, with high added value. Architectural investments tend to have this infrastructural characteristic. According to Ross, Weill and Robertson: "[Architecture describes] a foundation for execution, [which] is the IT infrastructure and digitized business processes."(2006).

Furthermore, infrastructural investments are generally difficult to valuate. "Infrastructure investments are hard to value because their benefits are elusive, spread across the company, and contingent upon follow on investments. The real options approach can be used to take a broad look at the alignment of the investment and corporate strategy. For instance, a telecommunications firm that buys the right to use the auction of the radio frequency can realize its value only after building a radio network and offering various services. The decisions to build the network [...] and offer services would be contingent on the degree of success of the preceding stages in the attractiveness of the realized market for the services." (Amram, et al., 1999).

9.2.3 Valuing Subsequent Investments

In this chapter, we showed that real options analysis is a viable approach for measuring and assessing the added value of architecture in financial business terms. Real Options Analysis provides an approach to calculate the benefits and costs in terms of a Probability Density Function. The revenue and the cost PDFs can be combined to one cash flow PDF and this is the basis for the investment analysis, i.e. to optimize business value, minimize risk, optimize option value, etc. In this analysis, we did not include the factor of time. Implementation of enterprise architecture takes timeframes from three to maybe ten years. Net present value calculations calculate the value of an investment based on interest based cash flows over a number of years. To include this type of analysis in the approach that we have developed, see Appendix 1 (page 128). In this Appendix, we are using our approach to analyze the financial effects of business transformation programs over several years.

9.2.4 Conclusions

Real Options Analysis provides a suitable approach to valuate enterprise architecture based business transformation. This method provides clear advantages compared to other valuation methods. There are two main reasons for this.

First, architectural investments generally have an uncertainty about the value of future services. Because of this nature of architectural investments, it is often not clear beforehand how the investments will be applied for maximal usefulness. Future users of the architecture implementation may find novel ways to use it and to generate additional value from it. This uncertainty provides its own value, which is not recognized by other valuation methods.

Second, architectural investments tend to have an infrastructural character. Infrastructural investments are hard to value, because their benefits are spread across company and are contingent upon follow on investments.

We can conclude that real options analysis is a valid approach to quantify architecture-based business transformation.

Our case study illustrates that the fact that Real Options Analysis provides continuum of possible outcomes allows decision-makers be better informed and that ROA allows for inclusion of the value of future contingencies.

9.3 Research Questions 3 and 4

9.3.1 Statistical analyst approach

In chapter 6 a statistical approach is described which allows this to measure the value of solution architecture for IT software development projects. In the case study, 49 projects are surveyed and the subsequent analysis showed clear positive results, which are described in Chapter 7 (see Table 7-11, page 105). The question is whether the type of effects and the direction of the effects that we have measured (architecture lowers budget overrun, lowers time overrun, increases the percentage delivered, etc.) are valid in the general situation. Based on this one study, we cannot provide definitive statements on this, also because of the conclusions of § 7.7 (page 110), where we found that there are significant differences in project budget overrun between various organizations. Nevertheless, one of the major findings of the analysis of § 7.5 is that

> *"A 'better' value of a project variable correlates with a 'better' outcome of the success variable,* for all identified significant correlations*.* *[...] This positive-positive trend gives an intuitive confirmation that the use of architecture is beneficial for projects; use of architecture does not counteract project objectives."* (Page 106.)

None of the identified correlations between architecture project variables and success variables counteracts project success; all correlations are in the same positive direction. We did not detect indications that architecture may have a negative effect on project results and conclude that the application of enterprise architecture at tactical level is beneficial for IT software development projects.

9.3.2 Conclusions

If we consider again the statement of §6.2 (page 74):

> *IT software development projects are more successful when they are developed under architecture.*

We find that the characteristics for project success may differ substantially, for different organizations. Because of the size of our survey and the fact that the survey is limited to one organization, we cannot make a statement on the role of project architecture in general. On the other hand, the correlations that we identified in the survey were all positive. In the general case, we can conclude that we found convincing indications that the use of solution architecture is correlated with a substantial improvement of several key success variables, but that further research – with a broader survey base – may provide more definitive answers.

9.4 Research Question 5

9.4.1 IT effectiveness

In Chapter 3, we discussed the value of IT for organisations. The research of Strassman (1997) and others indicate that there is no direct correlation between organizational performance and IT spending. As a solution to this dilemma, Soh and Markus (1995) discussed the concept of “The IT Use Process” which distinguishes between appropriate or inappropriate use of the assets, and which gives the relation between IT Assets and Impacts (see Figure 3-1, page 15). They remark that “While necessary, quality IT assets are not sufficient for IT impacts to occur. As [...] many [...] have observed, impacts from IT require ‘appropriate’ IT use. [...] Most treatments of the topic have assumed variance theory formulations of the "greater IT use leads to greater IT impacts” form. A large body of research [...] suggests that the value of reconceptualizing IT use as a probabilistic process that affects whether and how IT assets become IT impacts rather than as an input variable in a necessary and sufficient relationship.” (p. 38).

The majority of the published research on the value of IT, does not consider the measure to which the IT assets are used effectively or appropriately. The underlying assumption that "*greater IT use [automatically] leads to greater IT impacts"* is evidently not correct. The *IT Use Process* acts as a leverage point for improving the business impact of IT. In considering the business value of IT, one should consider the level of IT spending and the scale to which IT assets are used effectively or appropriately within the organisation. In chapter 8 we describe the four enterprise architecture maturity stages identified by Ross et al. These enterprise architecture maturity stages can help to understand the current maturity level of the enterprise architecture and, as a consequence, the relationship between IT spendings and business performance.

9.4.2 Commodization of IT

Still, there are more conclusions that can be drawn from this research. In an article by Nicholas Carr in the Harvard Business Review (2003) and the subsequent discussions (HBR, 2003) on the value of IT for organisations, Carr states "As IT's core functions [...] have become cheaper, more standardised, and more easily replicable, their ability to service the basis for competitive advantage has steadily eroded. Given this continuing and indeed inexorable trend, companies would be wise to manage IT as a commodity input, seeking to achieve competitively necessary levels of IT capability at the lowest possible cost and risk." He argues that IT has become a commodity and, as a consequence, it cannot be used as a strategic competitive factor anymore, because it is equally available for everyone. He illustrates this with other examples of technology commodization, such as the commodization of Railways and Electric Power about 100 years ago. Based on this argument, he advocates a conservative approach for IT investments and taking a defensive position. In his view, the phase for IT to be used as a strategic, offensive competitive instrument is over.

We do not argue with his statement that IT becomes more and more commodity. With 1.2 billion PCs in use (Computer Industry Almanac, 2009) and Google reported to hit the one trillion unique URLs (2008), the commodity aspect of IT cannot be denied. But Carr's implicit assumption seems to be that using IT as a commodity or as a strategic instrument is an 'either-or' choice – you either bring down the cost of IT and focus on reliability and continuity, or you invest heavily in IT and treat it as an offensive strategic instrument to gain competitive advantage.

While this choice may be applicable in the other examples that Carr mentions, the research of § 8.4 shows that this assumption is simply not correct for the IT industry. IT can be managed in such a way that the business impact and the use of

IT as strategic instrument for competitive advantage increases, while simultaneously the cost decreases and continuity and reliability increase.

This finding invalidates the argument of Carr and the subsequent debate about business impact versus commodization. By improving the enterprise architecture maturity along the lines described by Ross, both goals are achieved simultaneously. Therefore business impact versus commodization is not an 'either-or' choice but an 'and-and' choice. It is a very interesting further line of research to understand the exact reasons for this and why IT differentiates itself in this respect from other examples.

9.4.3 Conclusions

Based on our research finding and the literature, we conclude that enterprise architecture plays a pivotal role in improving the effectiveness of the use of IT assets within a corporation, improves IT impact on business performance and, consequently, allows IT investments have measurable effects on business performance.

9.5 Overall Summary

In this paragraph we will revisit the five key research questions and provide an answer based upon the research in this thesis.

Question 1: Can we define a suitable method for measuring and quantifying, in financial terms, the value of enterprise architecture-based business transformation?

> Yes, the Real Options Analysis approach, which was developed in this thesis, is a suitable method for valuing enterprise architecture based business transformations.

Question 2: Is the method usable in practice to determine the value of enterprise architecture-based business transformations?

> Yes, applicability of the method is illustrated using the real-life case example.

Question 3: Can we define a suitable method to measure and to quantify, in financial terms, the value of solution architecture?

> Yes, by comparing and statistically analyzing multiple projects we are able to measure and quantify in financial terms the value of solution architecture.

Question 4: Can we apply this method to determine the value of solution architecture?

> Yes, the method is applied using a survey of 49 projects. The value of solution architecture was clearly demonstrated by the results of this survey. The

question whether these results are general applicable, needs to be determined by further research with a larger survey base.

Question 5: How is the business value of IT related to the value of enterprise and solutions architecture?

Based on our research and relevant literature, there are clear indications that enterprise architecture plays a pivotal role in improving the effectiveness of the use of IT assets within a corporation and improves IT impact on business performance. As a consequence, higher maturity levels of enterprise architecture would allow IT investments have measurable effects on business performance.

Appendices

1.

Appendix: Valuing Enterprise Architecture Development Projects over Multiple Years

Implementation of Business transformation scenarios generally takes a phased approach. After each phase, the results of the previously phase are determined and the next phase is planned. This appendix describes an extension to the Real Options Analysis calculation method (described in chapters 4 and 5) by extending the method for use in a phased implementation effort over several years.

1.1 Cash Flow of a Business Transformation Scenario

Equation (4-24) describes the probability density function that considers one revenue source and one cost source. When calculating a business transformation scenario, there will be cost estimations and revenue estimations over several years. To calculate the probability density function of a scenario, we will need to combine the probability density functions of individual years into one business transformation probability density function.

If $cf_1(x)$, $cf_2(x)$, $cf_3(x)$, …, are the probability density functions for year 1, 2, 3,…, then they can be combined into one overall cash flow are function $tcf(x)$, which describes business value, costs and risks for the total program for several years.

We can define now define the probability density function of a multi-year business transformation cash flow program. The probability density function $tcf(x)$ is the convolution of the individual cash flow functions of the separate years. If we define the convolution operator as O, then:

$$tcf(x) = \text{O}_{i=1}^{n}\, cf_i(x)$$

$$= cf_1 \circ cf_2 \circ cf_3 \circ \cdots \circ cf_n \qquad (1\text{-}1)$$

$$= (p_1 \circ c_1) \circ (p_2 \circ c_2) \circ \cdots \circ (p_n \circ c_n)$$

where:

$tcf = Total\ Cash\ Flow\ Function - over\ several\ years$
$cf_i = Cash\ Flow\ Function\ for\ Year\ i$
$i = 1, 2, 3 \ldots$
$p_i = Profit\ function\ for\ year\ i$
$c_i = Cost\ function\ for\ year\ i$

This formula describes the overall cost/revenue probability density function of a scenario, where the individual probability density functions (e.g. describing the cash flow of one year) are merged in to one scenario function. Since the convolution operator has the commutative (4-15) and the associative (4-16) property, (1-1) defines the resulting probability density function univocally. The expected value of the scenario probability density function is the sum of the expected value of the individual PDF's (according to (4-22)).

For an illustration of convoluting the revenue in cost functions over five years, see the next table.

Year	Revenue Function	Cost Function	Cash Flow Function
1	p_1	c_1	cf_1
2	p_2	c_2	cf_2
3	p_3	c_3	cf_3
4	p_4	c_4	cf_4
5	p_5	c_5	cf_5
Total Revenue, Cost and Cash Flow Functions	$\boldsymbol{tp}$	$\boldsymbol{tc}$	$\boldsymbol{tcf}$

Table 1-1. Overview of convoluted revenue, cost and cash flow functions.

