MASTER THESIS

Using Enterprise Architecture for controlling complexity and improving business performance

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Abstract

Previous research has shown that the implementation of enterprise architecture (EA) in a company will be associated with several benefits and improvements in business performance, as EA will provide a holistic view of the organization as well as useful insights for organizing the IT systems and IT infrastructure in alignment with the business goals. Moreover, EA is a fundamental instrument in tackling and controlling complexity, and it examines the key business, information, application and technology strategies as well as their impact on the business functions. However, achieving a success in the implementation of EA is a major challenge that many organizations face, and thus many organizations are not able to address EA solutions for their organizational needs. Therefore, there are many cases when organizations or departments take the decision to make business or IT changes without considering their impact on the whole organizational architecture and thus this might lead to an increasement of complexity and has an impact on their business performance. This research aims to propose a method that consists of using enterprise architecture for controlling and reducing complexity, as well as for improving business performance. In order to achieve this goal, a design science research methodology was performed. The problem investigation phase is achieved through a systematic literature review and a survey is conducted in the case study. Based on the results of the problem investigation, the artifact (method) is designed. In order to show how this method could be implemented in a company, we have demonstrated its implementation in a case study. Finally, the method is validated through a diverse panel of experts by using a questionnaire which is based on the UTAUT model. Overall, the method is evaluated positively and is believed to contribute to the scientific community.

Key words:

Enterprise Architecture, complexity, business performance, ArchiMate.

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List of abbreviations

ADL	Architecture Description Language
ADM	Architecture Development Method
API	Application Programming Interface
BPMN	Business Process Model and Notation
BSC	Balanced Scorecard
DSRM	Design Science Research Methodology
EA	Enterprise Architecture
EABM	Enterprise Architecture Benefit Model
EAF	Enterprise Architecture Framework
FDP	FAIR Data Point
GUI	Graphical User Interface
IS	Information System
IT	Information Technology
KPI	Key Performance Indicator
ML	Machine Learning
PE	Process Engineer
QA	Quality Assessment
R&D	Research and Development
RASIC	Responsible, Approving, Supporting, Informed, Consulting
ROI	Return On Investment
RQ	Research Question
SLR	Systematic Literature Review
SWOT	Strengths Weaknesses Opportunities and Threats
TAR	Technical Action Research
UTAUT	Unified Theory of Acceptance and Use of Technology

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1.Introduction

1.1 Problem Statement

Nowadays, the relationships between business processes and IT systems that are part of an organization, are becoming more and more complicated. Sometimes these complex relationships among them are resulting from the variety and complexity that business processes and IT systems have. According to Hirvonen (2005), understanding the alignment between information technology and business is becoming a critical strategy enabler and it is considered a success factor for any organization due to the fact that this alignment is considered a key enabler in realizing value from IT investments (Earl, 1989; Henderson & Venkatraman, 1999).

Organizations have to deal with a large amount of information which differs in variety. A certain amount of information is required for completing or controlling a certain process. If the complexity of a process increases, then the information needed to complete or control that process will increase (Backlund, 2002). In addition, the growth of complexity of IT in organization makes the alignment between information IT and business processes more difficult and complex and this is leaning towards a demand of having a central instrument that could provide a holistic view of the organization (Seppanen et al., 2009).

Many organizations continue working and enlarging their business without having an enterprise architecture. According to Davenport and Prusak (1998), all organizations require data and some industries are extremely dependent on it. In addition, this data is being spread in different systems and it may be in different formats. Different departments may have different structures and may be using different IT systems. Employees that work in these large, international companies usually have to become familiar and to work with different IT systems as these are needed in their daily working tasks and processes (Davenport & Prusak, 1998). Despite being asked to do so, some of them might struggle with the complexity of these systems and have to spend many hours doing just some easy, simple tasks. This spread can lead to mis-alignments, mis-communication, to mistakes, to frustration, etc., between the employees within the same department and also with the other departments.

Miller (1995) and Fresse (1987) define the structure of an organization to be complex when:

1. It consists of many components or subsystems,
2. There are many relations and/or interactions between these components and/or subsystems,
3. When these relations are not symmetric,
4. When the arrangements of the components and/or subsystems are not symmetric,

5. There are a high number of different goals, plans and signals that are part of the timeframe.

Due to the fact that nowadays organizations have to deal with a complex environment (Child & Rodrigues, 2012), the management of the whole organization is becoming very difficult. There is a continuous need for organizations to comply with the changing environment.
In such cases, an organization needs to adapt (e.g., because there is a change in the market, a change in customer demands, a change in law and organization, a change in business goals, a change in technology, etc.), and if the organization is complex, this would be more difficult i.e. it would require more time, more money and more effort, as well as there is a small fraction of failure (Child & Rodrigues, 2012). Moreover, according to Van Der Raadt et al., (2010) the complexity that many large organizations face regarding their business processes and IT systems and procedures is not unique.

Enterprise architecture (EA) is a fundamental instrument in tackling and controlling this complexity (Van Steenbergen, 2011; Van der Raadt et al., 2004; Ross et al., 2006). Gartner (2012) defines enterprise architecture as a discipline for proactively and holistically driving enterprise responses to disruptive forces by identifying and analyzing the execution of change toward intended business vision and objectives. The most important characteristics of an enterprise architecture is to provide a holistic view of the organization and to provide the useful insights for organizing IT systems and infrastructure in alignment with the business goals and it examines the key business, information, application and technology strategies as well as their impact on the business functions (Van Steenbergen, 2011; Lankhorst, 2015; Rood, 1994).

1.2 Research Context and Motivation

In order to tackle the main problem of a need for change, which is described in the Problem Statement section, organizations must consider the implementation of an enterprise architecture, as the complexity of the organization will be reflected in this enterprise architecture.
Although the development and implementation of enterprise architecture started 30 years ago (Richardson et al., 1990), many organizations are still facing problems with EA implementation. Van Der Raadt et al., (2010) state that the main reason for this failure is that EA development is not an easy task and many organizations have not been able to address EA solutions for their organizational needs. According to Bakar et al., (2016) in a study about the assessment of EA implementation capability it is stated that Gartner Group has made a prediction that about 40% of EA implementations fail because the EA architects start with modelling rather than defining business needs and where the business must be in accordance to its IS and IT needs.

In addition, the achievement of IT business alignment must be a continuous process as it is influenced by changes in market conditions, by technological ongoing improvements as well as by the business strategy of the organization (Luftman, 2003). Achieving a success in the implementation of EA is a major challenge that many organizations face as this success also addresses the alignment between IT and business due to the fact that IT must support all the business processes (Wagner & Meshtaf, 2016).

As enterprise architecture needs to be expressed by an EA language (which is a notation), this is another reason for detecting complexity in the implementation of an EA. If there is an in-adequate notation which results in a dreadful (poor) design then the identified complexity is not due to the complexity of the organization, but it results from the architect, who is not using the notation properly (i.e., he does not use the right notation, he is using the notation not in the right way). Hence, the separation of these two sources of complexity must be determined.

Despite the above mentioned challenges, according to Adenuga et al., (2015) organizations must consider the implementation of EA as stakeholders could use this EA as means of communication, and it will enhance standardization, consistency, compliance and integration in the working environment. Therefore, the existing complexity of the organization will be reduced as the EA will harmonize the existing information systems, standards, policies, processes and the organization structure to the organization goals and objectives (Wagner & Meshtaf, 2016).

1.3 Research Goal

As previously mentioned, many companies are dealing with a high amount of complexity involved in their daily work and this complexity leads to a decrease of efficiency, to frustration, to more mistakes, etc. The main reason behind this is the non-existence of an enterprise architecture which will guide them through the need to change or adapt (as mentioned in section 1.2) and show its impact among different layers, before implementing this change. Thus, the high-level aim of this research is to improve the business performance by reducing the EA complexity that exists in an organization or in a department. Therefore, the main research question is:

Main RQ:

How can we improve business performance by reducing Enterprise Architecture complexity?

Furthermore, the main research question is further broken down into sub research questions and into knowledge questions which will be discussed in the following paragraphs.

Sub RQs:

1. What is the relationship between enterprise architecture and business performance?

To determine this sub research question the following knowledge questions must be considered.

a. What is EA?
b. What is the aim of having EA in an organization?
c. What is business performance?
d. How does EA contribute to business performance?

These knowledge questions will help in understanding the concepts: EA, business performance, the role that EA has in an organization, and the relationship between EA and business performance. Section 2 is focused on the background information and introduces the main contributions that are done in this field. Therefore, the above knowledge questions have been answered via the conducted SLR study (in the research topics paper).

2. What is the impact of EA benefit enablers to business performance?

This sub-research question is further divided into two knowledge questions.

a. Which are the main EA benefit enablers?
b. Which is a good approach for determining business performance?

In spite of the fact that section 2 gives all the crucial background information and the findings from literature, these questions will be answered there as well. First there will be an introduction to the main EA benefit enablers (section 2.3.1). Next the benefits of implementing EA will be discussed which will be associated with EABM models. Lastly, this section will introduce a good approach for measuring business performance and how it could be related to the EA benefit enablers.

3. How can we define complexity and how does it affect business performance?

This sub research question must be considered into two parts. The first part determines the dimensions of complexity and the complexity metrics, while the second part describes the proposed method, which is the main contribution of this thesis. In order to answer this sub research question, the following knowledge questions and design problem have been formulated:

a. Which are the dimensions of complexity?
b. Which are some metrics to measure complexity?
c. What is a good method that uses EA complexity management to improve business performance?

Sub-questions 3a and 3b are knowledge questions and they will be answered in section 2.3 via the conducted SLR. On the other hand, sub-question 3c is a design problem and it aims to propose a good solution (method) to the investigated problem.

As the proposed method is the artifact of this thesis, it will be elaborated on several sections. Therefore, first there will be the “design” of this method, which is part of the treatment design cycle, next the implementation of it in the case study, and lastly the treatment validation.

1.4 Research Methodology

The methodology of this research study adheres to the Design Science Research Methodology (DSRM) for research in the Information System (IS) field. Peffers et al., (2007) define design science as an attempt to create and evaluate artifacts, which are intended to serve human’s purposes(goals) and they propose a research process, composed of six phases. On the other hand, Wieringa (2014) defines design science as the design and investigation of artifacts in context, where the artifacts are designed to interact with a problem context in order to improve the conditions in that context. The design cycle is part of a larger cycle which is called the engineering cycle. The engineering cycle is defined as “*a rational problem-solving process*” and it is shown in figure 1 (Wieringa, 2014, p.27).

1. **Problem Investigation**: In this phase the main problem is identified and the motivation for handling this research is justified. A SLR research is conducted with the focus on the identification of existing contents and contributions on this field based on the guidelines by Kitchenham et al., (2009). Moreover, a survey is distributed to the employees of the case study so that they could share their opinion on their current working situation.

2. **Treatment design**: In this phase the main requirements are defined, and they are classified into functional and non-functional requirements. Eventually, the artifact that could treat the problem is designed. The artifact of this research is a method which consists of nine steps.

3. **Treatment Validation**: In this phase the validation of the designed artifact is done. There are several research methods that could be used. In our research, the research method that will be used for the validation is the expert opinion, which requires the formation of a group of experts.

4. **Treatment Implementation**: This phase aims to demonstrate the efficacy of the designed artifact in solving the problem in a case study. Therefore, in this phase, the enterprise architectures will be modelled. The baseline architecture will consist of several viewpoints, and it will help in a better understanding of the current situation. Next the target architecture will be modelled with the specification of the improvements and then a

migration plan will be made. In addition, in this phase there will be the measurement of business performance and the measurement of complexity.

5. **Treatment Evaluation**: In this phase, there will be an observation and measurement of how well the artifact (proposed architecture) supports a solution to the problem.

Figure 1 depicts the whole design cycle and the interactions between the five cycles.

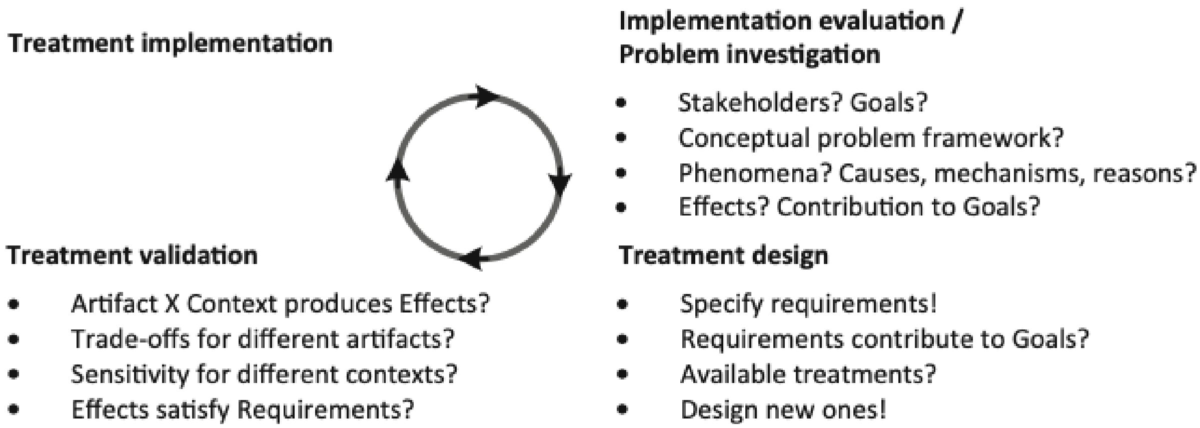


Figure 1.Design Science Engineering cycle (Wieringa, 2014, p.27)

1.5 Research Structure

The structure of this research will be in accordance with the research methodology phases. Hence, chapter 1 introduces the research and elaborates on the problem and justifies the motivation of doing this research. Chapter 2 describes some basic definitions in the EA field, elaborates on key concepts and describes the findings from the SLR research. Chapter 3 defines the requirements and designs the artifact as a solution to this problem. Chapter 4 shows the implementation of this artifact at the case study and chapter 5 demonstrates the validation of the designed artifact. Lastly, chapter 6 discusses the conclusions, the limitations and gives recommendations for future work. A detailed description of the research structure is given in table 1.