To recapitulate, to construct the probability density function of a multi-year business transformation scenario *tcf*, we start with defining the cost and revenue probability density functions for each year. The revenue functions have a normal distribution, while the cost functions have a lognormal distribution. Combining the cost and revenue functions into one cash flow function, gives the cash flow probability function per year. These cash flow functions are convoluted into one overall business transformation probability density function. Combining the revenue functions and gives a total revenue function (*tp*), which describes the total revenue expected from the transformation program. We can do the same for the total cost function (*tc*), which describes the total cost of the transformation program.

Cash Flow Discounting

Equation (1-1) describes the overall probability density function of a business transformation scenario. The expected value of this probability density function, is the sum of the expected values of the underlying probability density functions. However when summing up the expected values over several years, this equation does not discount the expected values with an interest percentage. Remember that, to calculate the Net Present Value, the expected value of future cash flows are multiplied with a factor $\frac{1}{(1+r)^i}$, where *r* is the interest rate and *i* is the year number. Discounting future cash flows is not yet incorporated in (1-1). To discount a cash flow, the expected value of the cash flow has to be multiplied by a factor $\frac{1}{(1+r)^i}$. To adjust (5-27) to incorporate discounting future cash flows, we will modify slightly the basic probability distribution functions (5-5) and (5-10). For (4-5), the expected value of the probability density function is equal to μ.

Normal Distribution

To incorporate the discounting of cash flow into a normal distribution, we redefine μ as μ_i, where $\mu_i = \frac{\mu}{(1+r)^i}$. Equation (4-5) then becomes:

$$p_i(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu_i)^2}{2\sigma^2}} \qquad (1\text{-}2)$$

where:

$$x = Value$$
$$\mu_i = \frac{\mu}{(1+r)^i}$$
$$\sigma = Standard\ deviation$$
$$r = Interest\ rate$$
$$i = Year\ number\ (1, 2, 3..n)$$
$$\mu = Mean$$

By replacing μ by μ_i, the expected value of the probability function p_i becomes:

$$E(p_i) = \frac{\mu}{(1+r)^i} \qquad (1\text{-}3)$$

Which produces the desired effect of the discounting the expected value of the revenue function with a factor by $(1+r)^i$.

Lognormal Distribution

In the case of the *lognormal* distribution (equation (4-10)) , the expected value of the PDF is given by $e^{\mu+\frac{\sigma^2}{2}} + \lambda$ (see (4-12)). Dividing this value by $(1+r)^i$ gives:

$$\frac{e^{\mu+\frac{\sigma^2}{2}} + \lambda}{(1+r)^i} = \frac{e^{\mu+\frac{\sigma^2}{2}}}{(1+r)^i} + \frac{\lambda}{(1+r)^i} \qquad (1\text{-}4)$$

Based on this, we can define:

$$\lambda_i = \frac{\lambda}{(1+r)^i} \qquad (1\text{-}5)$$

Simplifying the first term on the right side of the equal sign for (1-4) gives:

$$\frac{e^{\mu+\frac{\sigma^2}{2}}}{(1+r)^i} = e^{\mu+\frac{\sigma^2}{2}-i.\ln(1+r)} \qquad 1+r>0 \qquad (1\text{-}6)$$

Observing that

$$\ln(1+x) = \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n} x^n \qquad |x| \leq 1, x \neq -1 \qquad (1\text{-}7)$$

$$= x - \frac{x^2}{2} + \frac{x^3}{3} - \cdots \qquad (1\text{-}8)$$

And that

$$r \ll 1 \qquad (1\text{-}9)$$

By combining (1-7) and (1-9) we can simplify the expression $\ln(1+r)$ by stating:

$$\ln(1+r) \approx r \qquad (1\text{-}10)$$

Combining (1-6) and (1-10) gives:

$$\frac{e^{\mu+\frac{\sigma^2}{2}}}{(1+r)^i} \approx e^{(\mu-i.r)+\frac{\sigma^2}{2}} \tag{1-11}$$

From this, we can define:

$$\mu_i = \mu - i.r \tag{1-12}$$

Based on (1-5) and on (1-12) we can now redefine (4-10), this equation becomes:

$$cp_i(x) = \frac{e^{-(\ln(x-\lambda_\mathrm{i}) - \mu_i)^2/(2\sigma^2)}}{(x-\lambda_i)\sigma\sqrt{2\pi}} \qquad x > \lambda_i$$
$$= 0 \qquad x \leq \lambda_i \tag{1-13}$$

where:

$x = \ Cost\ of\ the\ Project$
$\sigma = Scale\ parameter$
$\lambda_i = \dfrac{\lambda}{(1+r)^i}$
$\lambda = Threshold\ parameter$
$\mu_i = \mu - i.r$
$\mu = Location\ parameter$
$r = Interest\ rate$
$i = Year\ number\ (1, 2, 3..n)$

By replacing μ by μ_i and λ by λ_i, the expected value of the probability density function cp_i is approximated by:

$$E(cp_i) \approx e^{(\mu-i.r)+\frac{\sigma^2}{2}} + \frac{\lambda}{(1+r)^i} \tag{1-14}$$

By using (1-2) and (1-13) instead of (4-5) and (4-10) , we can construct an overall probability density function for a scenario that incorporates the effect of a discounted cash flow.

1.2 Applying Multi-Year Cash Flow Discounting to the Financial Institution Case

1.2.1 Using a Phased Approach for Real Option Analysis

Chapter 5 introduces a mathematical model for the implementation of business architecture. The model describes the quantification of the benefits, quantification of the costs and builds up a probability model, based on the normal and lognormal probability distributions. The model provides insight and some key figures of the possible outcomes of the decision of building the business architecture. Considering the size of the business architecture and the effort that is needed to implement the architecture, it is clear that the implementation of the business architecture cannot be conducted into one overall step, but the implementation will have to take place using a phased approach. In this appendix, we will illustrate the applicability of real option analysis for a phased approach.

1.2.2 Phasing the Implementation of Enterprise Architecture

The number of the required phases is determined by the priorities of the sponsors (users of the business architecture) and by the change ability of the organization. Sponsors have specific priorities with regard to the delivered functionality, short-term versus longer term. Based on this prioritization the total functionality can be split up in a number of phases. The highest priority functionality will be realized during the first phase.

The functional requirements of the sponsors are described in terms of *Business Functions*. A Business Function is a *unit of work* that makes sense from a business point of view. The functionality of the business architecture can be described in terms of seven, high-level, business functions. See Table 1-2.

Num	Name	Description
I	**Scan, Store and Retrieve document to or from operational storage**	• Ability to digitalize paper documents by using bulk and/or individual scanners, with manual document type recognition or by using a separator page into the archive storage. • Searching and viewing the electronic document and retrieving the physical storage reference of the physical document. • Ability to insert/import an electronic document in the operational storage and to create new versions of the electronic document.
II	**Scan and retrieve to and from archive**	• Ability to digitalize paper documents by using bulk and/or individual scanners, with manual document type recognition or by using a separator page into the archive storage.

Num	Name	Description
		• Searching and viewing the archived electronic document and retrieving the physical storage reference of the physical document.
III	**Process received e-document**	• Automated processing of an e-document after the document header has been filled. • The e-document can trigger a process, task list or can go to the archive storage directly. • The e-document will be retrievable via the process or task.
IV	**Automatic recognition of document type**	• Automated recognition of the document type based on barcode / recognition string (bank produced documents). • Automated recognition of the document type based on pattern recognition in the document.
V	**Subscribe and inform**	• Search for a required document in the operational storage and subscribe for a new version of that document. • Full-in required document properties and subscribe for a document that fits those requirements. • Automated signal by email, task list or process trigger when the subscribed document had arrived in the operation storage.
VI	**Storage cleaning**	• Set the retention period of an electronic document based on an business event (e.g. archiving, termination of contract of business relationship). • Remove electronic document from operational or archived storage when retention period has expired.
VII	**Interpret Document**	• Automatic interpretation of document based on usage of Optical Character Reading (OCR) • Automatic interpretation of images (e.g. signatures) by means of image recognition

Table 1-2. Overview of business functions of the business architecture

The business functions described in this table are arranged to priority; business function I has the highest priority and VII the lowest. Based on these priorities and based on the change ability of the organization, we defined three phases for the implementation of the business architecture.

Phase	Business Function
1	I,II
2	III, IV, VI,
3	V, VII

Table 1-3. Overview of implementation phases

Each phase has a timeframe of one year; this means that it takes three years to realize the business architecture.

1.2.3 Cost per Phase

To calculate the cost per phase of the implementation of the business architecture we will use the cost calculation of Table 5-6, which is summarized below:

Type of cost	Factor	Cost
Development cost (one-time investment)	**The cost of implementation of the architecture functionality**	€ 1.750.000
	Cost of fitting the architecture within the existing environment	€ 450.000
	Cost for implementing the architecture within the sponsor's business process	€ 900.000.
Annual maintenance cost	**Operational costs to maintain the architecture**	Annual € 2.000.000 (First year € 1.000.000)

Table 1-4. Cost of implementing the business architecture (Summary)

This table describes the following cost components:

1. **Cost of implementing architecture functionality.** The architecture functionality is described in terms of business services. These are the one-time costs of implementing these business services.
2. **Cost of fitting the architecture within the existing environment.** These are one-time costs, mainly for creating interfaces to the systems.
3. **Cost for implementing the architecture within the sponsor's business process.** The scanning environment, as described in the business architecture, needs to be connected to the business processes of the using department. These are one-time costs to make this connection.
4. **Operational costs.** These are annual costs to maintain the application. These include maintenance costs (for small functional changes and bug fixes) and licensing costs.

Sub 1. Implementation of a business function requires the implementation of the supporting business services. (See for a description of the business services § 8.3.) Table 1-5 describes the relationship between business functions and the supporting services. Table 1-6 shows an overview of the business services that need to be implemented per phase. Using the opinion of an expert panel, the business services are divided in three categories that describe the implementation complexity of the service. The panel defined for the simple, medium and complex services an implementation cost of respectively € 50.000, € 100.000 and € 200.000. Based on this analysis, we can calculate the cost for implementing the business services per phase. This calculation is shown in Table 1-7.

		Business Service																			
		1		2	3		4	5	6	7	8	9	10		11			12	13	14	15
		a	b		a	b							a	b	a	b	c				
Business Function	I	♦	♦	♦	♦		♦	♦		♦		♦			♦	♦					
	II	♦	♦	♦	♦		♦	♦			♦	♦			♦		♦				
	III								♦	♦	♦		♦	♦	♦	♦	♦		♦		
	IV			♦				♦													
	V							♦							♦	♦				♦	♦
	VI														♦	♦	♦	♦			
	VII					♦															

Table 1-5. Relationships between Business Functions and Business Services

Phase	Business Function	Business Service
1	I, II	1a, 1b, 2, 3a, 4, 5, 7, 8, 9, 11a, 11b, 11c
2	III, IV, VI	6, 10a, 10b, 12, 13
3	V, VII	3b, 14, 15

Table 1-6. Overview of the Business services to be implemented for each phase

Phase	Business service complexity						Total	
	Complex		Medium		Simple			
	#	Costs	#	Costs	#	Costs	#	Costs
1			4	€ 400	8	€ 400	**12**	**€ 800**
2			4	€ 400	1	€ 50	**5**	**€ 450**
3	2	€ 400	1	€ 100			**3**	**€ 500**
Total	**2**	**€ 400**	**9**	**€ 900**	**9**	**€ 450**	**20**	**€ 1.750**

Table 1-7. Overview of the planned implementation cost for each phase (Costs x 1.000)

Sub 2. The cost of fitting the architecture within the existing environment is mainly determined by the cost of developing the required interfaces to the systems. These costs are entirely allocated to the first phase.

Sub 3. The cost of fitting the architecture with the sponsor's business process, depends on the number of business processes that are connected in a specific phase. The expectation is that two sponsors will be connecting during the first phase, two during the second phased and two during the third phase.

Sub 4. Operational costs are expected to be € 1 million after phase 1 and annually € 2 million after the implementation of phase 2 onwards. Operational costs differ from implementation costs, because they are *not* subject to the lognormal probability distribution. These costs contain the license costs and the costs for small operational functional changes; they can be forecasted quite precisely. When calculating the cash flow, they are taken at face value. Operational costs were not included in the analysis of § 5.4; we will include them in this phased analysis. See Table 1-8, for a summarization of these cost elements.

Cost element	Phase			Total
	1	2	3	
Implementation	€ 800	€ 450	€ 500	**€ 1.750**
Architecture fitting	€ 450			**€ 450**
Connecting to business process	€ 300	€ 300	€ 300	**€ 900**
Operational cost		€ 1.000	€ 2.000	**€ 3.000**
Total	**€ 1.550**	**€ 1.750**	**€ 2.800**	**€ 6.100**

Table 1-8. Total planned cost for implementation and operation (Costs x € 1.000)

This table shows the total overview of the cost and includes both the implementation cost and the operational cost.

1.2.4 Benefits per Phase

The financial benefits of the architecture are described in Table 5-4. However, not all the benefits are realized at the same time. Some benefits will be implemented by the activities of phase 1, some by phase 2, etc. Moreover, benefits follow investments. In other words, the benefits of phase 1 are only produced during phase 2, the benefits of phase 2 are produced during phase 3, etc. Because the total benefits are only available after the full implementation of the business architecture, we will use an overall timeframe of four years, to calculate the total value of the architecture. We evaluate the benefits of Table 5-4 and allocate them to a specific phase.

#	Benefit	Value (x 1000)	Allocated to year
1	**Improved Document handling**	€ 4500	3+
2	**Less use of paper**	€ 1250	3
3	**Transport reduction**	€ 3000	3
4	**Less documents stored in the Central Paper Archive**	€ 1000	3+
5	**Linking output documents to input documents (e.g. contracts)**	€ 500	3+
6	**Up-to-date customer info**	€ 1000	2

Table 1-9. Overview of the allocation of benefits to a phase

The notation “3+” means that the benefits only occur after year 3, hence our evaluation over 4 years. This allows us to include all benefits in our analysis. It is important to note that these benefits are annual benefits; they reoccur each year. For example, benefit 6 occurs first during year 2 (brought about by the activities of year 1) and then it reoccurs annually. Consequently, benefit 6 is included in the benefits analysis for a year 2, year 3 and year 4. Benefits are cumulative.

1.2.5 Net Present Value Calculation

The net present value of the enterprise architecture can be calculated by calculating the cash flow for each year and discounting this cash flow with an interest percentage. The interest rate that the financial institution uses internally for calculating NPV is 10%. This gives the following net present value:

	Year 1	Year 2	Year 3	Year 4
Cumulative Benefits	€ 0	€ 1000	€ 5250	€ 11250
Costs	€ 1550-	€ 1750-	€ 2800-	€ 2000-
Cash Flow	**€ 1550-**	**€ 750-**	**€ 2450**	**€ 9250**
NPV (10%)		**€ 5500**		

Table 1-10. Net Present Value Calculation for Implementing the Enterprise Architecture

The Net Present Value will be used to compare it with the outcomes of the real options analysis.

1.2.6 Real Options Analysis

Based upon the benefits and cost analysis in the previous paragraphs, we are now able to calculate the revenue and cost probability density functions per phase.

	Year 1	Year 2	Year 3	Year 4
Expected Value	€ 0	€ 1000	€ 5250	€ 11250
Standard Deviation	-	0.174	0.784	0.494

Table 1-11. Parameters for Revenue PDF's (EV x 10^3)

	Year 1	Year 2	Year 3	Year 4
Planned cost	€ 1550	€ 1750	€ 2800	€ 2000
Location	0.67	-0.060	0.0048	-
Scale	0.57	0.57	0.57	-
Threshold	0.24	1.11	2.12	-

Table 1-12. Parameters for Cost PDF's (EV x10^3)

See Figure 1-1 to Figure 1-4 for respectively the cost-benefit and cash flow analysis of year 1 to 4. These graphs are calculated using the interest-adjusted probability density functions as described in (1-2) and (1-13), with an interest percentage of 10%.

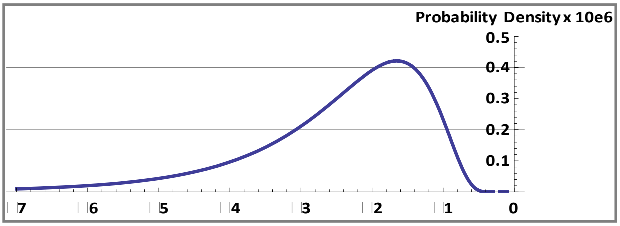


Figure 1-1. Costs for Year 1

Figure 1-1 shows the costs for year one; it shows only costs, there are no benefits yet.

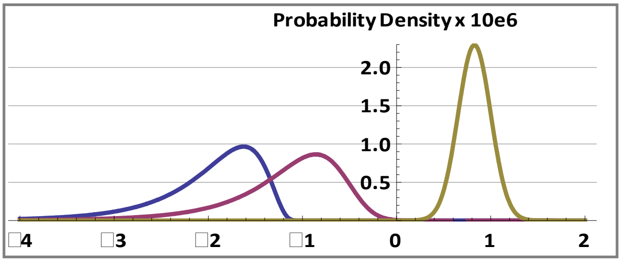


Figure 1-2. Benefits, Costs and Cash Flow for Year 2

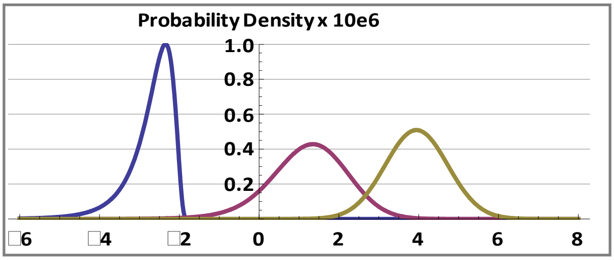


Figure 1-3. Benefits, Costs and Cash Flow for Year 3

In Figure 1-2 and Figure 1-3, the most right (yellow) probability density function describes the expected revenue of this phase, the most left (blue) probability density function describes the expected cost for the phase and the middle (red) probability density function described the expected net cash flow for the phase.

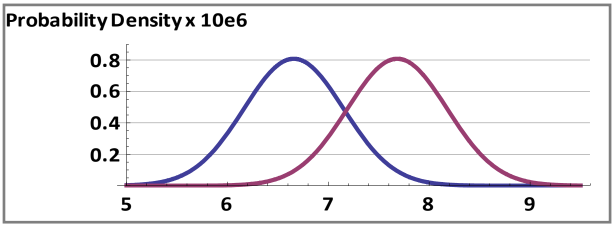


Figure 1-4. Benefits and Cash Flow for Year 4

Figure 1-4 shows the benefits for year 4 (right, red) and the cash flow for year 4, i.e., the cumulative benefits for year 4 minus the operational costs (left, blue).

1.2.7 Annual and Overall Cash Flow

The cash flow functions of year 1, 2, 3 and 4 are shown in Figure 1-5.

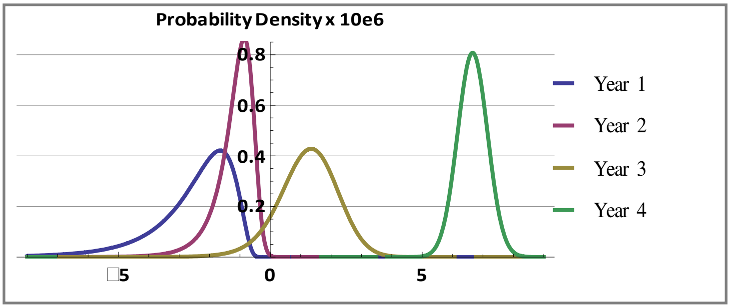


Figure 1-5. Annual cash flow PDF's

With the following cumulative distribution functions:

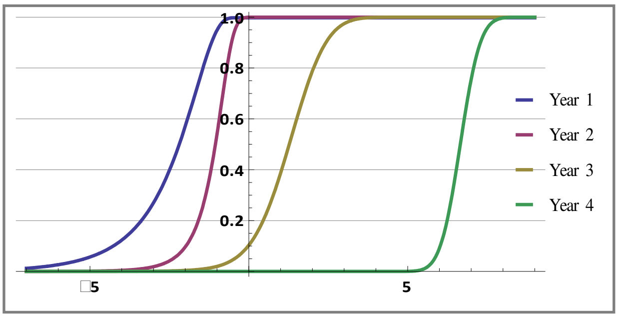


Figure 1-6. Cash flow CDF from left to right for year 1 to 4

The key figures for the cash flow probability density functions are shown in Table 1-13.

Key-figure	Cash-flow probability density function			
	Year 1	Year 2	Year 3	Year 4
Mean – Expected Value	- € 2.5M	-€ 1.2M	€ 1.2M	€ 6.7M
Median – 50% Value	- € 2.2M	-€ 1.1M	€ 1.3M	€ 6.7M
Mode – Most likely outcome	- €1.7M	-€0.9M	€1.3M	€ 6.7M
Option Value	€ 0M	€ 0M	€ 1.2M	€ 6.7M

Table 1-13. Key figures cash flow PDF per year (x 10^6)

Combining these four probability density functions into one overall function for the whole program gives the following result.

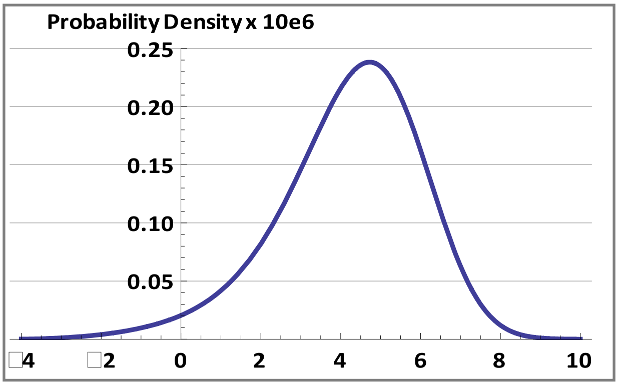


Figure 1-7. Overall cash flow probability density function

With the following cumulative distribution function:

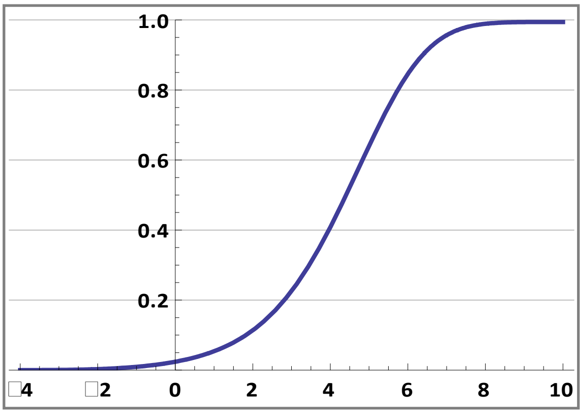


Figure 1-8. Overall cash flow probability density function

The overall cash flow probability density function has the following key figures:

Key-figure	Value
Expected Value	€ 4.18M
Option Value	€ 4.20M
Median – 50% Value	€ 4.4M
Mode – Most likely outcome	€4.7M
Probability of outcome < € 2M	11%
Probability of outcome > € 6M	15%

Table 1-14. Key figures of the overall cash flow probability density function

Comparing the expected value from this calculation with the Net Present Value calculation that was given in Table 1-10, we find that the real options analysis gives a lower expected value: € 4.18M versus € 5.5M, or 24% lower. This is because the real options calculation works with *expected value* of the cost (see the analysis on page 54), while the NPV analysis works with the *planned value* of the cost.

2.

Appendix: An Overview of Business Services for the Financial Case Study

This appendix describes the business services required for the implementation of the architecture-based business transformation scenario discussed in chapter 5.

2.1 Business services

The functionality of the business architecture can be described in terms of high-level Business Services. A *Business Service* describes a discrete part of the functionality of the overall architecture. The following business services where identified.