Thesis Chapter	Engineering cycle	Research Method	Research Question(s)
1. Introduction	Problem investigation	-	
2. Background	Problem investigation	SLR	RQ1 & RQ2 & RQ3
3. Treatment Design	Treatment Design	SLR	RQ3 (c)
4. Method Demonstration	Treatment Implementation	TAR and case study	RQ3(c)
5. Method validation	Treatment Validation	Expert opinion	RQ3(c)
6.Conclusion	-		

Table 1. Research structure

1.6 Systematic Literature Review Methodology

The systematic literature review that has been performed was based on the guidelines that are proposed by Kitchenham and Charters (2007) who conducted a SLR in software engineering, as well as on the paper by Rouhani et al., (2015) who have carried a SLR on EA implementation Methodologies. According to Kitchenham & Charters (2007) and Rouhani et al., (2015), a SLR process is composed of three major phases: planning, execution and result analysis (table 2). In this study, the execution phase was called the selection phase, as basically this phase handles the selection of the studies that were found in the scientific databases by using the inclusion and exclusion criteria.

Phase 1	Planning
1.1	Definition of the research questions
1.2	Selection of scientific databases
1.3	Formulation of search queries
1.4	Definition of inclusion and exclusion criteria
Phase 2	Selection of scientific databases
2.1	Execution of the formulated query on each scientific database
2.2	Selection of articles based on the inclusion criteria
2.3	Exclusion of irrelevant studies
2.4	Exclusion of duplicate studies
2.5	Evaluation based on full text & removal of short studies
Phase 3	Result Analysis
3.1	Data Extraction according to RQs
3.2	Quality assessment

Table 2**.** SLR phases and processes

The first phase in the SLR process was the planning which was focused on the definition of the objectives and the formulation of the research questions of the SLR, as well as on the specification of selecting the databases and the formulation of the search queries. Three scientific databases were chosen: IEEE, Springer Link and Google Scholar. These databases provide a good coverage of all the publications and developments in the field of EA and in IT systems. Then, the search queries were formulated based on the group of keywords that were related to the research questions and lastly, there was the formulation of the inclusion and exclusion criteria.

The second phase in the SLR process was the selection which was focused on the selection of the studies that were found in the scientific databases by using the inclusion and exclusion criteria. Once the potentially relevant studies had been found, they had to be assessed for their true relevance. The articles that were included in this study, were the ones that are focused on the EA field and on the implementation of EA, the articles that are published in English language because these indicates that these studies could have been peer reviewed internationally and highly cited papers about EA and/or IT systems and/or EA frameworks indicate that these studies have had a high impact on the field of EA and IT systems. On the other hand, the papers that are not considered are: the papers that are published not in English language, papers that are irrelevant to the research questions of this study as well as papers that are too short or incomplete. Hence, from the 660 studies that were previously found from the scientific databases, only 24 were selected.

After the selection of the primary papers, an extraction content that elaborates about the research purpose, research method and the output(s) of the papers was done. Most of the selected studies have used a literature review as their primary research method and have mostly outcomes in theoretical aspects. Interestingly, there were some studies that combine different research methods and/or have different outcomes.

Then, the next phase was the assessment of their quality. According to the SLR guidelines in the paper by Kitchenham (2009), four quality assessment (QA) questions had to be defined. These questions helped in the assessment of the research of each proposal and also provided a quantitative comparison between them. The whole research method chapter of the SLR can be seen in Appendix A, and the results from the SLR research are detailed in section 2.

2.Background

2.1 Enterprise Architecture

This background section describes some high-level information. It starts with an elaboration on the definitions of Enterprise Architecture and EA relationships. Section 2.1.2 discusses the implementation of EA in organizations and on the alignment and position of EA. Section 2.1.3 describes the EA modelling support tools and notation, and the ArchiMate language.

2.1.1 Definition of Enterprise Architecture

TEAF (2015) describes enterprise architecture as a blueprint for the system and the project that develops it. Enterprise architecture makes possible the creation of a relation between organizational mission, stakeholders' goals and objectives, business processes and the required IT infrastructure for executing them. Moreover, a good architecture design and documentation corresponds to an ease of maintenance so that the systems will not become obsolete before they are even built.

In other studies enterprise architecture is viewed as a discipline that consists of principles, methods and models that are used in the design and realization of an enterprise's organizational structure, business processes, IT systems and infrastructure (Lankhorst et al., 2010; Rood, 1994). Moreover, Lankhorst et al., (2010) argue that an enterprise architecture creates a holistic view of an organization and provides the useful insights for organizing IT systems and infrastructure in alignment with the business goals and it examines the key business, information, application and technology strategies as well as their impact on the business functions. Each of these strategies is a separate architectural discipline and the enterprise architecture is the connection and integration of all of them (figure 2).

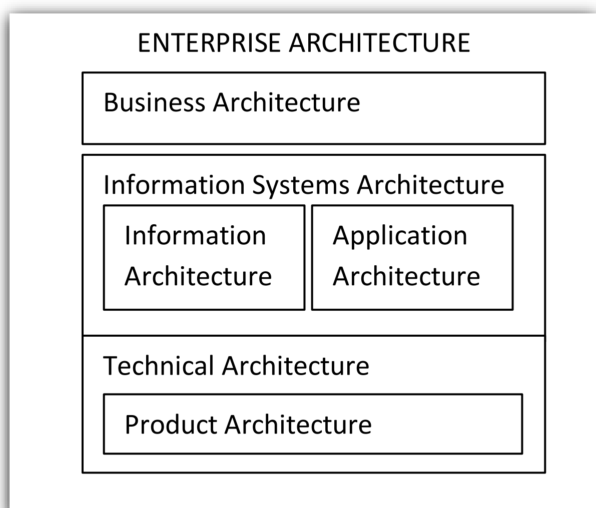


Figure 2. EA relationships

The ‘Business Architecture’ is focused on the definition of business processes, strategies and functional requirements. This architecture is the base of identifying the requirements for Information Systems, which are needed for supporting the business activities (Whittle & Myrick, 2016).

The ‘Information Architecture’ describes the various components that are related to the overall information infrastructure (e.g., the data’s physical and logical aspects, the management of data resources etc.). These components attempt to model the business model and the business requirements and aim to deliver an information system that will support the business processes and functions of the enterprise (Carter, 1999).

The ‘Application Architecture’ is concerned with the individual applications and their interfaces, and it provides a framework that is focused on the development, implementation and integration of all the applications that are required for the fulfillment of the business requirements (Mocker, 2009).

The ‘Technical Architecture’ is focused on the architecture of software-intensive systems, and it provides the necessary support in the foundations of the applications, data and processes that are used by a business (Booch, 2010).

The ‘Product Architecture’ is a subset of the Technical Architecture, and it is viewed as a scheme for the allocation of the product’s function to its physical components, as well as for the identification of standards and configurations for enabling the necessary technologies (Ulrich, 1995).

To conclude, all these architectures compose the Enterprise Architecture of an organization, and this enterprise architecture would not be fully implemented if one of these architectures is missing or if it is ignored.

2.1.2 EA in organizations

Some organizations settle enterprise architecture discipline to enable greater compatibility of information technology systems within their departments as well as for the integration of the IT components with the applications and the data (Boh & Yellin, 2014). In an organization, EA is focused on “*the integral structure of the processes, information distribution and technological infrastructure of the enterprise*” (van Steenbergen, 2011, p.3).

Tamm et al. (2011) argue that the aim of EA is the definition of a suitable operating platform which will serve in the supporting of an organization’s current and future goals as well as it will provide a roadmap for moving towards and achieving this vision. In addition, the primary goal of EA is to define the desirable future state (target architecture) of an organization in relation to its business processes and IT systems and to provide the migration plan to achieve this target architecture from its current (baseline) architecture.

Nowadays, there are some cases where EA is not only used as a top-down means for realizing the strategy of the organization, but it is also involved and helps in the formulation of the enterprise strategy (Ross et al. 2006; Radeke, 2011). In addition, Bookholt (2014) has come up with a visualization for the position of EA in an organization (figure 3), which shows that EA contributes to the organization's strategy and it is composed of the baseline architecture and the target architecture of the organization. In addition, EA defines the gap that exists between the baseline architecture and the target architecture of an organization and guides on the possible migration plan.

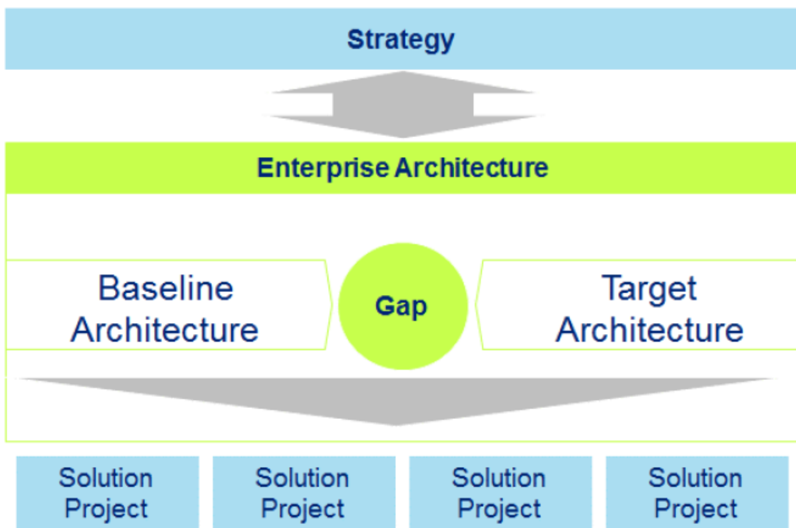


Figure 3. Position of EA in an organization (Bookholt, 2014)

2.1.3 EA Modelling support tools and Notation

Over the past years, many frameworks have been proposed for modelling enterprise architectures. However, many of these developed frameworks cannot guide in the development of detailed metamodels and provide a modelling notation. A complete approach for EA requires the coverage of the three main aspects. These aspects are: a *framework* (for supporting the subdivision of an architecture in different domains), a *language* (for defining the concepts that describe an architecture) and a *process* (for describing the way of working) (Iacob et al., 2012). Figure 4 illustrates how these aspects are related to each other.

According to Iacob et al., (2012) the ArchiMate open standard can fill the modelling gap and replace informal and proprietary techniques. Moreover, for covering the three aspects, ArchiMate could be combined with one the existing framework. Iacob et al., (2012) have demonstrated that the combination of TOGAF ADM with ArchiMate is operational and feasible.

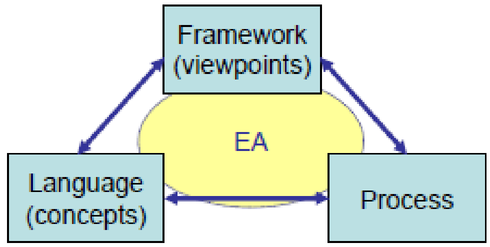


Figure 4. Aspects of the EA approach (Iacob et al., 2012)

2.1.3.1 The ArchiMate language

Some years ago, many business practices were struggling with the integration of their business processes and IT. This demand of integration triggered the development of the ArchiMate language which was developed as an open standard. ArchiMate is considered as an architecture description language (ADL) for enterprise architecture (Lankhorst et al., 2010). It serves organizations with a visual language for modelling, describing, analyzing and communicating concerns and solutions to the involved stakeholders. Lankhorst et al., (2009) highlighted that a main goal of the ArchiMate language is to deliver means for integration so that models can depict high-level structures within domains. Moreover, the ArchiMate Specification is an Open Group Standard that serves as an open and independent modeling language for EA (Josey et al., 2016).

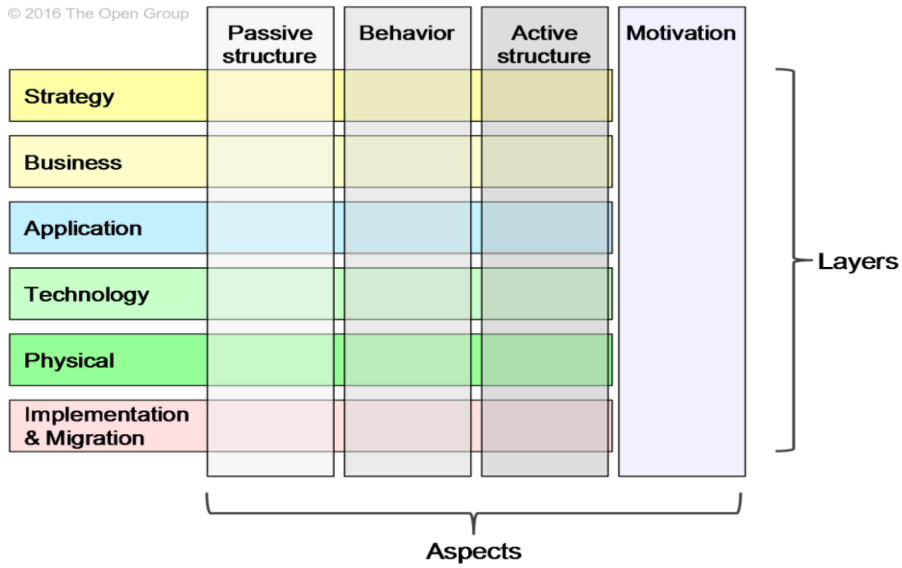


Figure 5. The ArchiMate framework (Iacob et al., 2012)

The ArchiMate language consists of five primary components: a framework, an abstract syntax, the language semantics, a concrete syntax and viewpoints (Iacob et al., 2012).
The ArchiMate framework (figure 5) consists of three aspects: Passive structure, Behavior, and Active structure and of seven layers: Strategy, Business, Application, Technology, Physical, Implementation and Migration, and Motivation layer.
Each layer is represented by corresponding elements which can be seen in figure 6.