Num	Business Service	Description	Complexity
1a	Determine authenticity of incoming document	Determine if the (paper) document received is an original and authentic document. The service can be implemented in increasing order of automation as follows: 1. Manual check 2. Automated check based on document characteristics	Medium
1b	Determine Integrity of incoming document	This service compares incoming documents to the version that was sent. The service can be implemented in increasing order of automation as follows: 1. Manual check 2. Automated check based on document characteristics	Medium

Appendices

Num	Business Service	Description	Complexity
2	Identify document type	Determine what the document type of the document received is. The service can be implemented in increasing order of automation as follows: 1. Manual identification 2. Automated based on a separator page 3. Automated based on barcode / recognition string 4. Automated based on pattern recognition (not recommended because of error sensitiveness)	Medium
3a	Scan document	Is used to image the paper document	Medium
3b	Interpret scanned image according to a template	Interpret specific parts of the document, such as OCR specific texts, compare signature, etc.	Complex
4	Retrieve Unique Document ID	Returns a unique Document ID that will be the primary identification for a specific document	Simple
5	Maintain document header	Adds meta-data to the document header	Simple
6	Determine action (process/task list/archive)	Determines what action is required as result of receiving the document. This can be: 1. Start a process and link the this process to the document (using service 10b) 2. Inform a running process (service 15) and the process to the document (using service 10b) 3. Have the document stored in the Electronic Archive 4. Add a task to a task list and link the task to the document as human interaction is required to determine which of the above actions will have to take place (using service 10a).	Medium
7	Store e-document in operational storage or work file	Stores a specific document in the operational storage.	Simple
8	Store e-document in archive storage	Stores a specific document in the archive storage. If the storage period can already been determined at the time of storing it into the electronic archive the end date at which the document will have to be removed will be determined. If not the document is stored infinitely for that moment. No date is set but it can be set later on (using service12).	Simple
9	Link e-document to location physical document	Create a (logical) link between the electronic document and the place where it is physically stored. E.g., an archive box number or reference number of the scanned device via which the physical storage location can be derived.	Simple

Num	Business Service	Description	Complexity
10a	Link Task to e-document	Attach e-document-ID to a task list	Medium
10b	Link process to e-document	Attach e-document-ID to a process of case.	Medium
11a	Search e-document	Search for e-documents using its meta data. It re-turns a list of document references that match the selection criteria.	Simple
11b	Read e-document from operational storage	Retrieves a specific e-document by its document reference from the archive storage.	Simple
11c	Read e-document from archive storage	Retrieves a specific document by its document refer-ence, form operational or archive storage.	Simple
12	Update storage period e-document	Sets the end date at which a specific document will have to be removed from the storage. This can be the operational or the archive storage.	Simple
13	Move e-document from operational sto-rage to archive	Copies a specific document form the operational storage to the archive storage and sets the date to remove e-document form operational storage. This can be used after the process in which the document is used is ended. This service works in combination with other services: 11b, 8, 12.	Medium
14	Subscribe for receiving an e-document	Register the required e-document meta-data (like document type, customer-id) for an e-document to be received in the operational storage for a specific process	Complex
15	Inform a process of received e-document	Triggers a process when an e-document matching the subscribed specifications has been stored in the operational storage.	Medium

Table 2-1. Overview of Business Services required to implement the business architecture

3.

Appendix: Raw Data Analysis and Transformation

This appendix describes the activities conducted for the raw data analysis and transformation phase, used to analyse the value of solution architecture, which is described in the chapters 6 and 7.

3.1 Budget Success Variable

3.1.1 Format of the Budget Success Variable

For each project the original budget and the actual budget was compared and standardized into a percentage. See the figure below for an overview of the budget success variable of these projects.

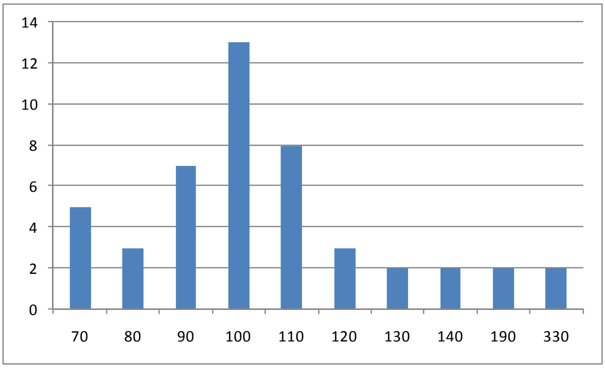


Figure 3-1. Histogram of project budget success variable

All projects are normalized to a standard scale. The value of 100 means that the project was exactly on budget, while, for example, the value of 120 means that the project was 20% over budget, etc.

3.1.2 Removing Anomalies – Budget Success Variable

Analyzing this histogram, we find that it has some unusual characteristics. First, the number of projects with 30% underrun (in the column that is labeled 70) is *higher* than the number of projects with 20% underrun; 5 versus 3. We considered several possible reasons for this increase and interviewed the involved project managers. The most plausible reason that emerged from this investigation is that project managers, in some cases, have overstated the cost of the project. Because of performance-related conditions, project managers have an incentive to calculate projects using margins that create an underrun.

A second noteworthy characteristic of the histogram is the presence of two projects with a score of 330, which means that there are two projects with 230% overrun. This overrun is surprisingly high, considering the gap between 140 and 190 and then the jump to 330. One would not expect two projects with this high overrun in a small sample of 49 projects. When investigating this issue, we found out that the selection of projects was not completely random. High-overrun projects cost a lot of money and attract a lot of management attention; they become well known. It is possible that these high-overrun projects were chosen because of the fact that they had high overrun and, consequently, that they are not representative for the total population of projects.

Both effects are aggravated because the number of projects is relative small; for both tails of the curve, the difference between high and low is only a few projects. Results that differ from the general trend, because of specific reasons that are not related to the trend, are called outliers. Because of the arguments above, we decided to remove these outlier results from our sample. The resulting histogram looks like:

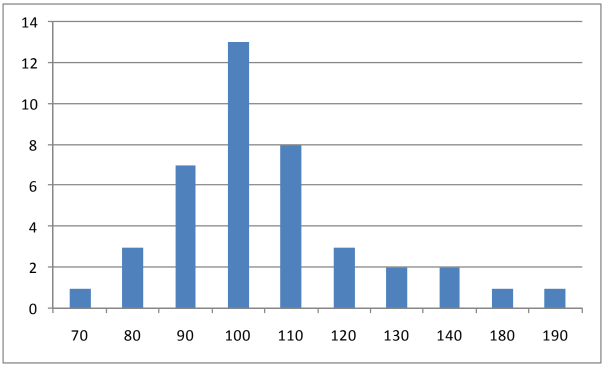


Figure 3-2. Histogram of project budget success variable after outlier elimination

3.1.3 Data Transformation – Budget Success Variable

We analyzed this distribution with Minitab for Normal and for Lognormal distribution characteristics, using a 95% confidence interval.

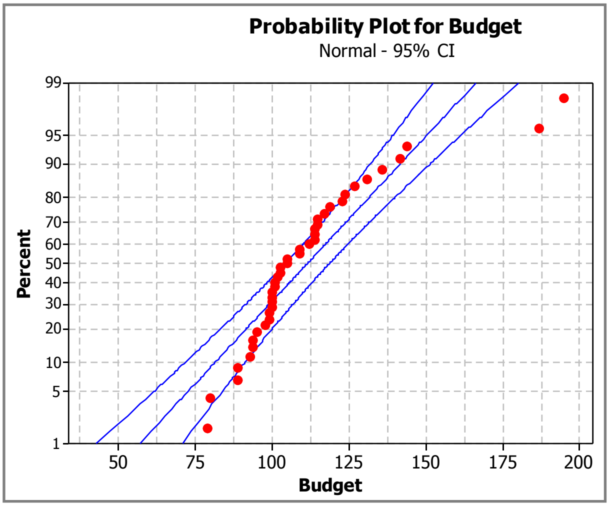


Figure 3-3. Analysis of project budget success variable for Normal distribution

The analysis compares the frequency of the actual figures and compares them to a theoretical distribution, while trying to minimize the error between the theoretical value and the actual frequency. A red dot describes the results of one individual project. The middle line is the "ideal" Normal distribution and the higher and the lower lines denote the 95% confidence intervals. We find that many points are located far outside of the confidence intervals and we will therefore reject the hypothesis that the actual distribution represents a Normal distribution. In this case, Minitab also provides a p-value for the probability of a normal distribution. The value is 0.5%, which is lower than the threshold value of 5%. Therefore, we reject the null hypothesis of normal distribution.

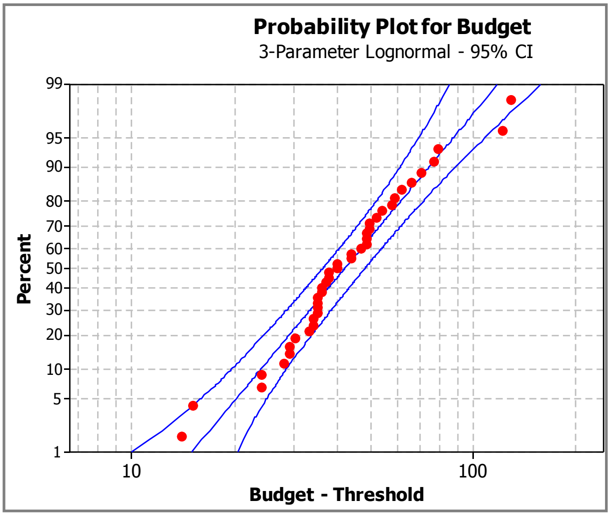


Figure 3-4. Analysis of project budget success variable for Lognormal distribution

Analyzing the figure for a lognormal distribution, we find that one project falls outside the 95% confidence interval. However, the match is much better compared to the normal distribution. We decided not to reject the working hypothesis that the information is lognormal distributed.

The related parameter values for the lognormal distribution are: $\mu = 3.74$, $\sigma = 0.44$ and $\lambda = 64.9$. The most likely outcome is 100 and the expected outcome is 111. Based on this analysis, we can transform the budget variable normal distribution by using the following transformation instruction:

$$b_t = \ln{(b - \lambda)} \qquad (3\text{-}1)$$

where

$$b_t = transformed\ budget\ value$$
$$b = original\ budget\ value$$
$$\lambda = threshold\ value = 64.9$$

See Figure 3-5 for the results of the transformation of budget overrun.

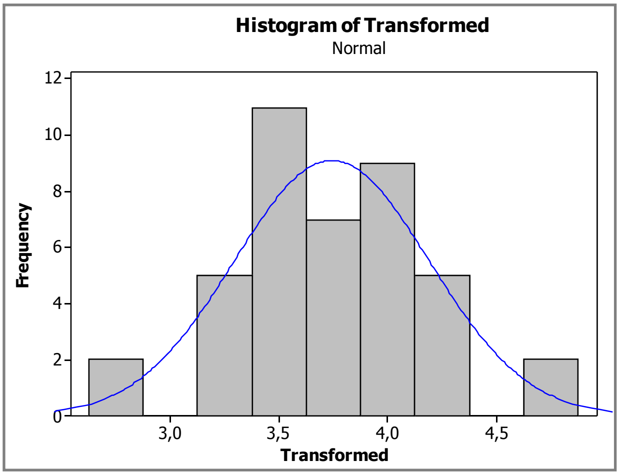


Figure 3-5. Histogram for transformed budget success variable

The p-value for this distribution is 15%, therefore we do not reject the null hypothesis that the transformed data is normal distributed.

3.2 Raw Data Analysis and Transformation – Time Success Variable

3.2.1 Data Transformation – Time Success Variable

The time success variable is also normalized to a standard scale with a value of hundred indicates that the project was on time, a value of 150 indicates that the project was 50% over time, etc. Following the same steps that we used for the budget distribution, we were also able to find a lognormal transformation instruction for the time variable.

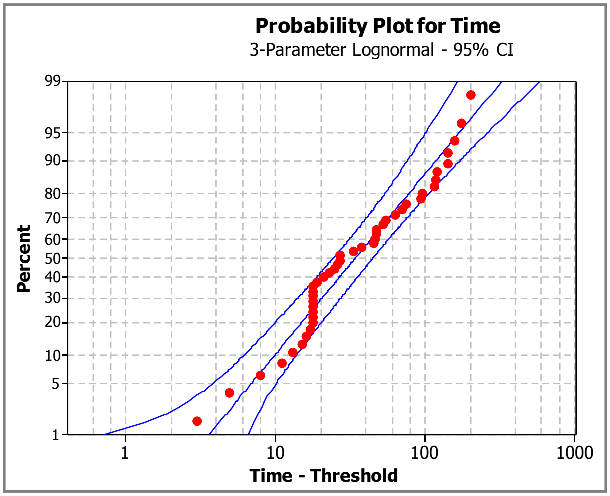


Figure 3-6. Distribution analysis of time overrun

Analyzing the figure for a lognormal distribution, we find that no project falls outside the 95% confidence interval. We decided not to reject the working hypothesis that the information is lognormal distributed.

The related parameter values for the lognormal distribution are: $\mu = 3.0$, $\sigma = 1.3$ and $\lambda = 94.3$. From the distribution follows, that the most likely outcome is 98 and the expected outcome is 141. Using formula (3-1) with a λ value of 94.3, we transformed the time variable to the normal distribution. See the histogram of Figure 3-7.

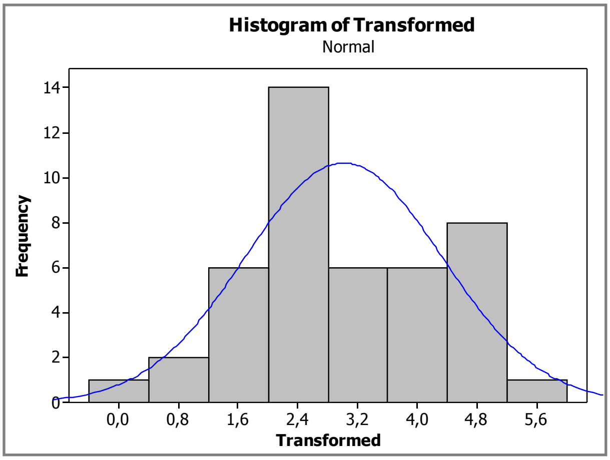


Figure 3-7. Histogram for transformed time success variable

The p-value for this distribution is 10%, therefore we do not reject the null hypothesis that the transformed data is normal distributed.

3.3 Reliability of Transformation for Budget and Time

The normal distributions of the budget and time success variables falls within the confidence intervals for normal distribution, albeit sometimes it is close. The basic problem that we face with the identification of the distributions is the limited number of data points that are available. Use of several hundred data points gives a more accurate understanding of the distributions. Pyzdek states: “the approach works best if you have at least 200 data points, and the more the merrier.” (2003). However, only a limited number of projects were available for analysis and we will have to do with the information that we have. To our advantage, the ANOVA test that we use is rather robust to deviations from normality (Lindman, 1974). This allows us to use the ANOVA test even when the actual distribution of the data does not fully comply with the normal distribution.

3.4 Raw Data Analysis – Customer Satisfaction Success Variable

Customer Satisfaction is measured using a standard procedure and a standard scale, across all projects. The scale goes from 1 (very bad) to 5 (very good). The procedure that is used to measure customer satisfaction is called OTACE (*On Time above Customer Expectation*) and it is a standard procedure were the customer gives a weighted score, and based upon a number of criteria. The criteria (and the priority of each criterion) are defined before the project starts and scored afterwards. For the measurement of the customer satisfaction, 44 projects were available.

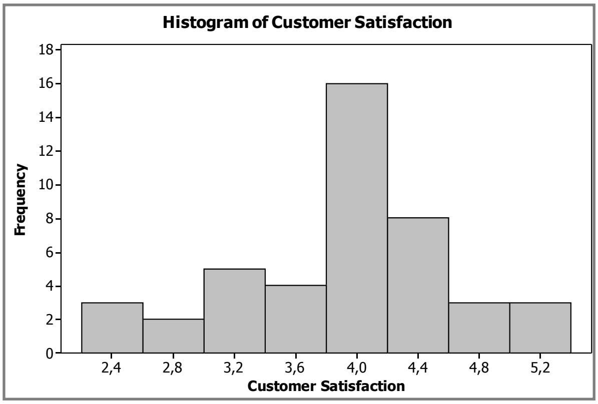


Figure 3-8. Histogram of Customer Satisfaction success variable

We were not able to determine a standard distribution type for this distribution. Because the variable is numerical and continuous, we will use regression for the analysis of this variable.

3.5 Raw Data Analysis – Percentage Delivered Success Variable

The success variable *Percentage Delivered* is represented in a percentage, where 100% indicates that all the required functionality was delivered. In the actual results, we find that the minimum was 60% and the maximum was more than 120%. In this last case, we find that the project delivered more functionality than those planned. Most of the projects deliver 100% of the planned functionality.

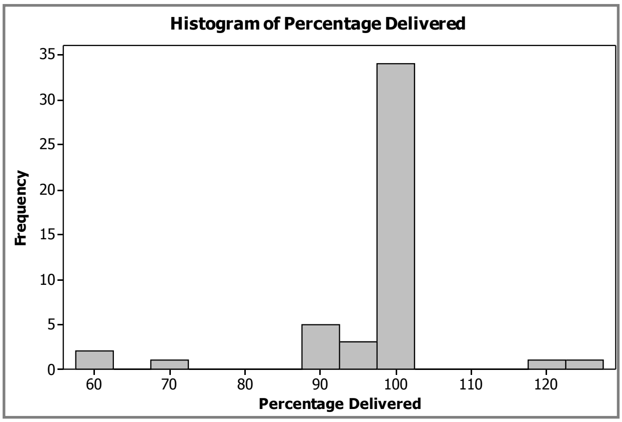


Figure 3-9. Histogram of Percentage Delivered success variable

As the variable is numerical and continuous, we will use regression for the analysis of this variable.

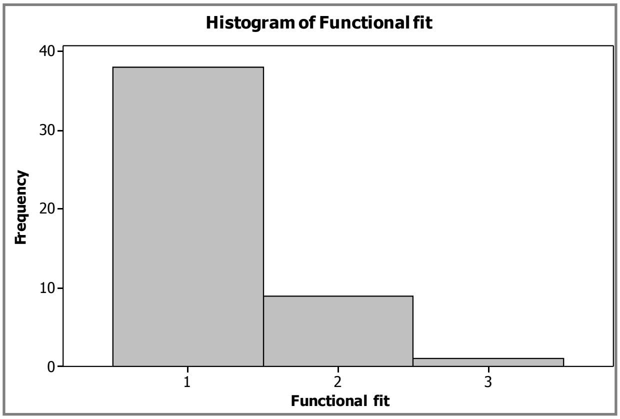
3.6 Raw Data Analysis – Functional and Technical Fit Success Variable

The success variables Functional Fit and Technical Fit are both represented as a multiple-choice variable with three possible choices. The three choices are:

Question	Answer 1	Answer 2	Answer 3	Explanation
Functional fit of the project results	>90% of functional requirements are realized, including all the 'must haves'	Between 80 and 90 percent of the functions are realized	Less than 80% of the functions are realized	What is the percentage of defined functions realized at the end of the project?
Technical fit of the project results	The project results met technical requirements.	The project met the main technical requirements	The project was not able to meet the main technical requirements	Balance in the non-functional requirements of project results, such as maintainability, resilience, scalability, security, availability, etc.

Table 3-1. Answers for functional and technical fit (from questionnaire)

See the figures below for an overview of the histogram of the answers.



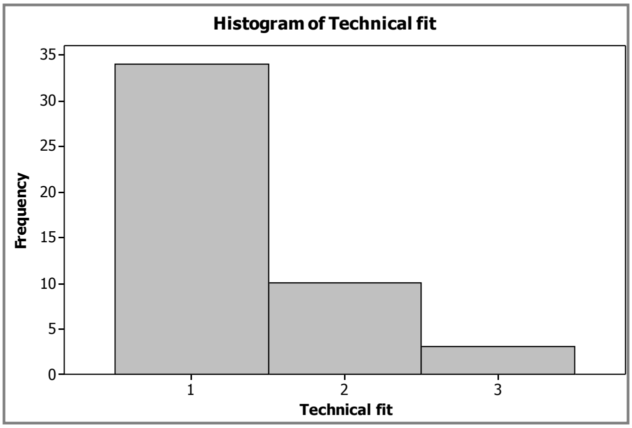


Figure 3-10. Histograms of Functional and Technical Fit

For the analysis of these success variables, we use the Kruskal-Wallis test.

4.

Appendix:

Analysis Null-Hypothesis

This appendix describes the activities conducted for the Null-Hypothesis analysis phase, used to analyse the value of solution architecture, which is described in the chapters 6 and 7.

4.1 H_0 statement I – Expected Value of Project Budget

4.1.1 Overview

Statement I reads:

"Application of enterprise architecture is not significantly correlated with the expected value of the actual project budget (as percentage of the planned budget)."

Hypothesis testing delivers the following results:

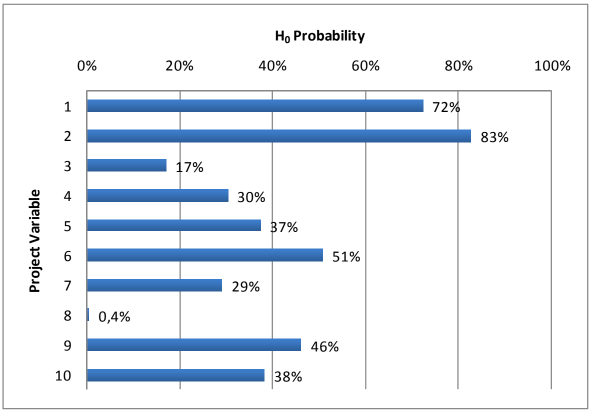


Figure 4-1. Probabilities H_0 Statement I

4.1.2 Project variable 8 – Architecture Governance

Variable 8 tests significant. The question and answers for project variable 8 are:

Question	Answer			Explanation
	1	2	3	
Architecture governance process in the customer's organization	Yes, there was a fully functional architecture governance process present	Yes, but the scope was limited or responsibilities not fully defined	No architecture governance process in the customer's organization	Architecture governance means that project architecture is based on a domain architecture, which is based on the enterprise architecture. Vice versa, results from project architectures are fed back to higher levels. The customer has a *Design Authority* process to block projects that do not comply with the higher-level architectures.

Table 4-1. Question and answers for project variable 8

Overview of the results for variable 8:

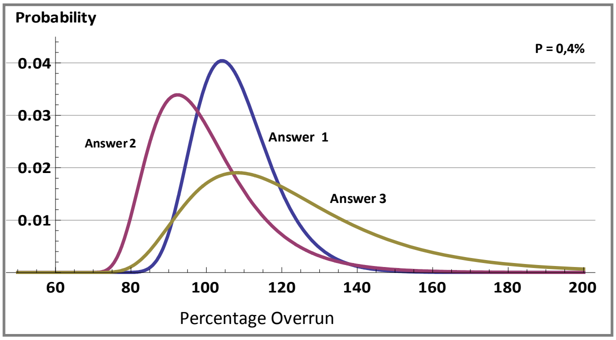


Figure 4-2. Distributions for project variable 8 samples

Answer	Expected value	n
1	108	8
2	100	15
3	122	19

Table 4-2. Key figures for project variable 8 samples

When examining Figure 4-2 and Table 4-2, it seems that answers 1 and 2 have a comparable distribution and the expected value is similar. Distribution 3 is clearly different and has a higher expected value. This pattern is explainable, because answer 1 and 2 are variations on the same theme. We decided to retest variable 8; taking together answers 1 and 2.