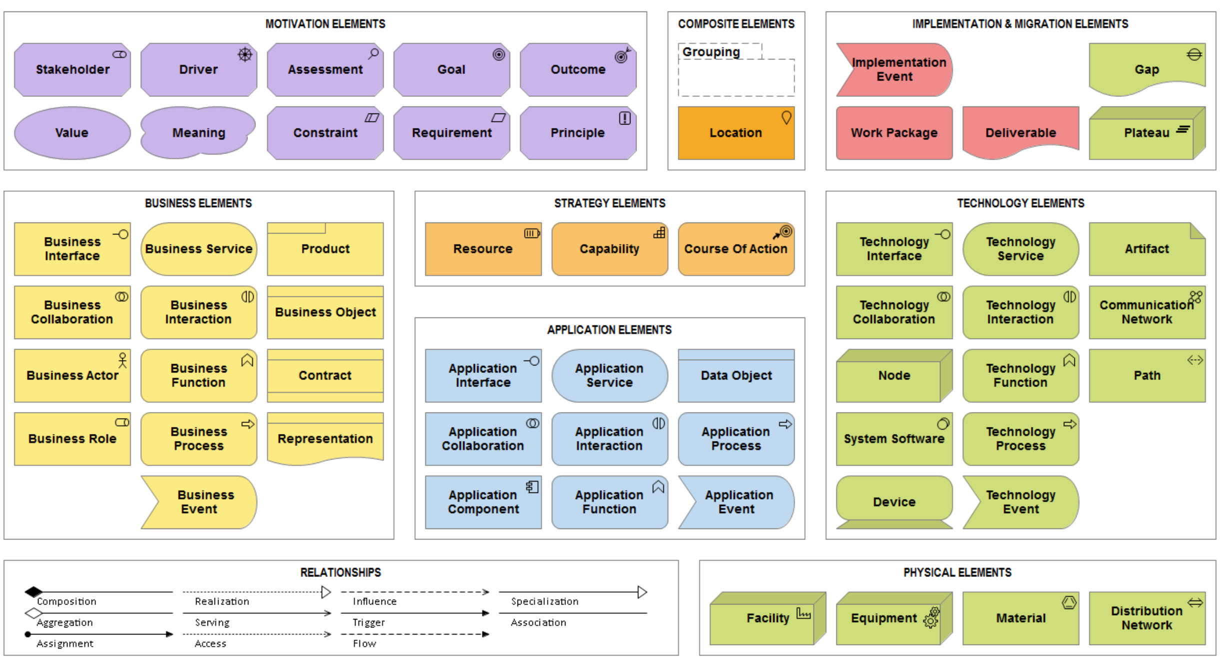


Figure 6. The ArchiMate elements (Iacob et al., 2012)

Structural Relationships		**Notation**	**Role Names**
Composition	Represents that an element consists of one or more other concepts.		← composed of → composed in
Aggregation	Represents that an element combines one or more other concepts.		← aggregates → aggregated in
Assignment	Represents the allocation of responsibility, performance of behavior, storage, or execution.		← assigned to → has assigned
Realization	Represents that an entity plays a critical role in the creation, achievement, sustenance, or operation of a more abstract entity.		← realizes → realized by
Dependency Relationships		**Notation**	**Role Names**
Serving	Represents that an element provides its functionality to another element.		← serves → served by
Access	Represents the ability of behavior and active structure elements to observe or act upon passive structure elements.		← accesses → accessed by
Influence	Represents that an element affects the implementation or achievement of some motivation element.	+/-	← influences → influenced by
Association	Represents an unspecified relationship, or one that is not represented by another ArchiMate relationship.		associated with ← associated to → associated from
Dynamic Relationships		**Notation**	**Role Names**
Triggering	Represents a temporal or causal relationship between elements.		← triggers → triggered by
Flow	Represents transfer from one element to another.		← flows to → flows from
Other Relationships		**Notation**	**Role Names**
Specialization	Represents that an element is a particular kind of another element.		← specializes → specialized by
Relationship Connectors		**Notation**	**Role Names**
Junction	Used to connect relationships of the same type.	(And) Junction Or Junction	

Table 3. ArchiMate relationship types and Notation (The Open Group n.d)

To connect the different elements that exist from different layers with each other, there are several types of relationships that can be used. As defined by ArchiMate 3.0 Specification, there are four relationship categories: *Structural relationships* which model the static construction or composition of concepts of the same or different types, *Dependency relationships* which show how elements are used to support other elements, *Dynamic relationships* which are used to model behavioral relationships and *Other relationships* which do not fall in one of the above categories. Table 3 shows the relationships categories and their types.

2.1.3.2 The ArchiMate language and the TOGAF ADM

As previously mentioned, for achieving a complete EA approach all the three aspects should be covered. The combination of the ArchiMate language with the TOGAF Architecture Development Method is very comprehensive. TOGAF is owned by the Open Group (The Open Group n.d) and is a tool or process used to develop different information technology (IT) architectures. In addition, TOGAF is a vendor and a technology neutral architecture framework that enables the tools and methods to design, produce, use and maintain an enterprise security architecture as well as it provides a tested and iterative process for developing enterprise architecture (Rouhani et al., 2013).

TOGAF and ArchiMate complement each other as TOGAF provides an elaborate method which includes processes, guidelines and techniques while ArchiMate provides a well-defined language which also includes a graphical notation for EA modelling (Iacob et al., 2012). Figure 7 shows a mapping of how ArchiMate can be used in relation to the phases of the TOGAF ADM (Josey et al., 2016).

The Business, Application and Technology layer in the ArchiMate language cover the description of the Business, Information systems, and Technology architecture of the ADM cycle. The Strategy and Motivation elements of the ArchiMate language can support the Requirements Management, Preliminary, and Architectural Vision phases of the TOGAF ADM.
The Implementation and Migration elements of the ArchiMate support the implementation and migration of the Opportunities and Solutions, Migration Planning and Implementation Governance.

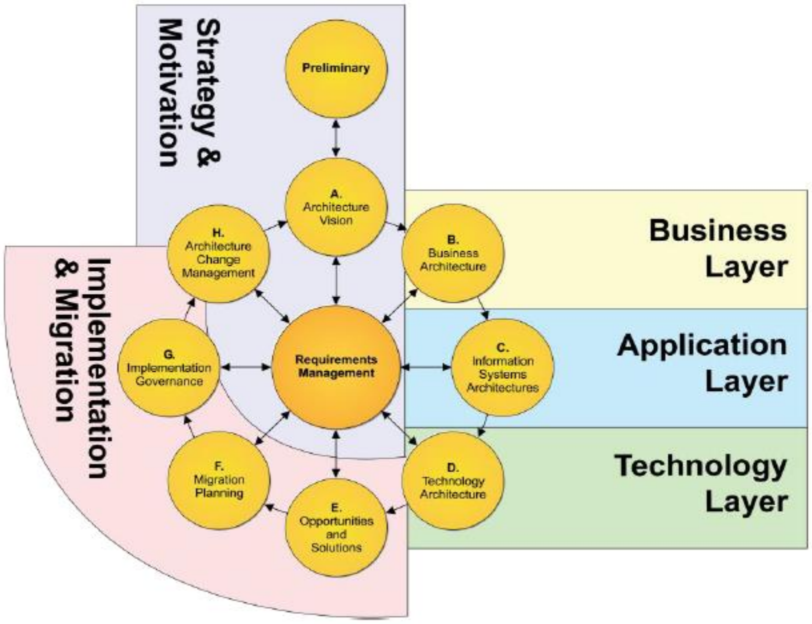


Figure 7. Mapping between the ArchiMate language & TOGAF ADM (Josey et al., 2016)

2.2 Complexity

Complexity is often defined as the state of having many parts or components and being difficult to understand or work efficiently with them. Similarly, in previous research studies, complexity is related to the number of components or elements, to the number of existing relationships, to the variety or variation, and to heterogeneity (Davis & LeBlanc, 1988; Kinsner, 2008; Flood & Carson, 1993). Interestingly, Schutz et al., (2013) have concluded that the total amount of complexity of an EA must consider the existing complexity within each domain as well as the complexity of the relations between the domains. Hence, section 2.2.1 describes the classification of complexity, section 2.2.2 identifies some of the metrics of measuring complexity and section 2.2.3 elaborates on the role that EA has in dealing with complexity.

2.2.1 Classification of complexity

Over the last decades, there have been many studies in complexity science and in the aspects of complexity. Schneider et al., (2014) have presented four dimensions of complexity: ordered complexity vs. disordered complexity, qualitative vs. quantitative complexity, subjective vs. objective complexity and structured vs. dynamic complexity. The first dimension (ordered complexity vs. disordered complexity) is based on the number of variables that have to be considered. Organized complexity refers to a moderate number of variables, whereas disorganized complexity refers to a large, inconsistent number of variables or to an unknown number of variables. The second dimension (qualitative vs. quantitative complexity) makes a distinction between quality and quantity, where the qualitative complexity refers to the qualitative evaluation of a certain number of attributes of variables in a system. Moreover, the third dimension (subjective vs. objective) of complexity is based on the role that the observer has. Hence, objective complexity refers to the notion of being independent of any observer, while subjective complexity occurs when there is at least one individual who is observing a system.

Lastly, the fourth dimension (structured vs. dynamic complexity) refers to number of system components, where structural complexity refers to the number of variables, as well as to the cause-effect relationship among them, and dynamic complexity refers to the observation of the interdependencies and to the changes of interactions that may happen between the variables of a system. Schneider et al., (2014) have shown that the identified dimensions are independent from each other but not exclusive, meaning that each notion of a given dimension could be combined with another notion from another dimension. In addition, Schneider et al., (2014) have designed a framework in which each dimension is orthogonal to all the others (figure 8).

In this framework (figure 8), the 1^{st} dimension is clustered in the x-axis, the 2^{nd} dimension is in the z-axis and the 3^{rd} dimension is clustered in the y-axis, where each notion is represented by a single small cube. For visualizing the 4^{th} dimension (ordered vs. disordered complexity) they have used different colors within the cube (dark blue=ordered, light blue=disordered).

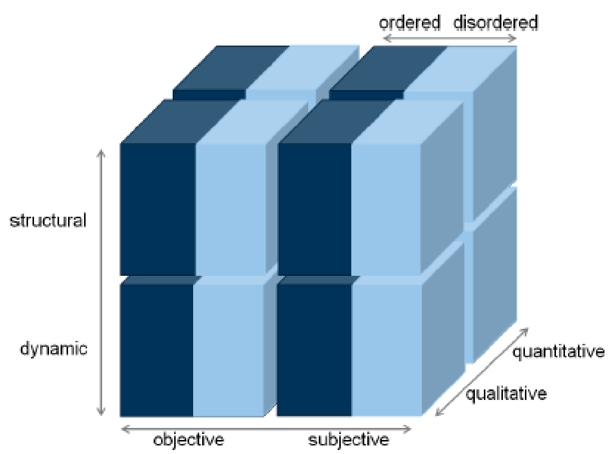


Figure 8. Complexity dimensions (Schneider et al., 2014)

Similarly, Efatmaneshnik and Ryan (2016) have conducted research with the focus on objective and subjective complexity and they have proposed a general framework for measuring the complexity of a system. In this framework (figure 9), subjective complexity is relative to the observer, whereas objective complexity is independent of the observer. Moreover, all the elements in this framework are context dependent.

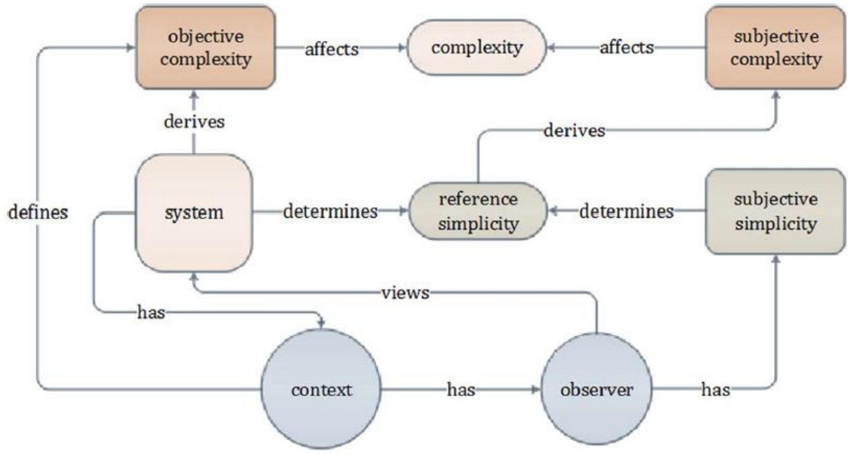


Figure 9.Objective and Subjective complexity (Efatmaneshnik & Ryan, 2016)

Jochemsen et al., (2016) state that capturing the subjective complexity can help organizations to manage their IT architecture more efficiently. Cognitive software complexity has been studied for a long time and thus, there are many exciting cognitive complexity metrics. Cant et al., (1995) measured cognitive complexity in terms of relative time that it takes a test group to understand a pattern. Hence, Cant et al., (1995) define cognitive complexity as the mental processes a software engineer uses for interpreting code. These processes consist of searching and processing. A further specification is shown in figure 10, where the cognitive complexity of a software is classified into problem complexity, stakeholder characteristics and structural complexity (Cant et al., 1995).

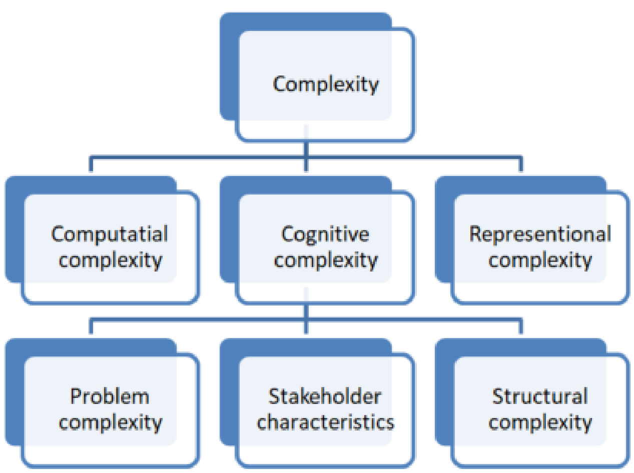


Figure 10. Cognitive complexity classification (Cant et al., 1995)

There are several principles that aim to maximize cognitive effectiveness. Moodly (2009) has defined four main principles which can be seen in table 4.

No.	**Principle**	**Explanation**
1	Perceptual discrimination	The detection of different features is figures, e.g., color, shape or size.
2	Perceptual configuration	Refers to visual characteristics.
3	Working memory	Makes possible that information is temporarily stored.
4	Long-term memory	Prior knowledge which guides on the transformation of information from working to long-term memory.

Table 4. Principals for cognitive effectiveness (Moodly, 2009)

Another aspect of complexity is focused on representational complexity. Lantow (2014) states that the level of detail in documentation, has an impact on the understanding. Moreover, Moodly (2009) states that the visual notation (e.g., the EA viewpoints) greatly affect the understanding.

2.2.2 The metrics for measuring complexity

Nowadays, there are many metrics for measuring complexity. Iacob et al., (2018) have carried out a SLR for the identification of existing complexity metrics in the different dimensions, and then have carried semi-structured interviews for gaining insights in the perceptions from the stakeholders of an organization and in the subjective complexity attributes. The outcome from the SLR study was the identification of 42 metrics (table 5), which were categorized in consideration to the complexity dimensions in figure 8. Some of the found metrics are: *the number of relations, the number of existing elements or cardinal elements, the element entropy, the relation entropy, the number of patterns, the propagation cost* etc.

Nr	Metric	Objective / Subjective	Structural/ Dynamic	Quantitative/ Qualitative	Ordered/ Disordered
1	Number of relations	Objective	Structural	Quantitative	Ordered
2	Number of elements	Objective	Structural	Quantitative	Ordered
3	Number of cardinal elements	Objective	Structural	Quantitative	Ordered
4	Number of cardinal relations	Objective	Structural	Quantitative	Ordered
5	Cyclomatic Complexity	Objective	Structural	Quantitative	Ordered
6	Element Entropy	Objective	Structural	Quantitative	Disordered
7	Relation Entropy	Objective	Structural	Quantitative	Disordered
8	Conformity	Objective	Structural	Quantitative, qualitative	Disordered
9	Interface Complexity Multiplier	Objective	Structural, Dynamic	Quantitative, qualitative	Ordered, Disordered
10	Redundancy	Objective	Structural	Quantitative, qualitative	Disordered
11	Number of OS and middleware	Objective	Structural	Quantitative	Ordered
12	Functions/systems	Objective	Structural	Quantitative	Ordered
13	Number of patterns	Objective	Structural	Quantitative	Ordered
14	Application age	Objective	Structural	Quantitative	Ordered
15	Number of hardware platforms	Objective	Structural	Quantitative	Ordered
16	Betweenness centrality	Objective	Structural	Quantitative	Disordered
17	Quantified expert opinion	Objective	Structural	Quantitative	Ordered
18	Pattern coverage	Objective	Structural	Quantitative	Ordered
19	Elements/ type	Objective	Structural	Quantitative	Ordered
20	Relations/elements	Objective	Structural	Quantitative	Ordered
21	Processes/elements	Objective	Structural	Quantitative	Ordered
22	Elements/process	Objective	Structural	Quantitative	Ordered
23	Service-time Actual	Objective	Structural	Quantitative	Ordered
24	Domains/Application	Objective	Structural	Quantitative	Ordered
25	Software categories/app	Objective	Structural	Quantitative	Ordered
26	SLOC	Objective	Structural	Quantitative	Ordered
27	Halstead difficulty	Objective	Structural	Quantitative	Ordered
28	Number of functions	Objective	Structural	Quantitative	Ordered
29	Apps/user	Objective	Structural	Quantitative	Ordered
30	Customization	Objective	Structural	Quantitative	Ordered

31	Number of instances	Objective	Structural	Quantitative	Ordered
32	Number of software frameworks	Objective	Structural	Quantitative	Ordered
33	Number of new applications	Objective	Structural	Quantitative	Ordered
34	Number of retired applications	Objective	Structural	Quantitative	Ordered
35	Number of physical servers	Objective	Structural	Quantitative	Ordered
36	Number of virtual servers	Objective	Structural	Quantitative	Ordered
37	Visibility Fan-In	Objective	Structural	Quantitative	Ordered
38	Visibility Fan-Out	Objective	Structural	Quantitative	Ordered
39	Requirements/ app	Objective	Structural	Quantitative	Ordered
40	Propagation cost	Objective	Structural	Quantitative	Disordered

Table 5. Complexity metrics (Iacob et al., 2018)

After doing the clustering of these metrics, Iacob et al., (2018), observed that there is a very low variation among the metrics among the dimensions, where 79% of them can be described as: objective-structural-quantitative-ordered. Furthermore, 98% of the found metrics are clustered at the objective dimension.

All things considered, the different dimensions of complexity help better in understanding the roots of complexity in an organization. Many metrics that help in measuring the complexity have been identified and a classification of the complexity metrics on these dimensions is shown in table 5.

2.3.3 The role of EA in dealing with complex IT systems

Having an EA for your organization will impact a lot your business as EA will provide an integrated view of the organization, where all the aspects are considered (van Steenbergen, 2011). This integrated view presents design and modeling choices among the business, IS and Technical architecture. Moreover, this study has stated that EA offers many benefits that are related to complexity and deals with reducing it and offers an increase in the understatement and a better communication within the organization.

Another study by Rojas et al., (2017) states that so far there are many existing initiatives to measure the complexity of specific architectures for IT systems and the approaches that are done during the implementation stage have resulted to be very accurate for measuring the structural complexity of IT systems. These approaches enable the identification of what reduces complexity (e.g., the high cohesion between the elements) and on the other hand what increases complexity (e.g., the high coupling between the elements).

Furthermore, Boh and Yellin (2014) have conducted an empirical study about the usage of EA standards and their results show that the use of EA standards is effective in helping organizations for a better management of their IT systems and resources. In addition, EA addresses the double challenge of increasing IT efficiency as well as the continuing of business innovation (Shah & Kourdi, 2007).

In spite of the integrated view that is enabled from the EA, many prior studies have shown that EA will also make the complexity manageable, and it will prevent the increasement of further complexity within the organization (Lankhorst et al., 2005; Van der Raadt et al., 2004; Ross et al., 2006).

To conclude, there are many studies that have been conducted on the identification of the role that Enterprise Architecture has played in the existing complexity within an organization. Many researchers have found out that EA helps a lot in facing the challenges of reducing complexity and it offers a better alignment between the business processes and IT systems.

2.3 Business Performance

Business performance is defined as "*the operational ability to satisfy the desires of the company's main stakeholders*" (Smith & Reece,1999, p. 153), and if an organization aims to enlarge its business and to know it's accomplishments then the business performance must be assessed and measured properly (Smith & Reece, 1999). By looking in the existing literature it reveals that EA benefits do not have a direct influence on business performance, but benefit enables do. Hence, section 2.3.1 elaborates on benefit enablers and on the relationship that exists between EA activities, benefit enablers and business performance. Section 2.3.2 describes the contribution of EA to the business performance and section 2.3.3 elaborates more on the implementation of EA in an organization and on the potential benefits.

2.3.1 Benefit Enablers

In this thesis, an activity is a work that is performed within a business process. An activity can be atomic or not atomic (OMG, 2011). Hence, Architecture Development can be viewed as a business process of an EA department and EA activities determine: as-is (baseline) architecture, to-be (target) architecture, gap analysis etc.

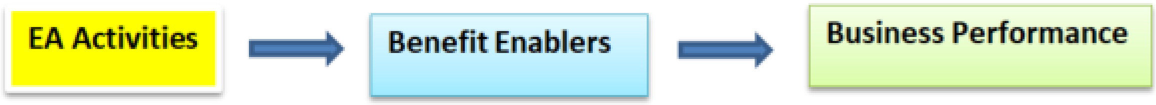


Figure 11. The relationship between EA activities & Business performance (Tamm et al., 2011)

Tamm et al., (2011) have named the intermediate benefits (figure 11) as benefit enablers. Based on the literature, it can be pointed out that one of the benefits which takes a lot of attention is *Organizational Alignment* (Chan & Reich, 2007). More specifically, the alignment of business and IT is a potential benefit that comes from implementing EA in an organization (Brown, 2004; Rakede 2011; Tamm et al., 2011; van der Raadt et al., 2008; Radeke, 2011). Figure 12 represents an overview of all benefit enablers. *Organizational Alignment* is the extent to which the subunits of an organization share a common understanding, the *Information Availability* is the extent of useful, high-quality accessible information, *Resource Portfolio Optimization* is the extent to which an organization makes use of its existing resources and makes new investment, and lastly, *Resource Complementarity* is the extent to which the resources of an organization support the achievement of its goals (Tamm et al., 2011).

The Information Availability refers to a good quality of information in terms of accuracy, accessibility and completeness (Lee et al., 2002). The Resource Portfolio Optimization is focused on organizational resources. In the case of EA, the crucial resources are the human resources, IT and organizational processes. Possible optimization may refer to the removal of non-value-adding human or IT resources or replacing them with better alternatives. Resource Complementary is similar to Resource Portfolio Optimization, but this benefit enabler refers to the combination of existing resources in new and innovative ways, which can provide the organization with a better competitive advantage (Tamm et al., 2011).

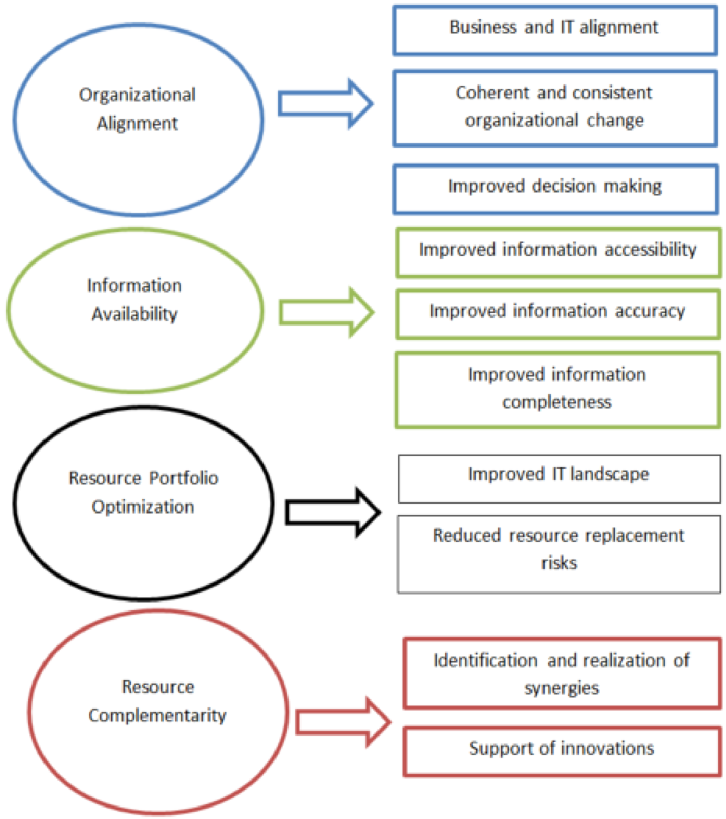


Figure 12. Overview of benefit enablers (Bookholt, 2014)

2.3.2 EA contribution to Business Performance

The impact of Enterprise Architecture on business performance can be defined in different ways. Business objectives are goals that organizations set and try to fulfill in order to achieve a better business performance. A good approach for defining business objectives is the Balanced Scorecard (BSC). The balanced scorecard can be seen as the heart of an organization's efforts which shows how results are achieved, and defines and communicates the priorities to the managers, employees, investors and to customers (Kaplan & Norton, 1993). It consists of four perspectives: *Financial*, *Customer*, *Internal*, and *Learning & Growth* perspective.

The financial perspective of the BSC describes the business performance outcomes in terms of financial indicators (e.g., ROI, cost reductions, etc.) (Kaplan & Norton, 1992). The customer perspective concerns indicators that refer to the organization' value propositions for its customers (e.g., number of products, customer satisfaction, etc.), the internal perspective describes indicators which are related to critical key processes for the realization of the outcomes in the financial and customer perspectives, and the learning & growth perspective describes intangible business outcomes and it is concerned with the type of jobs and systems and the organizational characteristics (e.g., culture, alignment, etc.) (Kaplan & Norton, 1992).

Similarly, EA benefits are used to describe organizational outcomes. A detailed elaboration on EA benefits can be seen in section 2.3.3. Many researchers (Boucharas et al., 2010), Plessius, Slot, & Pruijt, 2012) support the alignment of the BSC structure with the EA benefits. An overview of this alignment is shown in figure 13, where on the left side there are the BSC perspectives and on the right side the EA benefits.

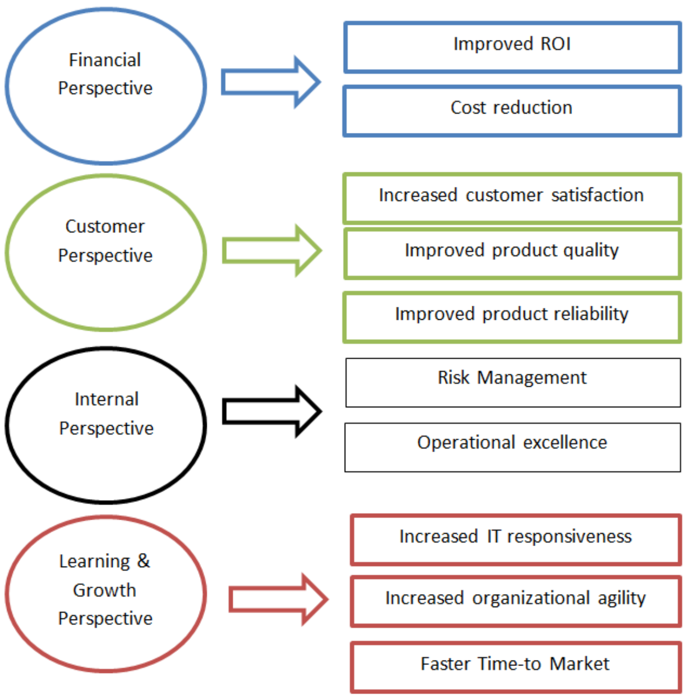


Figure 13. Business performance benefits (Bookholt, 2014)

2.3.3 Benefits of implementing EA and its role in the business performance

Many researchers and practitioners have conducted studies for the identification of the EA benefits and they argue the existence of a various number of valuable benefits that arise in the organization from the implementation of Enterprise Architecture.

Niemi (2006) and Boucharas et al., (2010) have published studies with the focus on charting the benefits of EA by conducting a literature review and then a focus group interview of practitioners on the results from the literature review. The most cited benefits in the literature review and in the focus group interviews are:

1) reduced costs, which is related to other benefits, e.g., reduction of duplication, integration of systems etc.
2) providing a holistic view of the enterprise,
3) improved business and IT alignment by defining a common business vision by EA,
4) improvement in change management by documenting the current state, the target state and the transitions plans,
5) improvement in risk management by preparing an enterprise for unplanned changes,
6) improvement of interoperability and integration by increasing collaboration between organizational functions, and
7) shortened cycle time, which is related to reuse of standardization.

In addition, Niemi and Pekkola (2019) have handled another study and their conclusion was that organizations benefit from EA in different stages: since the initiation when comprehensive understanding is required up to years later when measurable outcomes (e.g., cost savings) are materialized. They had conducted a review of literature on EA benefits and the outcome was a list of a total 250 different benefits which have a different range: very abstract benefits such as business-IT alignment up to concrete, measurable benefits such as cost reduction. Moreover, Niemi and Pekkola (2019) have conducted also a qualitative case study in a large Finnish public-sector organization and their results indicate that organizations can benefit from EA from day one, until the later stages when measurable outcomes take place.

The results from these studies are shown in figure 14, where the EA benefits are categorized by Niemi (2006) according to the Giaglis et al., model.