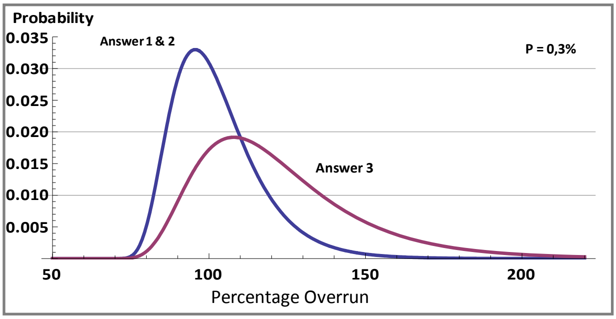


Figure 4-3. Distributions for project variable 8 samples. Answer 1 and 2 joined.

Answer	Expected value	n
1 & 2	103	23
3	122	19

Table 4-3. Key figures for project variable 8 samples. Answer 1 and 2 joined.

4.2 H_0 statement II – Variance of Project Budget

4.2.1 Overview

Statement II reads:

"Application of enterprise architecture is not significantly correlated with the variance of the actual project budget (as percentage of the planned budget)."

The hypothesis testing delivers the following results:

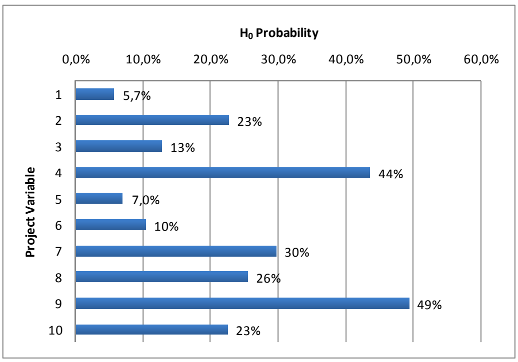


Figure 4-4. Probabilities H_0 Statement II

Appendices

4.2.2 Project Variable 1 – Architect involved in calculation

Variable 1 tests almost significant. The question and answers for project variable 1 are:

Question	Answer			Explanation
	1	2	3	
Was an architect involved in the technical calculation process?	Fully Involved	Partially involved	Not Involved	Fully involved means active participation in the calculations and discussions. Partially involved means reviewing the calculation that was done by someone else.

Table 4-4. Question and answers for project variable 1

The sample sizes for answers 1, 2 and 3 are respectively: 17, 4 and 19. The sample size for answer 2 is too small. We decided to eliminate answer 2 and retest the null-hypothesis. This gave the following result:

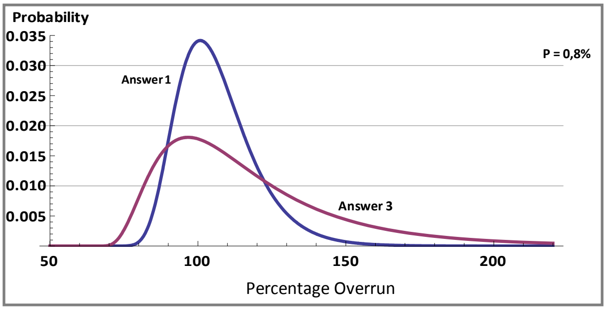


Figure 4-5. Distributions for project variable 1 samples. Answer 2 eliminated

Answer	Expected value	Standard Deviation	n
1	106	13	17
3	118	34	19

Table 4-5. Key figures for project variable 1 samples. Answer 2 eliminated

4.2.3 Project Variable 5 – Quality Project Architecture

Variable 5 also tests almost significant. The question and answers for project variable 5 are:

Question	Answer			Explanation
	1	2	3	
Quality of the project architecture	High quality: Complete, good-design, well-documented and usable by development. Solution is traceable to requirements.	Medium quality: architecture is usable but not optimal.	Poor quality: architecture is not relevant, or no project architecture is done	Architecture is the high-level design, which gives constrains, principles and the embedding to the outside world.

Table 4-6. Question and answers for project variable 5

Overview of the results for variable 5:

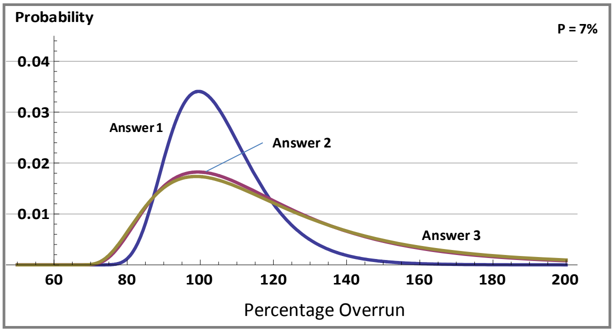


Figure 4-6. Distributions for project variable 5 samples

Answer	Expected value	Standard Deviation	n
1	105	13	22
2	118	32	15
3	120	35	5

Table 4-7. Sample size for project variable 5

The distributions for answer 2 and answer 3 are virtually identical. Apparently, in practice there is little difference between medium quality project architecture and poor quality project architecture. In addition, answer 3 has a small sample size. Therefore, we decided to retest with joined answers 2 and 3. With this, we compare high-quality project architecture with medium and poor quality project architecture.

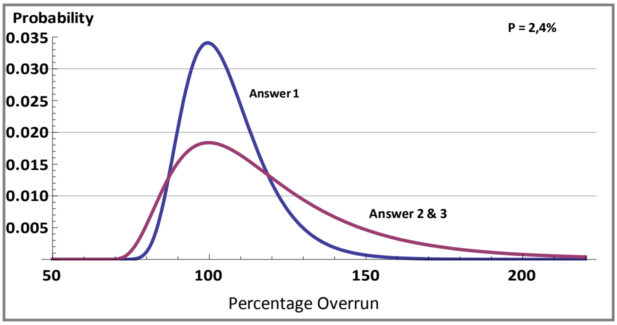


Figure 4-7. Distributions for project variable 5 samples. Answer 2 and 3 joined.

Answer	Expected value	Standard Deviation	n
1	105	13	22
2 & 3	119	31	20

Table 4-8. Key figures for project variable 5 samples. Answer 2 and 3 joined.

4.3 H_0 statement III – Expected Value of Project Timeframe

4.3.1 Overview

Statement III reads:

"Application of enterprise architecture is not significantly correlated with the expected value of the actual project timeframe (as percentage of the original timeframe)."

Hypothesis testing delivers the following results:

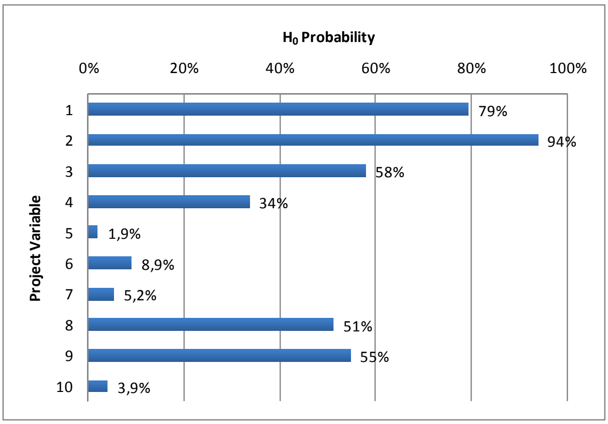


Figure 4-8. Probabilities H_0 Statement III

Variables 5 and 10 test significant while 6 and 7 are close.

4.3.2 Project variable 5 – Quality project architecture

See for the question and answers of variable 5 Table 4-6. Again, we join answer 2 and 3 together. Overview of the results for variables 5:

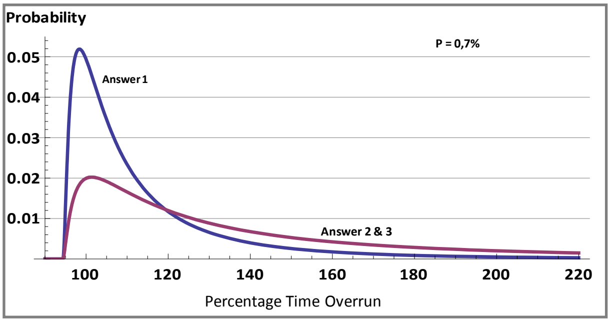


Figure 4-9. Distributions for project variable 5 samples. Answer 2 and 3 joined.

Answer	Expected value	n
1	116	24
2 & 3	171	20

Table 4-9. Key figures for project variable 5 samples. Answer 2 and 3 joined.

4.3.3 Variable 6 – Quality Domain Architecture

The question and answers for variable 6 are:

Question	Answer			Explanation
	1	2	3	
Quality of the custom-er's domain architec-ture	High: The Domain Architecture is up-to-date, complete, relevant and applicable	Medium: The Domain Architec-ture is present but not quite up-to-date or complete	Low: The Domain Architecture is out-of-date, incomplete or nonexistent	The domain architecture is the architecture of the organizational part. For instance the financial insti-tution may have a domain architecture for Credits, or for Mortgages, etc.

Table 4-10. Question and answers for project variable 6

Overview of the results for variable 6:

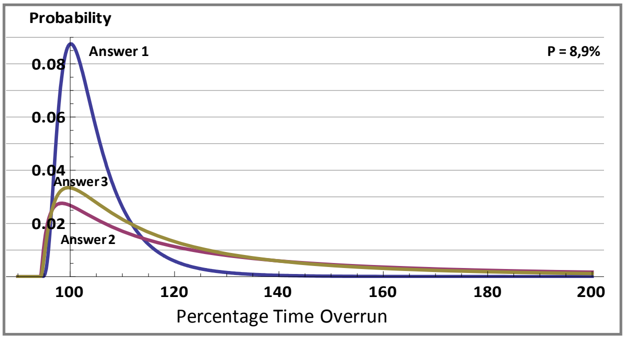


Figure 4-10. Distributions for project variable 6 samples

Answer	Expected value	Standard Deviation	n
1	105	8	8
2	164	165	22
3	133	65	14

Table 4-11. Key figures for project variable 6 samples.

The distributions for answer 2 and 3 are similar. If the combine these two answers, we get the following results.

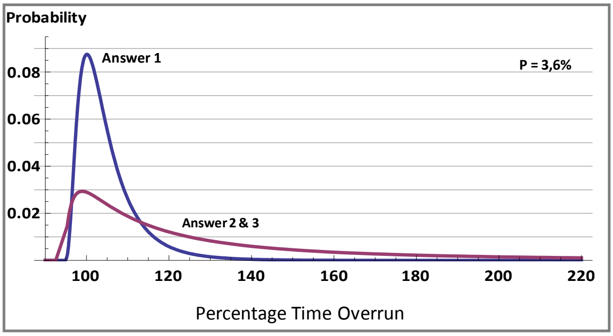


Figure 4-11. Distributions for project variable 6 samples. Answer 2 and 3 joined

Answer	Expected value	Standard Deviation	n
1	105	8	8
2 & 3	149	113	36

Table 4-12. Key figures for project variable 6 samples. 2 and 3 joined

4.3.4 Project Variable 7 – Quality Enterprise Architecture

The question and answers for variable 7 are:

Question	Answer			Explanation
	1	2	3	
Quality of the customer's enterprise architecture	High: The Enterprise Architecture is up-to-date, complete, relevant and applicable	Medium: The Enterprise Architecture is present but not quite up-to-date or complete	Low: The Enterprise Architecture is out-of-date, incomplete or nonexistent	The enterprise architecture is the architecture description, which applies to the whole organization.

Table 4-13. Question and answers for project variable 7

Overview of the results for variable 7:

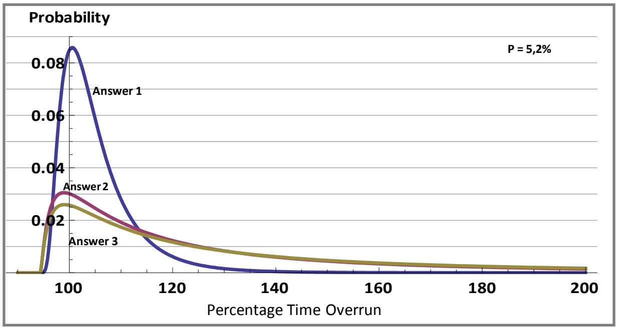


Figure 4-12. Distributions for project variable 7 samples

Answer	Expected value	Standard Deviation	n
1	105	7	9
2	145	101	19
3	162	149	16

Table 4-14. Key figures for project variable 7 samples.

We find that the sample distributions for answer 2 and 3 are alike, while the distribution for answer 1 is clearly different. We decided to join answer 2 and 3 and retest.

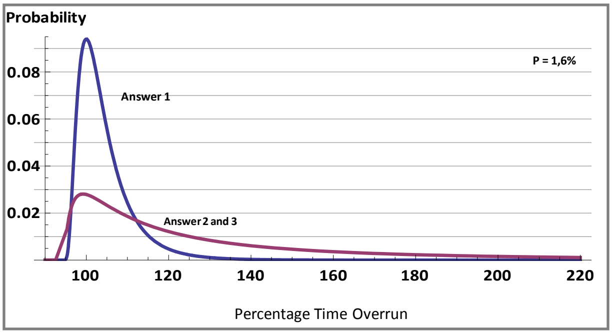


Figure 4-13. Distributions for project variable 7 samples. Answer 2 and 3 joined.

Answer	Expected value	Standard Deviation	n
1	105	7	9
2 and 3	151	115	35

Table 4-15. Key figures for project variable 7 samples. Answer 2 and 3 joined.

4.3.5 Project variable 10 – Compliancy Testing

The question and answers for variable 10 are:

Question	Answer 1	Answer 2	Answer 3	Explanation
Was there compliancy testing between architecture and project execution	Yes, there was a formal procedure where the controlling architect had to sign-off any significant discrepancies between architecture design and implementation.	Yes, there was a compliance procedure with a controlling architect. The procedure, however, was informal.	No, there was no compliancy testing between the architecture design and the implementation.	Compliancy testing assures that the architecture design is indeed followed during execution. This is generally done by a controlling architect.

Table 4-16. Question and answers for project variable 10

The sample sizes for answers 1, 2 and 3 are respectively: 4, 16 and 24. The sample size for answer 1 is too small. Answer 1 is eliminated and the null-hypothesis is retested. Overview of the retested results for variable 10:

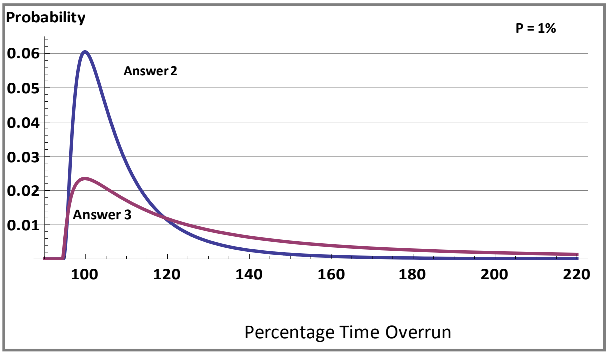


Figure 4-14. Distributions for project variable 10 samples. Answer 1 eliminated.

Answer	Expected value	n
2	110	16
3	166	24

Table 4-17. Key figures for project variable 5 samples. Answer 2 and 3 joined.

4.4 H_0 statement IV – Variance of Project Timeframe

4.4.1 Overview

Statement IV reads:

"Application of enterprise architecture is not significantly correlated with the variance of the actual project timeframe (as percentage of the original timeframe)."

The hypothesis testing delivers the following results:

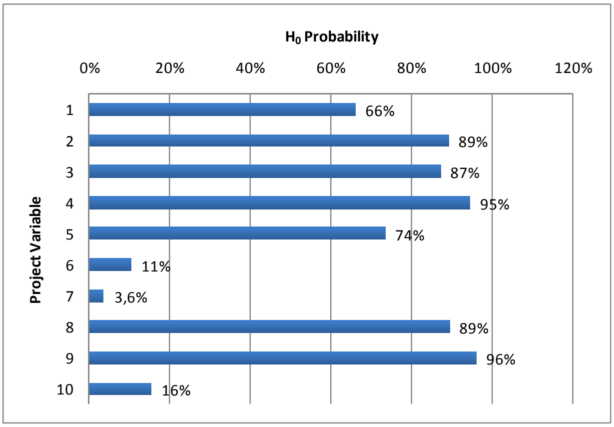


Figure 4-15. Probabilities H_0 Statement IV

4.4.2 Variable 7 – Quality Enterprise Architecture

Initially, project variable 7 has a p-value of 8%, for time variance. (The project variable is shown and examined on page 164.) Because answers 2 and 3 are alike, we decided to join them. After retest, the p-value is 3.5%, so the difference in variance has become significant.

4.5 H_0 statement V – Customer Satisfaction

Statement V reads:

"Application of enterprise architecture is not significantly correlated with the expected value of customer satisfaction."

The hypothesis testing delivers the following results:

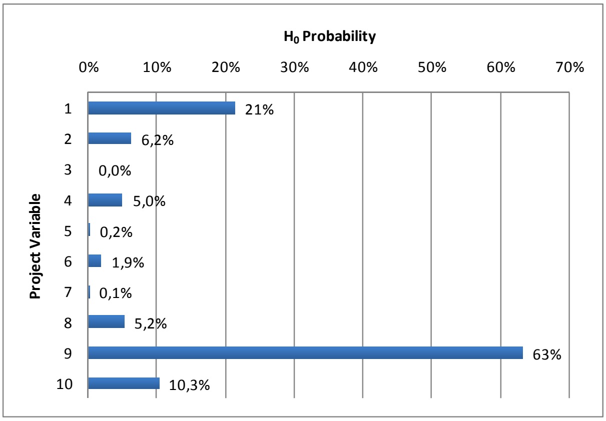


Figure 4-16. Probabilities H_0 Statement V

Variables 3, 4, 5, 6 and 7 test significant, while 2 and 8 are close.

4.5.1 Project variable 3 – Certification and Level Engagement

Questions and answers for variable 3 are:

Question	Answer			Explanation
	1	2	3	
Level of Certification of architect regarding the engagement	Certification level consistent or higher with engagement requirements	Certification level is under engagement level, but the architect is coached by experienced people	Certification level is under project level, no coaching was available	Is the (estimated) level of the engagements comparable with the level of certification of the architect?

Table 4-18. Question and answers for project variable 3

Overview of the results for variable 3:

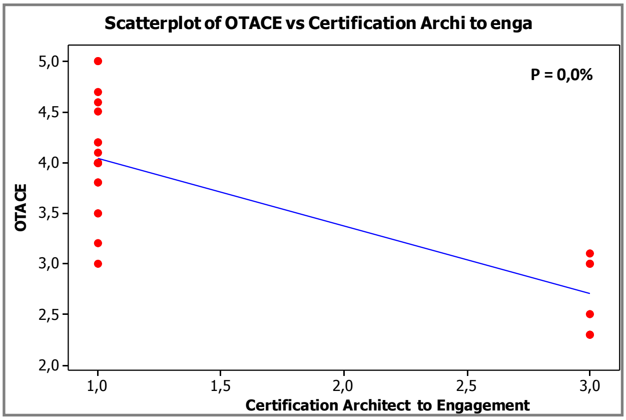


Figure 4-17. Regression for project variable 3

Formula $OTACE = 4.71 - 0.63 * Var3$

R^2 51%

Answer	OTACE	N
1	4.1	24
2	(Removed because of sample size of 2)	
3	2.8	6

Table 4-19. Key figures for project variable 3 regression

4.5.2 Project variable 4 – Level of Experience

Questions and answers for variable 4 are:

Question	Answer			Explanation
	1	2	3	
Level of experience of the architect	Architect has broad experience with this type of engagement	Architect has some experience with this type of engagement	Architect has no experience with this type of engagement	What was the previous experience of the architect with this type of engagement?

Table 4-20. Question and answers for project variable 4

Overview of the results for variable 4:

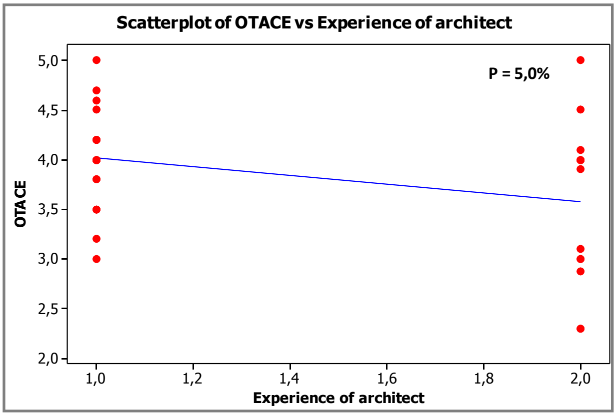


Figure 4-18. Regression for project variable 4

Formula $OTACE = 4.46 - 0.44 * Var4$

R^2 8.5%

Answer	OTACE	N
1	4.0	21
2	3.6	14
3	(Removed because of sample size of 1)	

Table 4-21. Key figures for project variable 3 regression

4.5.3 Project Variable 5 – Project Architecture

See for the question and answers of variable 5 Table 4-6. Again, we join answer 2 and 3 together. Overview of the results for variables 5:

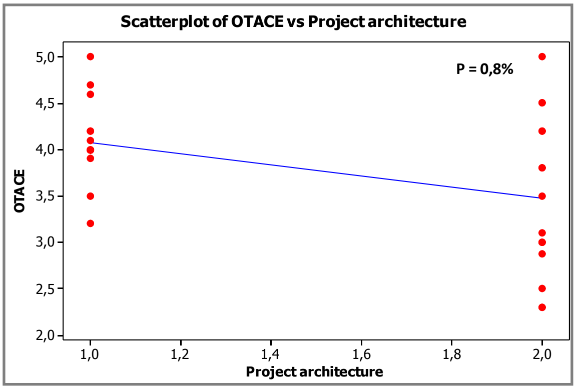


Figure 4-19. Regression for project variable 5

Formula	$OTACE = 4.67 - 0.60 * Var5$
R^2	16.8%

Answer	OTACE	N
1	4.1	20
2	3.5	16
3	(Removed because of sample size of 4)	

Table 4-22. Key figures for project variable 5 regression

4.5.4 Project Variable 6 – Domain Architecture

See for the question and answers of variable 6 Table 4-10. Overview of the results for variable 6:

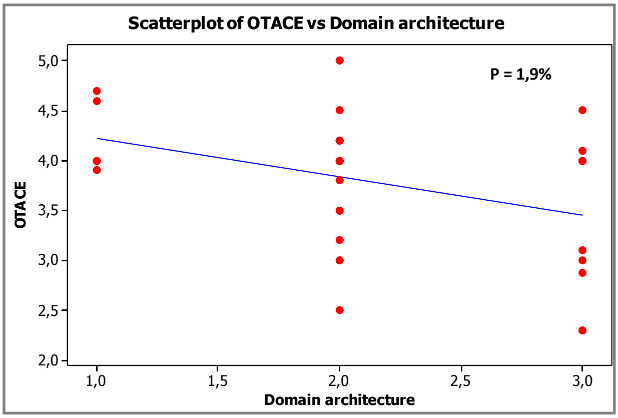


Figure 4-20. Regression for project variable 6

Formula	$OTACE = 4.61 - 0.39 * Var6$
R^2	12.5%

Answer	OTACE	N
1	4.2	7
2	3.8	19
3	3.4	10

Table 4-23. Key figures for project variable 6 regression

4.5.5 Project Variable 7 – Enterprise Architecture

See for the question and answers of variable 7 Table 4-13. Overview of the results for variable 7:

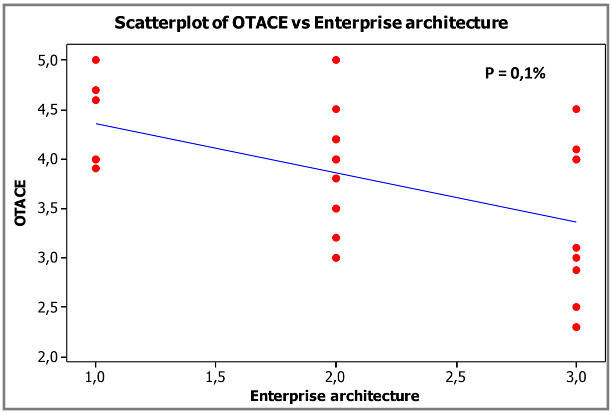


Figure 4-21. Regression for project variable 7

Formula	$OTACE = 4.86 - 0.50 * Var7$
R^2	24.3%

Answer	OTACE	N
1	4.4	7
2	3.9	18
3	3.4	11

Table 4-24. Key figures for project variable 7 regression

4.5.6 Other Variables

The project variable is 2 (Certification Architect) and 8 (Architecture Governance), tested almost significant. Nevertheless, none of these two variables became significant on closer examination.