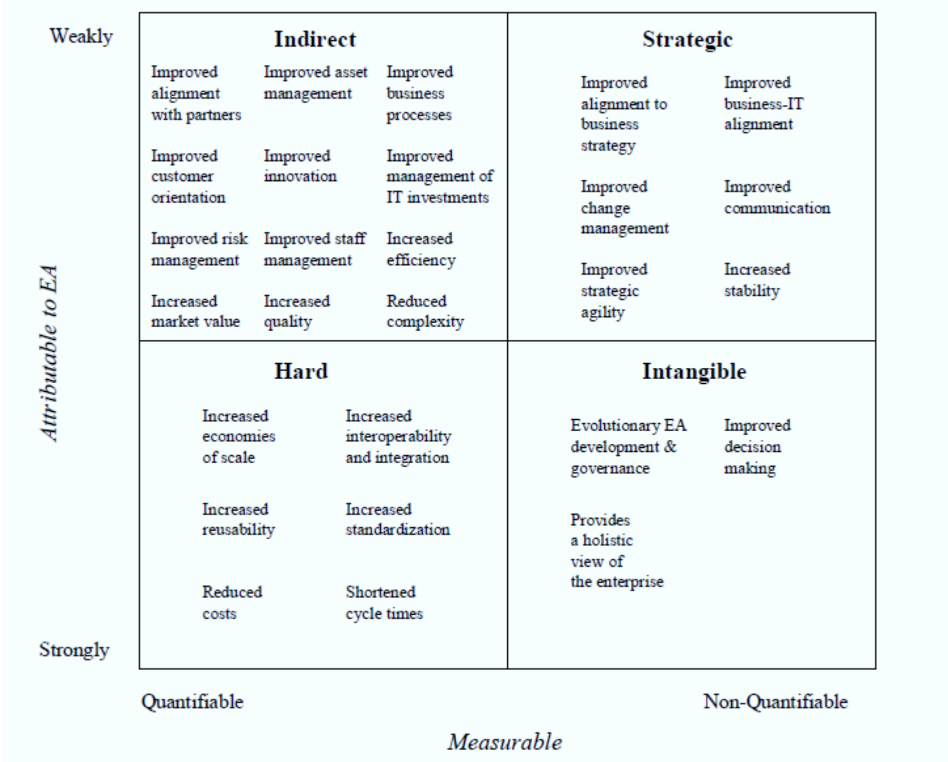


Figure 14. Categorization of EA benefits (Niemi, 2006)

A company can utilize enterprise architecture for a better organization and structure of enterprise-wide information by providing the appropriate architectural details, design choices and models to different stakeholders of the organization (e.g., end-users, engineer architects, systems architects etc.) (Shah & EL Kourdi, 2007).

Furthermore, Boucharas et al., (2010) have identified the contexts for which Enterprise Architecture has been found to be of value and then, they have classified them into an Enterprise Architecture Benefits Map (EABM). The EABM (figure 15), is a good visual-oriented way of presenting the EA benefits and their relationships so that they can be easily understood and effectively and efficiently utilized in an enterprise. As shown in (figure 15), the EABM consists of four main Perspectives, where each perspective consists of several categories. The four Perspectives are: the Financial Perspective, which consists of the Financial Outcome Benefit Category, the Customer Perspective, which consists of the Customer Outcome Benefit Category, the Internal Perspective that describes the different business process benefits-results, and lastly the Learning & Growth Perspective, which describes the different intangible asset benefit-results.

By observing the EABM (figure 15), there is a noticeable difference in the mapping of the benefits among the different perspectives. Almost 50% of the identified benefits from Boucharas et al., (2010), belong to the Learning & Growth Perspective, around 30 % to the Internal Perspective, 16% is clustered in the Financial Perspective, and thus less than 5% of the benefits are presented at the Customer Perspective.

On the other hand, as mentioned also in the previous section Tamm et al., (2011) have constructed an EABM by clustering the benefits in different perspectives that are called EABM constructs or Benefit Enablers. These constructs (figure 16) are: the Organizational Alignment, Information Availability, Resource Portfolio Optimization and Resource Complementarity.

There are eight relationships that exist in this EABM model. P1a-P4a describes the relationship of EA quality with the benefit enablers, whereas P1b-P4b describes the relationship of benefit enabled with the organizational benefits. Moreover, a difference among the thickness of the arrows (figure 16) is quite noticeable. The thickness of the arrows in P1a-P4a determine the strength of the relationship, based on how the EA plans are dependent on these benefit enablers. Hence, the organizational alignment (P1a) is achieved to a large extent through the EA plans, Information Availability (P2a) is partly contingent on enactment as it is presented as a thin line, Resource Portfolio Optimization and Resource Complementary are dependent partially through the EA plans as they are presented with thin dotted lines.

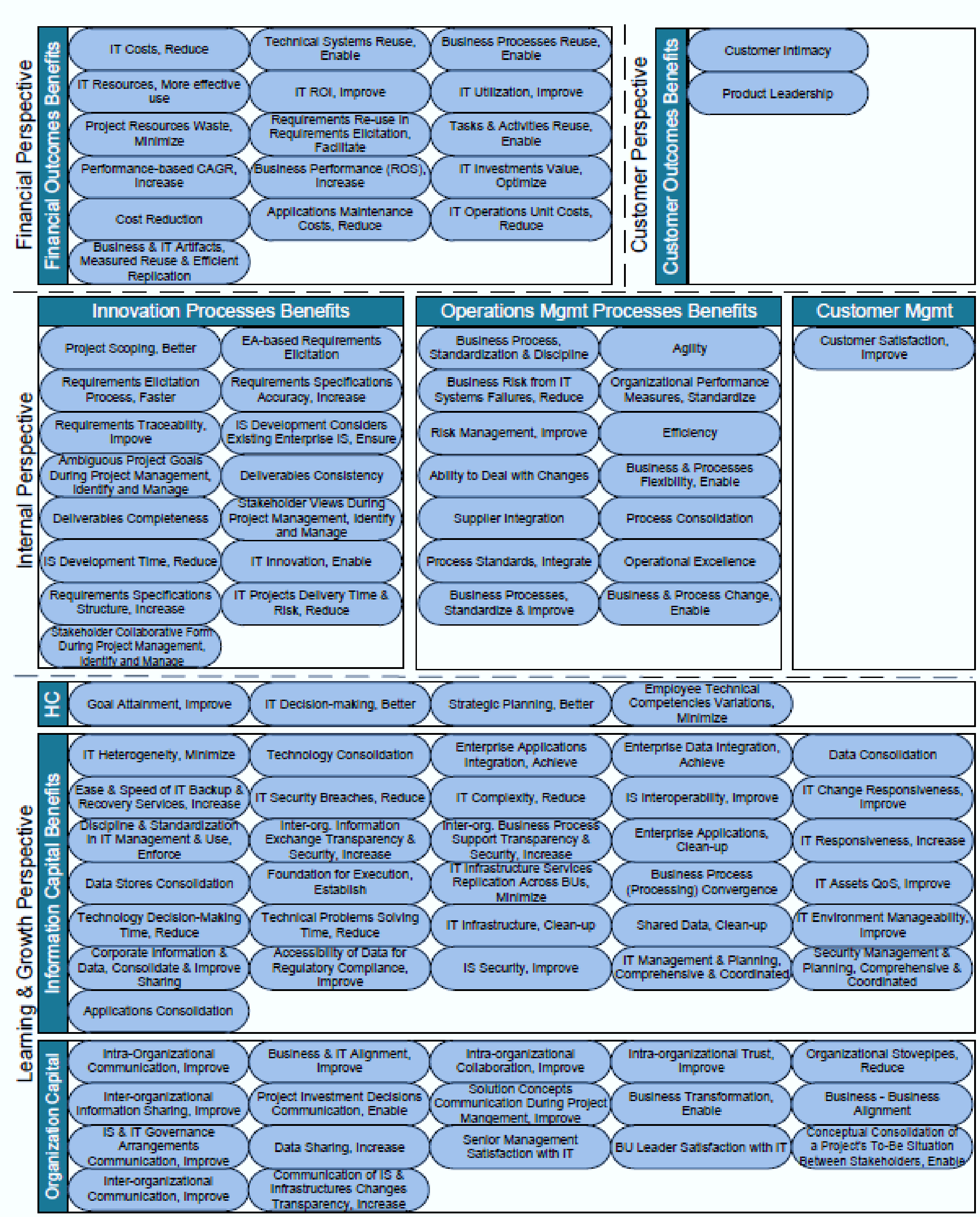


Figure 15. Enterprise Architecture Benefit Map (Boucharas et al., 2010)

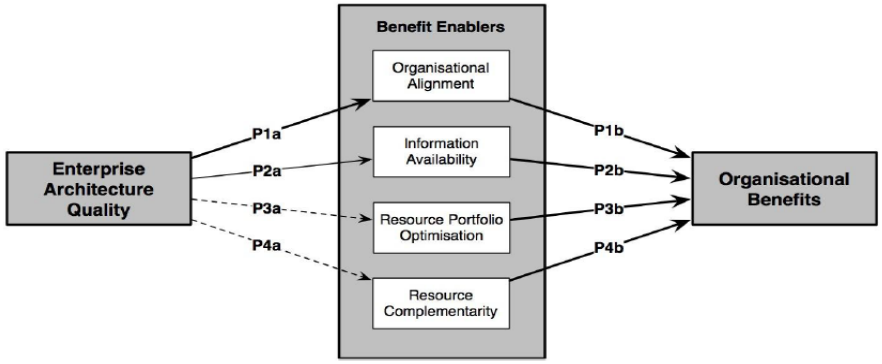


Figure 16. EA Benefits model (2) (Tamm et al., 2011)

Moreover, Alwadain (2019) has carried out an interesting study with the focus on the development of a conceptual EA-benefits realization process model. For the development of this model, Alwadain (2019) was based on the theoretical basis of how IT and Enterprise Architecture create business value in the paper by Tam et al., (2011). The process theory model with the focus on "how IT creates business value" is composed of three interconnected process models (figure 17).

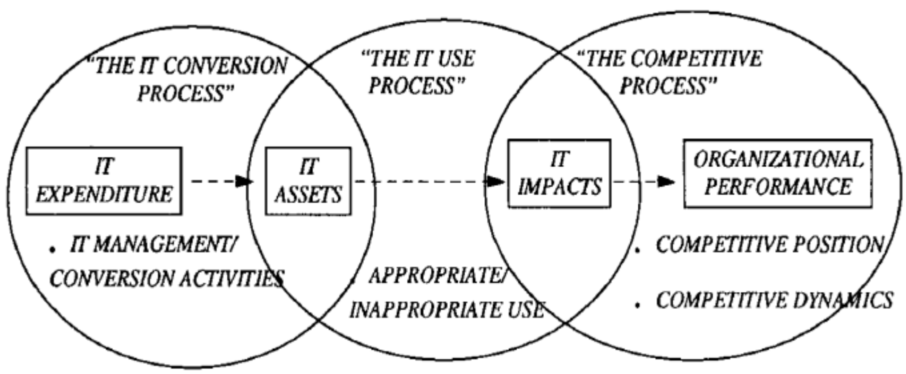


Figure 17. The process theory of how IT creates business value (Alwadain, 2019)

The first process in this model (figure 17), is the IT conversion process in which the EA investments are turned into EA assets, the second process is the IT use process that is concerned with the effective development and usage of EA assets in order to generate positive EA impacts, and thirdly the competitive process describes how the impact of enterprise architecture leads to enhanced business performance.

In addition, another interesting classification was done by Tamm et al., (2011) who based the classification on the benefit enablers: Organizational Alignment, Information Availability, Resource Portfolio Optimization and Resource Complementarity, whereas Boucharas et al., (2010) have classified the benefits into the four perspectives of the Balanced Scorecard (BSC): financial, customer, internal and Learning & growth business performance factors. An interesting alignment of these two models has been done by Bookholt, (2014) and the relationships between them are shown in figure 18.

Organizational Alignment (benefit enabler) has a positive influence on the financial and learning & growth-related business performance factors. Information Availability is claimed to improve customer, internal and learning & growth-related business performance factors. To continue, the third benefit enabler, Resource Portfolio Optimization influences positively all the four perspectives of the BSC, and lastly Resource Complementarity has a positive influence on the customer and internal business performance factors.

To sum up, from the selected studies it was possible to identify an enormous number of benefits that are enabled from enterprise architecture. It is clear that EA plays an important role in business performance, and it helps in the realization of organizational goals.

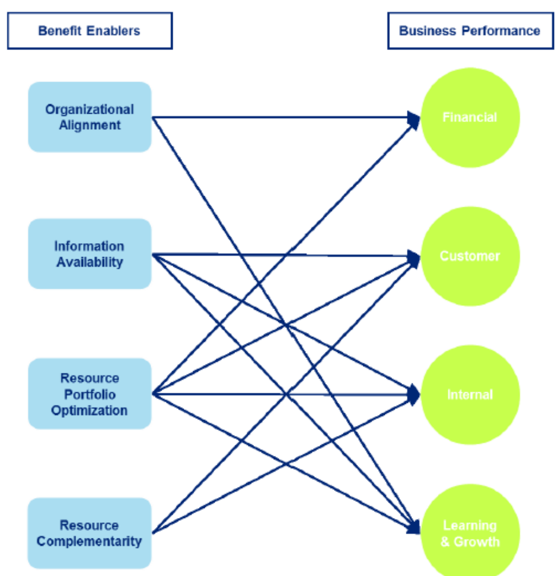


Figure 18. Relationships between benefit enablers & business performance (Bookholt, 2014)

2.4 A survey about complexity

As part of the problem investigation phase of the engineering cycle, a small survey with the focus on the employees in the Mould department was conducted. The aim of this survey is to understand better the current situation and the complexity that the whole department is dealing with. The survey consists of two parts and in total there are 11 questions. During the past meetings with the Mould department employees, many of them mentioned the usage of a high number of IT systems that are needed in their daily work. Hence, in this survey the first question is about the number of IT systems that are being used and most of them have said that they use between 10- 20 IT systems (figure 19).

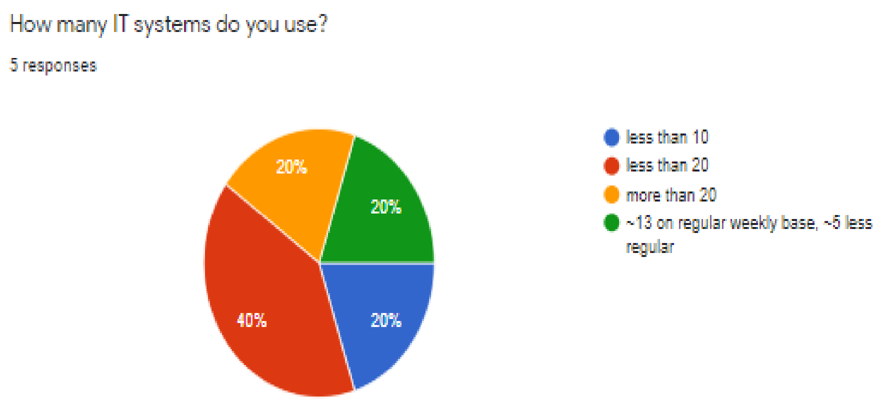


Figure 19. Number of IT systems

To continue, another question is about defining the amount of existing complexity by using the Likert scale. As shown in figure 20, 60% of the respondents are dealing with a medium amount of complexity and 40% are dealing with a high amount.

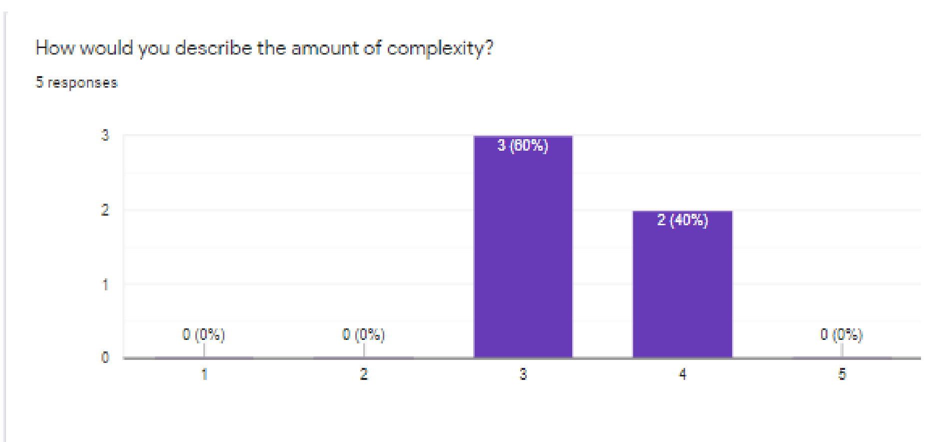


Figure 20. The amount of complexity

Moreover, the employees were asked to share their opinion about the effects that complexity has on business performance, and 80% have responded that complexity results in a reduction of efficiency, more required time and in the existence of misalignments (figure 21). The whole survey and all the responses are shown in Appendix B.

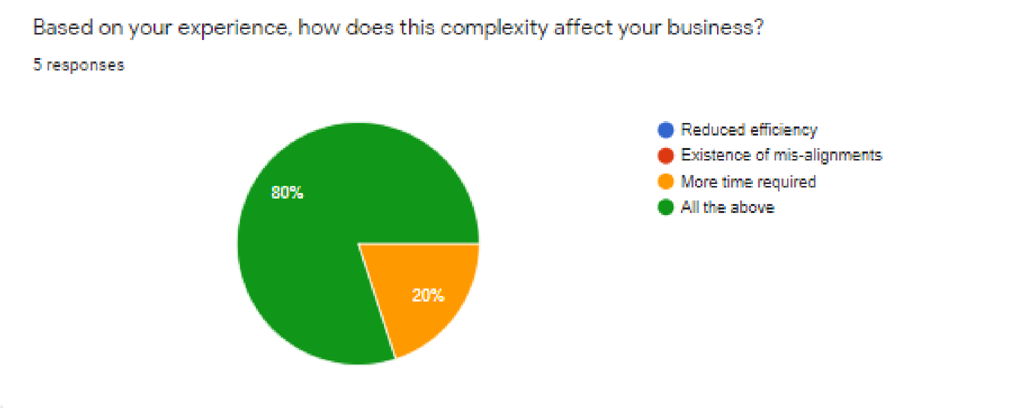


Figure 21. How does complexity impact business performance

3. **Treatment Design**

3.1 Specification of the requirements

After the problem investigation and literature research phase, this section infers the objectives of the intended solution to the identified problem. When designing an artifact, a significant amount of attention is given to the requirements. Wieringa (2014) defines a requirement as "*a property of the treatment desired by some stakeholder, who has committed resources (time and/or money) to realize the property*" (Wieringa, 2014, p.51). A requirement can also be defined as a goal for the to-be designed treatment (Wieringa, 2014). Hence, the goal of this step is to specify one or more requirements that will be related to the to-be-designed treatment and that could help in treating the problem.

Requirements can be classified in different ways. A classical classification is in functional or non-functional requirements, where the functional requirements are related to the desired functions of the artifact and the non-functional requirements specify the quality properties of the interaction of the artifact with its context (Wieringa, 2014). The specification of the requirements is as below:

Functional requirements:
The introduction of a good method, that uses EA and helps in managing complexity, and that measures business performance.

Non-functional requirements:
The artifact should have the following quality properties:

- **Efficiency** - When the method is implemented, it must improve the job performance e.g., by decreasing the required time, minimizing the waste, by using less resources etc.
- **Cost effectiveness** **-**When implemented it should enhance improvement of business performance (e.g., improvement of ROI)
- **Implementation time**: - It must be easy to use and fast to learn.
- **Usability** - When implemented it will increase productivity and it can be used in different projects.

In addition, to justify the choice for some requirements, a contribution argument is required. The contribution argument is an argument that specifies that if an artifact satisfies the requirements, it will contribute to the stakeholder goals in that problem context (Wieringa, 2014).

The following contribution argument is given in the case company:

If the method that uses EA satisfies the reduction and the control of complexity and it measures business performance, and assuming that the department of the company, continues to use the IT systems for the same business processes as modelled in the baseline architecture, then the method contributes to the department's goals of increasing efficiency (level performance), transferability, cost-effectiveness and implementation time.

3.2 Artifact design

This section describes the design of the artifact. As mentioned before, the design problem in this thesis is the sub- RQ3c, which is to propose a good method that uses EA for managing complexity and improving business performance. As described in the previous section (section 3.1), the method takes into account the fulfillment of two functional requirements that are related to a good control of complexity and to the measurement of business performance. Moreover, there are also some non-functional requirements that should be considered (as described in section 3.1).

From the conducted SLR, we came across many papers that have demonstrated the role of EA in organizations (as described in section 2.1.2). Tamm et al., (2011) argue that EA aims to define a suitable operating platform which will support an organization's current and future goals as well as it will provide a roadmap for moving towards and achieving this vision.
It is interesting to see that the number of large organizations that embark on an EA is increasingly rising as these organizations aim to discover the amount of complexity that exists in their business processes, in information systems and in technical infrastructure (Raadt et al., 2010). The causes of the amount of complexity in an organization could be: mergers and acquisitions (Pablo, 1994) the existence of high diversity between the operating models of multiple business divisions (Moore, 2005) or the low maturity of the IT infrastructure (Myers et al., 1998),

As EA provides the means for choosing the most feasible (optimal) solution to a complex organizational problem (Johnson et al., 2007), the main focus of this method will be on the development of an EA, which is usually divided into phases of creating the baseline architecture (the 'as-is' view) and the target architecture (desirable situation, 'to-be' view) (Shah & Kourdi, 2007). According to Shah & Kourdi (2007), the baseline architecture serves as the starting point

that identifies the relationships between the different components that exist among the different layers, as well as identifies where there is room for improvement.
Hence, the first step of the method is focused on the modelling of the baseline architecture and on the understanding of the current situation of the organization.

Due to the fact that one of the functional requirements of the designed artifact is to measure the business performance, the method should guide on how to measure the business performance of an organization. According to Sim and Koh (2001), traditional performance measurement systems are narrow as they are only focused on financial figures, and they often fail to capture organizational long-term success. On the other hand, the balanced scorecard tells the managers to make a commitment to introduce an array of measures or scorecards that will help with guiding better their decision making and will provide greater profitability because here the manager's position themselves to better serve their employees, customers and shareholders (Sim &Koh, 2001). In order to support their beliefs, Sim and Koh (2001) have conducted research in 83 electronics companies and the final results show that balanced scorecards are very effective. Hence, we have decided that the definition of the KPIs should be one of the first steps (step 2) in this method and later these KPIs should be measured (step 4).

Moreover, the defined functional requirement (section 3.1) also supports the management (control) of complexity. From the conducted SLR, we came across the paper from Iacob et al., (2018), who have identified the most common complexity metrics and have defined constructs from each of them. Hence, in step 3 the most common complexity metrics are identified, and then in step 5 the complexity metrics are measured in the organization.

To continue, according to Lankhorst (2009), the target architecture is beneficial when dealing with complexity, because it structures the overall solution into business and services, information systems and technical infrastructure layers, and it models the structure of an organization as it should be in order to achieve the strategic and operational goals of its stakeholders (Seppänen 2008). The target architecture decomposes the complexity of the organization into comprehensible and manageable business and IT components (Lankhorst, 2009), and this allows a better understanding and communication between the various stakeholders of the organization (Smolander & Paivarinta, 2002). Hence, step 7 of this method consists of modelling the target architecture.

EA also provides an implementation roadmap in order to guide the implementation of this target architecture. Pulkkinen et al., (2007) argue that an implementation roadmap describes the steps to reach the organization's target state which is described in the desirable proposed (target) architecture. Hence, step 8 of this method consists of the migration gap, and according to Shah & Kourdi (2007) this migration gap should represent the baseline architecture's intermediary alternatives and analyze existing gaps and lead the shift to the target architecture.

Lastly, the last step of this method is to re-measure the business performance of the changed situation. This is very beneficial for determining if the proposed solution is good or if it still needs improvement. The steps of our method are shown in table 6.

Step	Description
1.	Understand the current situation w.r.t. information system (modelling baseline architecture): ➢ What are the business processes, which associated actors and information? ➢ Who are the stakeholders, what are their goals? Threats? Opportunities? ➢ Which software applications are supporting these processes? ➢ How are the software applications connected? Infrastructure?
2.	Selection of KPIs.
3.	Selection of complexity metrics.
4.	Measurement of business performance.
5.	Measurement of complexity.
6.	Analyze the as-is current situation (baseline architecture): ➢ Identification of misalignments between business products and services on one hand and market situation and stakeholder goals on the other hand. ➢ Identification of misalignments between business processes and the required IT systems. ➢ Identification of problems with the business processes and the required IT systems. ➢ SWOT analysis.
7.	Propose a desirable situation (target architecture).
8.	Analyze the migration to the proposed situation (gap analysis).
9.	Re-measurement of business performance. Has it improved?

Table 6. Method proposal

To have a better visualization of the method, we have decided to model it into BPMN (Business Process Modelling and Notation), which is a widely used process modelling notation (Object Management, Group 2014). The BPMN semantics (table 7) clearly describe the different tasks within the different steps of the method and also show what input is needed for certain tasks.
As shown in table 6, the method consists of 9 steps. Figure 22 shows the modelled method into BPMN and a description of each of the steps will be given in the following sections.

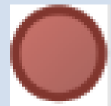
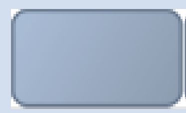
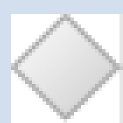
Construct	Description	Representation
Start event	**A *start event* indicates where a particular process will start.**	
End event	**An *end event* indicates where a process will end.**	
Intermediate event	**An *intermediate event* indicates where something happens somewhere between the start and the end of a process.**	
Task	**A *task* is an atomic activity that has to be carried out with the process.**	
Data object	**A *data object* provides information about which data is required and how it is being used and produced by different tasks. Data objects are connected to tasks by associations.**	
Gateway	**A *gateway* represents a certain decision that has to be made in-between tasks.**	