4.6 H_0 statement VI – Percentage Delivered

Statement VI reads:

"Application of enterprise architecture is not significantly correlated with the expected value of the percentage delivered."

The hypothesis testing delivers the following results:

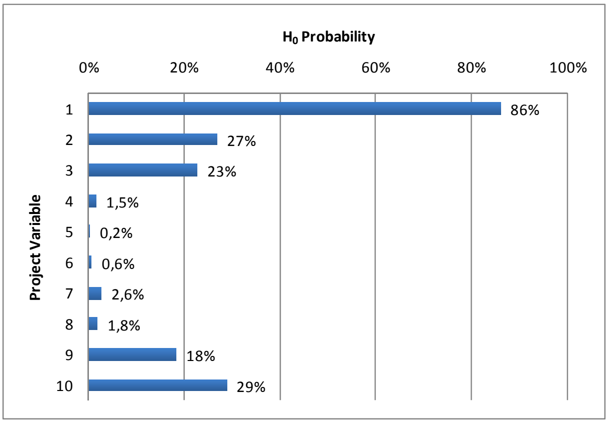


Figure 4-22. Probabilities H_0 Statement VI

Project variables 4, 5, 6, 7 and 8 test significant.

4.6.1 Project Variable 4 – Experience Architect

See for the question and answers of variable 4 Table 4-20. Overview of the results for variable 4:

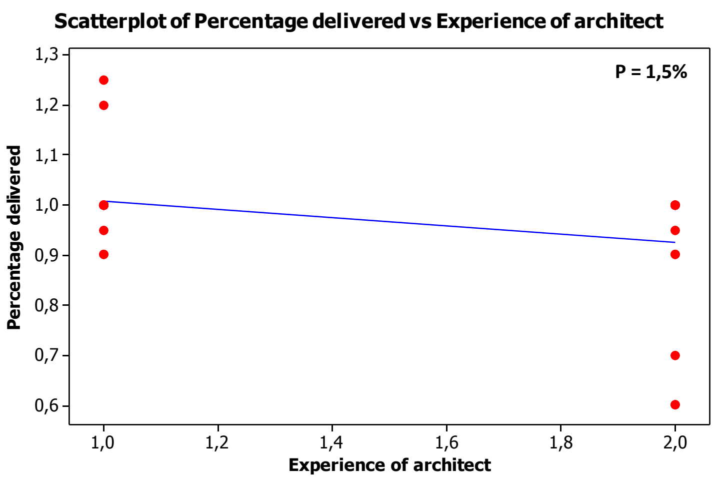


Figure 4-23. Regression for project variable 4

Formula	$PD = 109 - 8.30 * Var4$
R^2	11.6%

Answer	PD	N
1	100%	25
2	92%	18
3	(Removed because of sample size of 2)	

Table 4-25. Key figures for project variable 4 regression

4.6.2 Project Variable 5 – Project Architecture

See for the question and answers of variable 5 Table 4-6. Overview of the results for variable 5:

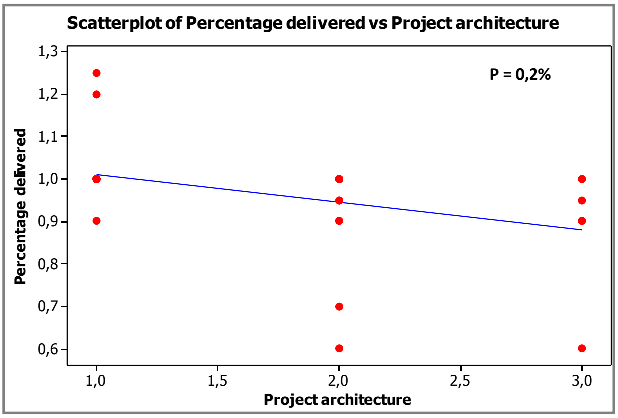


Figure 4-24. Regression for project variable 5

Formula	$PD = 108 - 6.54 * Var5$
R^2	16.9%

Answer	PD	N
1	101%	25
2	95%	16
3	88%	6

Table 4-26. Key figures for project variable 5 regression

4.6.3 Project Variable 6 – Domain Architecture

See for the question and answers of variable 6 Table 4-10. Overview of the results for variable 6:

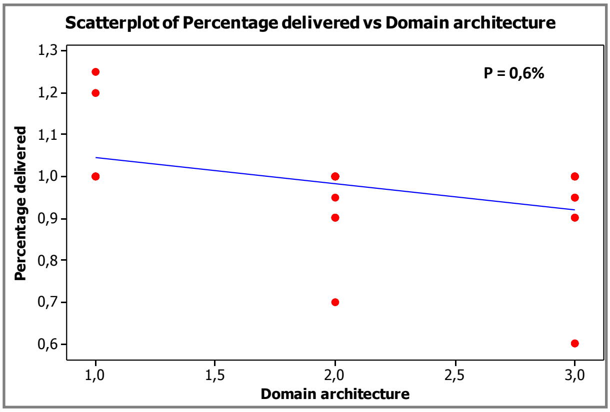


Figure 4-25. Regression for project variable 6

Formula	$PD = 111 - 6.18 * Var6$
R^2	13.8%

Answer	PD	N
1	105%	8
2	99%	24
3	92%	15

Table 4-27. Key figures for project variable 6 regression

4.6.4 Project Variable 7 – Enterprise Architecture

See for the question and answers of variable 7 Table 4-13. Overview of the results for variable 7:

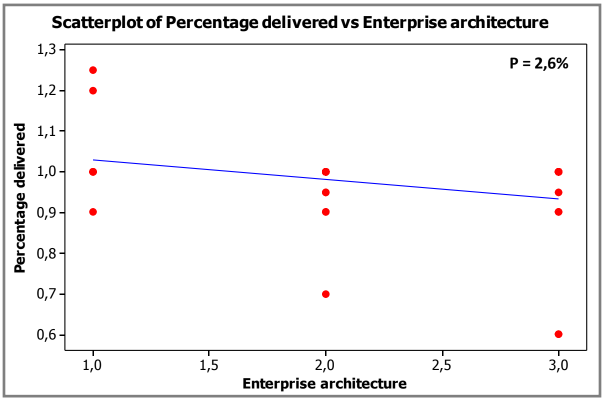


Figure 4-26. Regression for project variable 7

Formula	$PD = 108 - 4.78 * Var7$
R^2	8.6%

Answer	PD	N
1	103%	9
2	98%	21
3	94%	17

Table 4-28. Key figures for project variable 7 regression

4.6.5 Project Variable 8 – Architecture Governance

See for the question and answers of variable 8 Table 4-1. Overview of the results for variable 8:

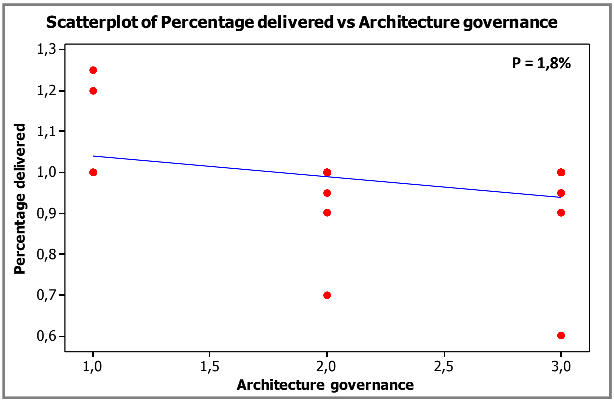


Figure 4-27. Regression for project variable 8

Formula	$PD = 109 - 5.1 * Var8$
R^2	10.2%

Answer	PD	N
1	104%	7
2	99%	18
3	94%	22

Table 4-29. Key figures for project variable 8 regression

4.7 H_0 statement VII – Functional Fit

Statement VII reads:

“Application of enterprise architecture is not significantly correlated with the expected value of the functional fit.”

The hypothesis testing delivers the following results:

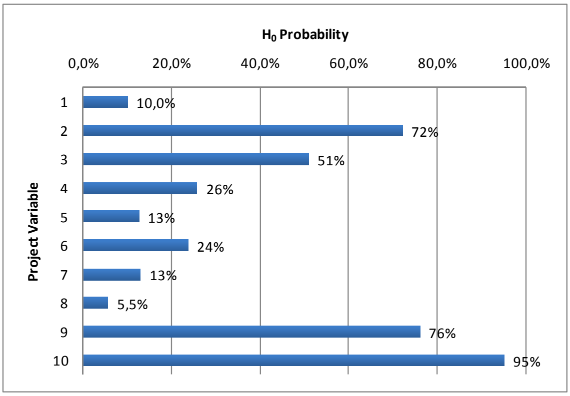


Figure 4-28. Probabilities H_0 Statement VII

None of the variables tests significant. Project variable 8 (Architecture Governance) is close. However, the variable did not become significant on closer examination.

4.8 H_0 statement VIII – Technical Fit

Statement VIII reads:

"Application of enterprise architecture is not significantly correlated with the expected value of the technical fit."

The hypothesis testing delivers the following results:

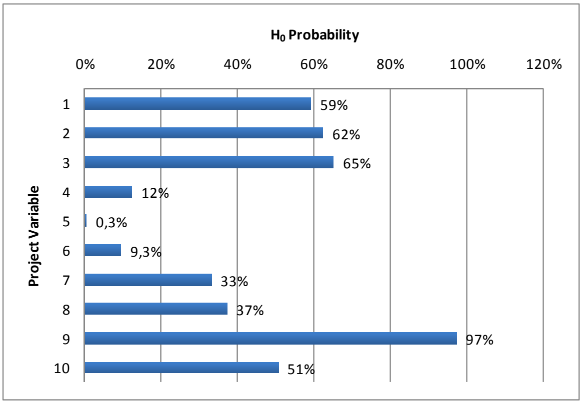


Figure 4-29. Probabilities H_0 Statement VIII

Project variable 5 tests significantly.

4.8.1 Project Variable 5 – Project Architecture

See for the question and answers of variable 5 Table 4-6. Overview of the results for variable 5:

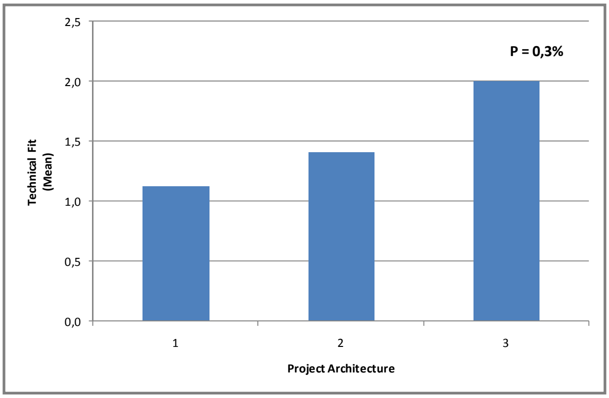


Figure 4-30. Means of technical fit versus project variable 5

Quality Project Architecture	Technical Fit	N
1 (high)	1.1	24
2 (medium)	1.4	17
3 (low or none)	2.0	6

Table 4-30. Key figures for project variable 8 Kruskal-Wallis test

Technical fit of the project results answer overview:

1 = *The project met all technical requirements*

2 = *The project met the main technical requirements*

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