Table 7. BPMN notations

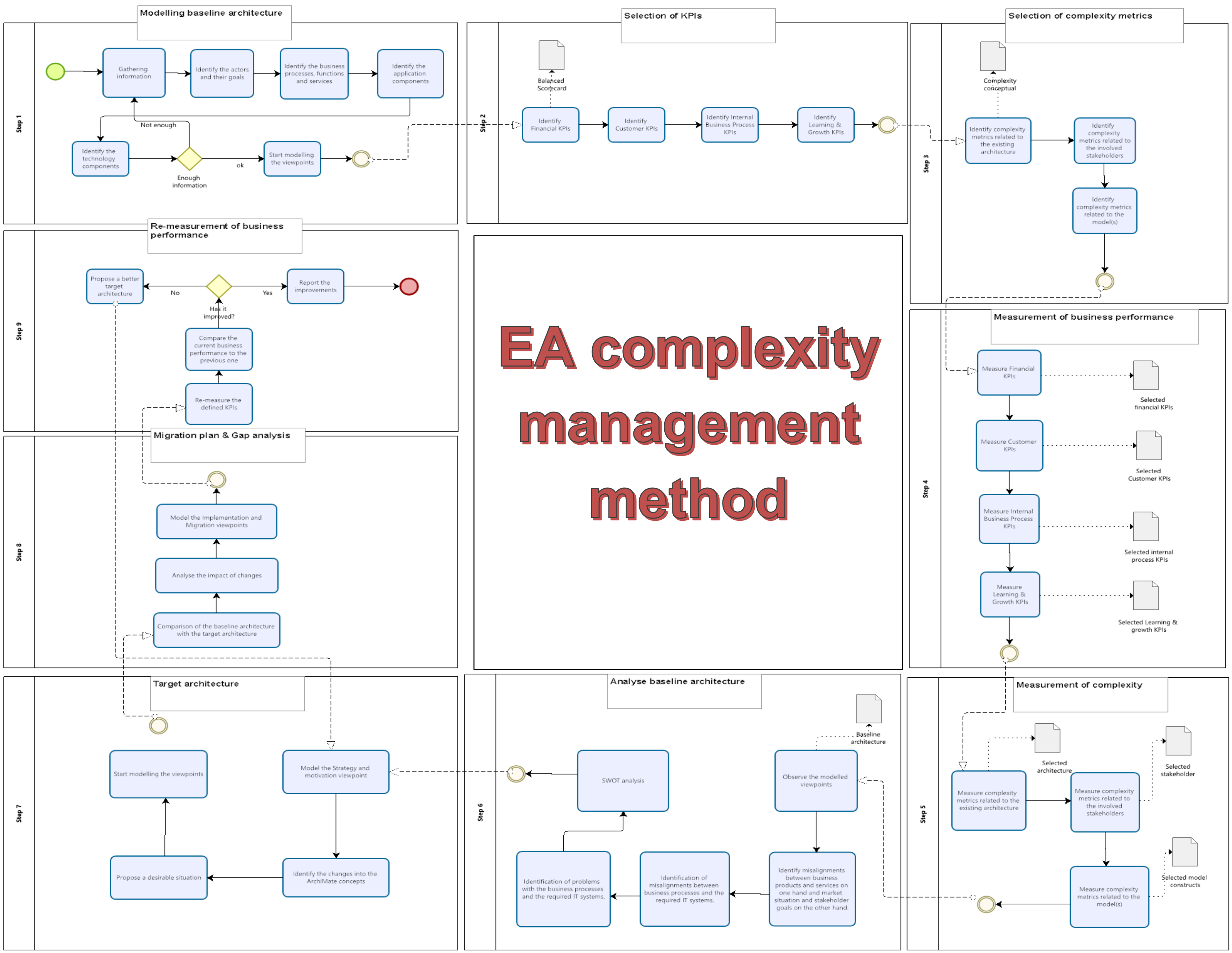

EA complexity management method
Modelling baseline architecture
Step 1
Gathering information
Identify the actors and their goals
Identify the business processes, functions and services
Identify the application components
Not enough
Identify the technology components
Enough information
ok
Start modelling the viewpoints
Selection of KPIs
Step 2
Balanced Scorecard
Identify Financial KPIs
Identify Customer KPIs
Identify Internal Business Process KPIs
Identify Learning & Growth KPIs
Selection of complexity metrics
Step 3
Complexity conceptual
Identify complexity metrics related to the existing architecture
Identify complexity metrics related to the involved stakeholders
Identify complexity metrics related to the model(s)
Measurement of business performance
Step 4
Measure Financial KPIs
Selected financial KPIs
Measure Customer KPIs
Selected Customer KPIs
Measure Internal Business Process KPIs
Selected internal process KPIs
Measure Learning & Growth KPIs
Selected Learning & growth KPIs
Measurement of complexity
Step 5
Measure complexity metrics related to the existing architecture
Selected architecture
Measure complexity metrics related to the involved stakeholders
Selected stakeholder
Measure complexity metrics related to the model(s)
Selected model constructs
Analyse baseline architecture
Step 6
Baseline architecture
Observe the modelled viewpoints
SWOT analysis
Identify misalignments between business products and services on one hand and market situation and stakeholder goals on the other hand
Identification of misalignments between business processes and the required IT systems.
Identification of problems with the business processes and the required IT systems.
Target architecture
Step 7
Start modelling the viewpoints
Model the Strategy and motivation viewpoint
Propose a desirable situation
Identify the changes into the ArchiMate concepts
Migration plan & Gap analysis
Step 8
Model the Implementation and Migration viewpoints
Analyse the impact of changes
Comparison of the baseline architecture with the target architecture
Re-measurement of business performance
Step 9
Propose a better target architecture
No
Has it improved?
Yes
Report the improvements
Compare the current business performance to the previous one
Re-measure the defined KPIs

Figure 22. Method proposal

3.2.1 Baseline Architecture

The first part of the proposed method is focused on the analysis of the current situation in an organization. Hence, modelling the baseline architecture is the first step (figure 23) and then this process is followed by the selection of KPIs and selection of the complexity metrics.
It may be assumed that companies have an up-to-date enterprise architecture and therefore the existing one could be used as the starting point. However, practice has shown that many organizations do not have an established EA (Löhe & Legner, 2014), or do not have an updated EA and hence this step will endorse the whole current EA model of an organization. Marella et al., (2019) say that EA should be presented as it is right now and then the target perfect scenario must be reflected after a correct execution.

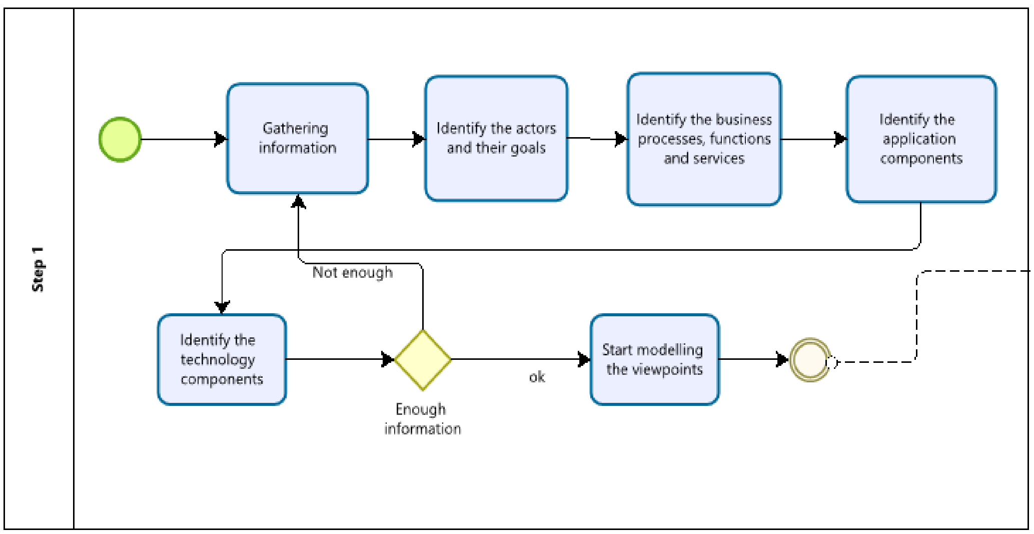


Figure 23. First step of the method

This step of the method is very crucial as the modelling of the baseline architecture will be associated with a detailed analysis of the situation and the identification of misalignments.

Approach

Based on the conducted SLR, the ArchiMate notations will be used for modelling as modelling with ArchiMate provides consistency across all the architecture models (Jonkers et al., 2011). As shown in figure 5, the ArchiMate framework consists of six layers.
The concepts from the business layer are categorized into three groups: business structure, business behavior and business information (Iacob et al., 2012). The business structure elements are mostly used to model the structure of the organization, the business behavior concepts show the behavior of the enterprise which is executed by instances of the active structural concepts within the organization, and the business information consists of passive structural elements.

Similarly, to the business layer, also the application layer consists of the structure, behavior and information concepts. The technology layer consists of models which show how the technology supports the application layer. Hence, this step consists of gathering all the relevant information for identifying all the involved stakeholders and their goals, the business processes, the IT systems, the technology that is being used, etc.

Method

In order to have a good understanding of the current state, several interviews and discussions with the stakeholders' companies are required. Also, as the most important part is to comprehend the overall model of the organization and to gain some insights in the complexity that they are struggling with and how it affects their business performance, having a good input is very important. Thus, the input in this step is gathered through interviews with the employees, existing organizational documentations and discussions with other stakeholders.

Deliverable

The deliverable of this step will be the modelled viewpoints, which describe the baseline architecture of the organization. In this baseline architecture, the elements that will be mostly used are from the Business, Application, Technology and Motivation layer. These elements will be modelled in different viewpoints. The first viewpoint will present the motivational context of the company and will cover the stakeholder's perspective by defining the drivers, the goals and the requirements. The next viewpoint will be the organization viewpoint, which is focused on the internal structure of the company and helps in identifying competencies, authorities and responsibilities in an organization (Iacob et al., 2012). The business process viewpoint shows the high-level structure and composition of the business processes. It helps in the identification of the offered services and of stakeholder's responsibilities (Iacob et al., 2012).

The application behavior viewpoint helps in identifying the internal behavior of the applications, the application services and functions, and the functional overlap between different applications (Iacob et al., 2012). Another important viewpoint is the overview viewpoint, which shows the cross relationships among all the above-mentioned layers and it helps in having a better presentation and understanding of the as-is situation. A summary of the main goals of each viewpoint is given in table 8.

Viewpoint	Goal	Main concepts
Overview viewpoint	To show the cross relationships among all the layers and helps in having a better presentation and understanding of the as-is situation.	Business role, Business actor, Business process, Business product, Business object, Application Component, Stakeholder, Drivers, Goals, Requirements
Motivation viewpoint	To cover the stakeholder's perspective by defining the drivers, the goals and the requirements	Stakeholder, Drivers, Goals, Requirements
Organization viewpoint	To identify competencies, authorities and responsibilities in an organization	Business role, business actor, location
Business Process viewpoint	To show the high-level structure and composition of the business processes. It helps in the identification of the offered services and of stakeholder's responsibilities.	Business role, Business actor, Business process, Business product, Business object,
Application viewpoint	To identify the internal behavior of the applications, the application services and functions, and the functional overlap between different applications.	Application Component, Application function, Application service, Data object
Technology usage viewpoint	To show how the application components are supported by the technology	Node, Communication Network, Technology interface

Table 8. Summary of the viewpoints

3.2.2 KPIs

The second step (figure 24) of the proposed method is the selection of the Key Performance Indicators (KPIs). KPIs are defined as the critical indicators of measuring progress towards an intended result, and they provide a focus for strategic and operational improvement, as well as they create an analytical basis for decision making (Roubtsova & Michell,2013). They can be classified into different types i.e., financial KPIs, Customer- focused KPIs, Process performance metrics, etc.

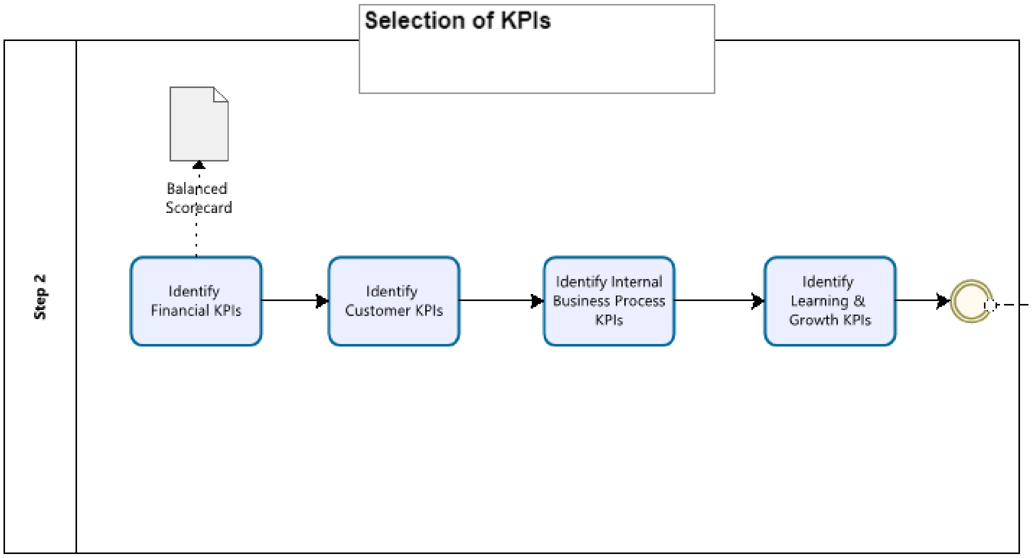


Figure 24. Second step of the method

Approach

Many studies have made a distinction between subjective and objective performance measurement, because it is necessary to use subjective performance measures as a substitute for objective measures (Dess & Robinson, 1984). Dawes (1999), Wall et al., (2004) and Kim (2006) have distinguished the use of subjective and objective measures based on three characteristics: indicators, measurement standard and scale anchors (table 9).

	Aspect	**Subjective Measures**	**Objective Measures**
1	Indicators	Focus on overall performance	Focus on actual financial indicators
2	Measurement standard	Participants are asked to rate performance relative to their competitors	Participants report absolute financial data

3	Scale anchors	The usage of Likert scale which varies from “very low” to “very high”.	Likert scale is not used.

Table 9. Subjective vs objective measures of business performance

Song et al., (2005) show that subjective measures allow different comparison across firms and context, such as: time horizon, industry types or economic condition. In addition, Wall et al., (2004) state that subjective measures are a good alternative if the measures focus on the firm’s current condition and the objective data is not compatible with the intended level of analysis.
Therefore, this step aims to identify relevant KPIs for each perspective of the Balanced Scorecard, and to specify if the data of these KPIs is gathered through subjective or objective measures.

Method

According to Giannopoulos et al., (2013) the balanced scorecard can be applied to almost all industry sectors despite their size (i.e., BSC can be applied to manufacturing or industry organizations, to large or small organizations, as well as to the public or private sector.), and this BSC should have three key structural features (Kaplan and Norton, 1996; 2001):

1. Its measures are derived from strategy;
2. A balance exists between the measures;
3. The measures are linked in a casual way.

In this step the balanced scorecard will serve as a guide and in the following sections each of the perspectives will be described and the most common indicators of each perspective will be identified.

Financial Perspective

According to Kaplan & Norton (1992) the financial perspective refers to the financial view of a company that is presented to its shareholders, and it also considers the implementation and execution of the strategy and how it contributes to bottom-line improvements.
Hence, this perspective considers the financial concerns of the organization or specific business case to appeal to the shareholders or involved stakeholders. There is a need for traditional financial data under this perspective and the most common performance measures incorporated here are:

- **Cost**
  The amount of money that the company spends for paying its employees. Each employee is assigned to do specific tasks and this indicator can be operationalized as time spend for tasks*average employee cost (Chan & Chan, 2004).

- **Cash Flow or Monthly recurring profit (MRP)**
  According to (Kaplan and Norton, 1993), this indicator is usually present in many organizations. As one of the main outcomes in a department is the number of completed projects, MRC can be operationalized as the amount of the money value generated by the number of finished projects per month.
- **IT cost**
  Organizations spend a lot of money on their IT systems and IT employees.
  This indicator can be calculated as the time that is spent with the IT department (asking for help, for guidance) (Ross et al., 2006), and acquisition costs (Aziz et al., 2005; Morganwalp & Sage, 2004).

Internal Business Process Perspective

In this perspective the focus is on how an organization can identify and measure their key internal business processes at which they must excel to lead their internal business results towards financial success and customer satisfaction.

- **Throughput time**
  This considers the total time that is required since many delays can happen. Hence, according to Chan & Chan (2004) there should be an evaluation on the time spent in waiting for approvals, (time of response from suppliers), system downtime (the sharing of information) etc.
  It can be measured as value-added time/ total lead time, where value-added time is the time spent producing the products.
- **Process compliance**
  Internally, according to Cox et al., (2003) this indicator can tackle the percentage of non-conforming products that are being produced. This can be operationalized as the number of misaligned projects/ total number of projects per 1 year.

- **Flexibility**
  According to (Bookhlot, 2014) the flexibility of both business processes and IT, and the ability of the employees to continue to do their work by using alternative systems are very important. This can be operationalized by using the Likert scale where the employees will be asked about their experience.

Customer Perspective

The customer perspective is focused on the customer’s opinion and feedback for the company and how the company wants to be seen by its customers (Norreklit, 2000), as the companies create value through their customers. One of the main priorities of a company is the satisfaction of its customers (Kaplan & Norton, 1992), and this satisfaction can also be viewed as a very crucial KPI on the effort of the business to become more successful (Anderson & Sullivan, 1994). According to Kaplan & Norton (1992), the customers usually have four main concerns related to the product or service that they receive from the company: time, quantity, performance & service and cost.

- **Customer intimacy**

  According to Boucharas et al., (2010) is a very prominent benefit, and it results from a better understanding of customer needs (Butler, 2000). This indicator can be calculated by a Likert scale by asking directly the customers about how often the information is accurate, how often is it accessible and how often is it complete (Bookhlot, 2014).

- **Product/Service quality**

  Product or Service quality is related to Product leadership, which refers to the offering of state-of-art products or services to all the customers (Bookhlot, 2014). This indicator can be measured by asking directly the customers about how satisfied they are with the product or service that they received from the company.

Learning & Growth Perspective

According to Kaplan & Norton (2000), the learning & growth perspective of the balanced scorecards identifies the infrastructure that the organization must possess in order to create long-term growth and improvement. Hence, this perspective is focused on capabilities and skills that an organization must excel at in order to improve its internal business processes performance that create value for customers and its shareholders. Giannopoulos et al., (2013) describe that some of the indicators that could be used to measure the learning & growth of the organization, should be related to the employee education and his skills, to the employee satisfaction and to retention rates, whereas Kaplan & Norton (2000) argue that learning and growth come from three main sources: people, systems and organizational procedures.

- **Human capabilities**

  Human capabilities refer to continuously improving employee’s skills. According to (Sim and Koh, 2001), this indicator can be calculated as the time and resources that are spent for employee training and development. Employee training is positively related to the improvement of delivery and customer satisfaction, as well as to lower manufacturing costs, higher sales, and faster time to market (Sim and Koh, 2001).

- **Information System capabilities**

  According to Kaplan and Norton (1992) this indicator can be measured by considering the time that the company needs for generating (developing) new technologies.

- **Time -to- market**

  Time-to- market is viewed as a key to success and profitability (Cooper and Kleinschmidt, 1994; Choperana, 1996; DroÈge et al., 2000). This indicator can be measured by calculating all the time that is needed to bring a new product or service to market, and this time could be improved by using innovative high-tech systems (DroÈge et al., 2000).

Deliverable

The deliverable of this step would be the measurement of the KPIs. A summary of all these indicators that could be measured is shown in table 10.

Perspective	Indicator	Operationalization	Measure Type
Financial	**Cost**	Time*average employee cost	Objective
	Cash Flow or Monthly recurring profit	Profit per project*nr of projects	Objective
	IT cost	Time spent* average employee cost + payment for new licenses	Objective
Internal Business Process	**Throughput time**	Value-added time/ total lead time	Objective
	Process compliance	Number of misaligned projects/ total number of projects per 1 year	Objective
	Flexibility	Likert scale	Subjective
Customer	**Customer intimacy**	Likert scale	Subjective
	Product/Service quality	Likert scale	Subjective

Learning & Growth	**Human capabilities**	Time & resources that are spent for employee training and development	Objective
Learning & Growth	**Information System capabilities**	Total time for developing new technologies	Objective
	Time -to-market	Time needed for introducing a new product/service	Objective

Table 10. BSC indicators

3.2.3 Complexity metrics

As one of the main functions of the proposed method is the management of complexity, the third step (figure 25) is the selection of the crucial complexity metrics that must be measured. In the conducted systematic literature review, the dimension of complexity as well as the classification were identified (section 2.2). This SLR led to the identification of some of the existing research in this field. A model for measuring architectural complexity was proposed by Iacob et al., (2018), who after conducting some interviews have assigned a code and a construct at the identified metrics (table 5). Also, these constructs were classified into groups.

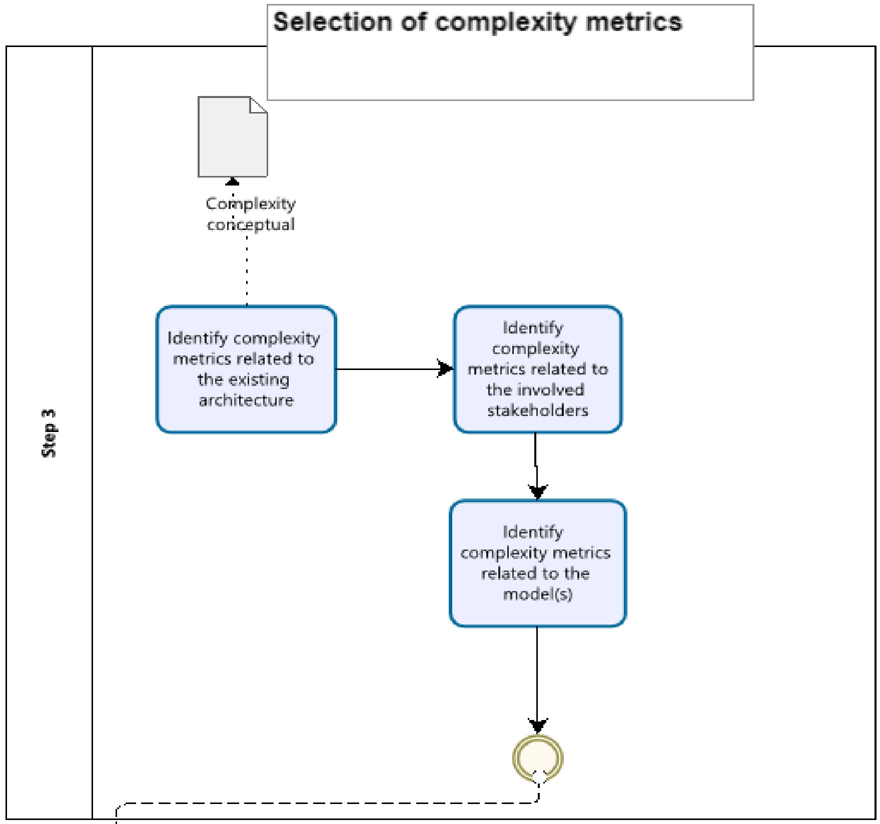


Figure 25. Third step of the method

Approach

The third step of the method aim to identify all the relevant complexity metrics. As one of the functional requirements of the proposed method is about managing complexing, and the main focus will be on objective and subjective complexity, the metrics groups that are relevant are: Architecture, Stakeholder and Model. Thus, only a part of the constructs' classification by Iacob et al., (2018) is shown in table 11. The most interesting and important outcome by Iacob et al., (2018) is the theoretical model which was based on the constructs' classification. This model served as a basis for the creation of the complexity conceptual model (figure 26), where the constructs are listed in the left part, the codes in the middle and the complexity dimension are in the right.

Group	Code	Construct
Architecture	Application complexity	Application complexity
	Business complexity	Business complexity
	Number of elements and relations	Size
	Variation in technology	Heterogeneity
	Coupling	Coupling
	Dependency	Coupling
Stakeholders	Stakeholder education and background	Education
	Stakeholder Interest and affinity	Affinity
	Stakeholder knowledge and experience	Experience
Model	Abstraction level of documentation	Documentation quality
	Communication to stakeholders	Communication
	Notation of documentation	Documentation quality
	Presence of documentation	Documentation quality

Table 11. Complexity constructs

Method

The conceptual model (figure 26) serves for the better measurement of complexity. However, not all the identified metrics and constructs can be operationalized. Due to the scope of this research, in the architecture group only the application complexity will be further measured, in the stakeholder group there will be the measurement of stakeholder affinity and education, and in the model group there will be the measurement of documentation quality and communication. The operationalization of these constructs were based on the literature review, where the stakeholder constructs and model construct were mostly based on Iacob et al., (2018).

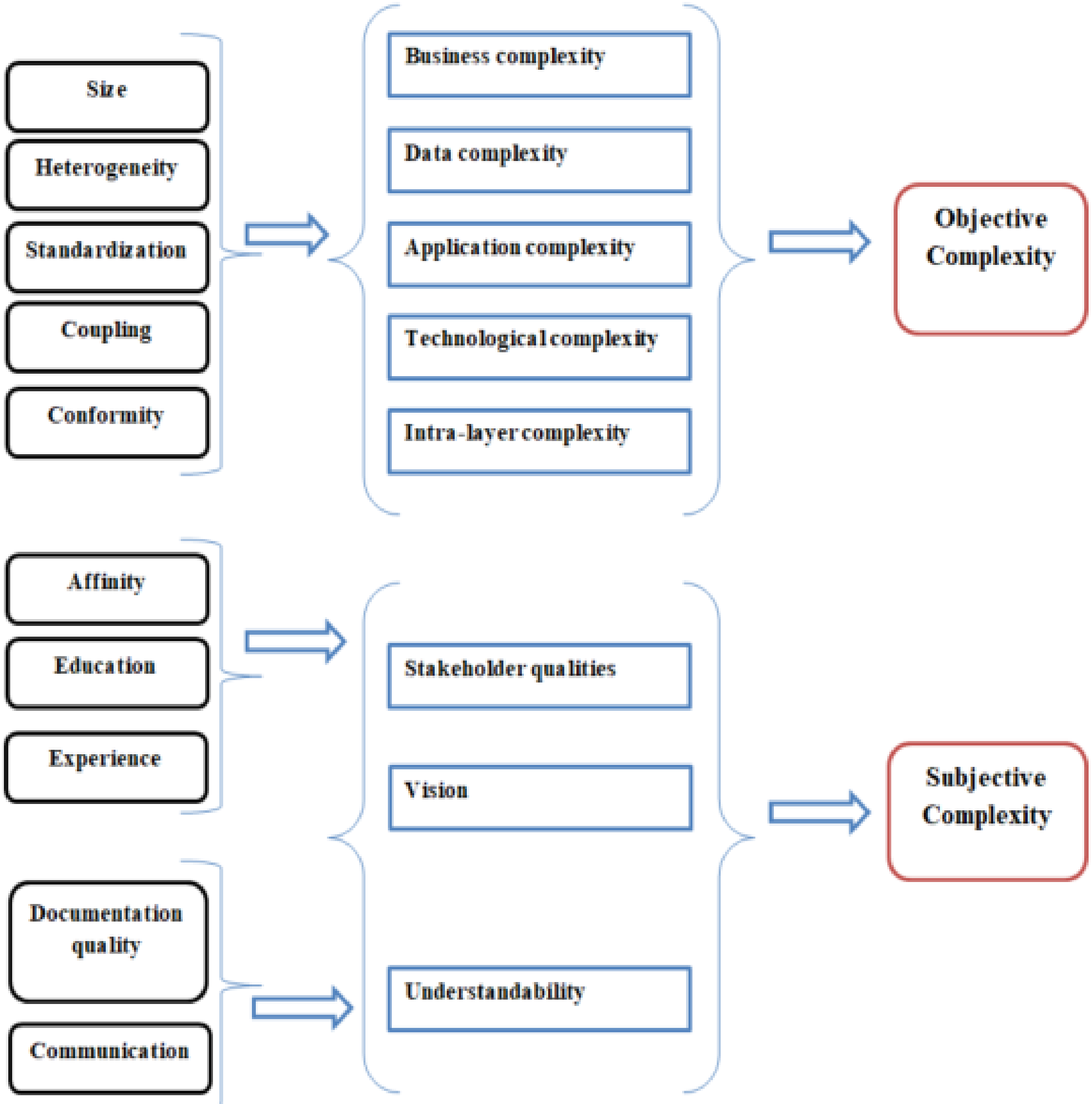


Figure 26. Complexity conceptual model

Deliverable

The deliverable of this step would be the measurement of complexity metrics. A summary of all these metrics and how they could be measured is shown in table 12.

Code	Construct	Metric name	Metric definition	Calculation
Architecture	Application complexity	Number of applications	Number of applications used per each project	Ask each employee how many applications they must use per each project. Then calculate the average
		New applications	Number of new applications per year	Count the number of new introduced applications per year
		Retired applications	Number of retired applications per year	Count the number of retired applications per year
		Number of functions	Total number of functions per system	Total no of functions/system
Stakeholders	Education	Education level	Measures the level of education of a stakeholder	Ask participants about their level of education. This will be a multiple-choice question i.e., bachelor's degree, master's degree, PhD, PDEng.
	Affinity	Technology affinity	Measures the affinity of a stakeholder about technology	Ask participants about their level of affinity. There are 5 statements and participants will give an answer by using the Likert scale. Thus, there will be a score from 1 to 5 and then the average will be calculated. The statements are: 1. Technology is an important part of my life. 2. I enjoy learning about new technologies. 3. My job requires me to know about new technologies. 4. I usually have no trouble

				learning new technologies. 5. I relate well to the technology used in my job. 6. I am comfortable with new technologies required in my job. 7. In my job I know how to deal with technological malfunctions or problems. 8. Solving a technological problem is a fun challenge. 9. I find most technologies easy to learn. 10. I feel as up to date on technology as my pears.
	Experience	Years of experience	Measure the experience of the stakeholder in the organization.	Ask the participants about their experience. Check box: less than 1; 1-3; 3-5; 5+ years.
Model	Documenta-tion quality	Available level of detail	Measures the availability of different levels of detail in a documentation.	Count how many levels of abstractions (physical, logical i.e., tables, view) are available in the documentation
	Communic-ation	Documen-tation availability	Measures the availability of documentation	Ask the participants to use the Likert scale to answer these questions: 1. I know where to find the necessary documentation. 2. I struggle with finding the documentation, I must search a lot for it. 3. Most of the time, I can't find it myself.

Table 12. Operationalization of complexity metrics

3.2.4 Measurement of KPIs

The fourth step of the method is the measurement of the KPIs in the organization. As shown in figure 27, this step covers the measurement of financial KPIs, customer KPIs, internal business process KPIs, as well as learning & growth KPIs.

Approach

As previously mentioned, the business performance could be measured by using the balanced scorecard of Kaplan and Norton (1992). Section 3.2.2 defines the most common indicators for each of the perspectives of the BSC, which could be measured in a company.

Method

For measuring these KPIs the input must be received directly from the company. Hence, interviews with the employees should be conducted, and the company should also provide the right information and documentation.

Deliverable

The deliverable of this step would be the measured KPIs, which will indicate the business performance of the company.

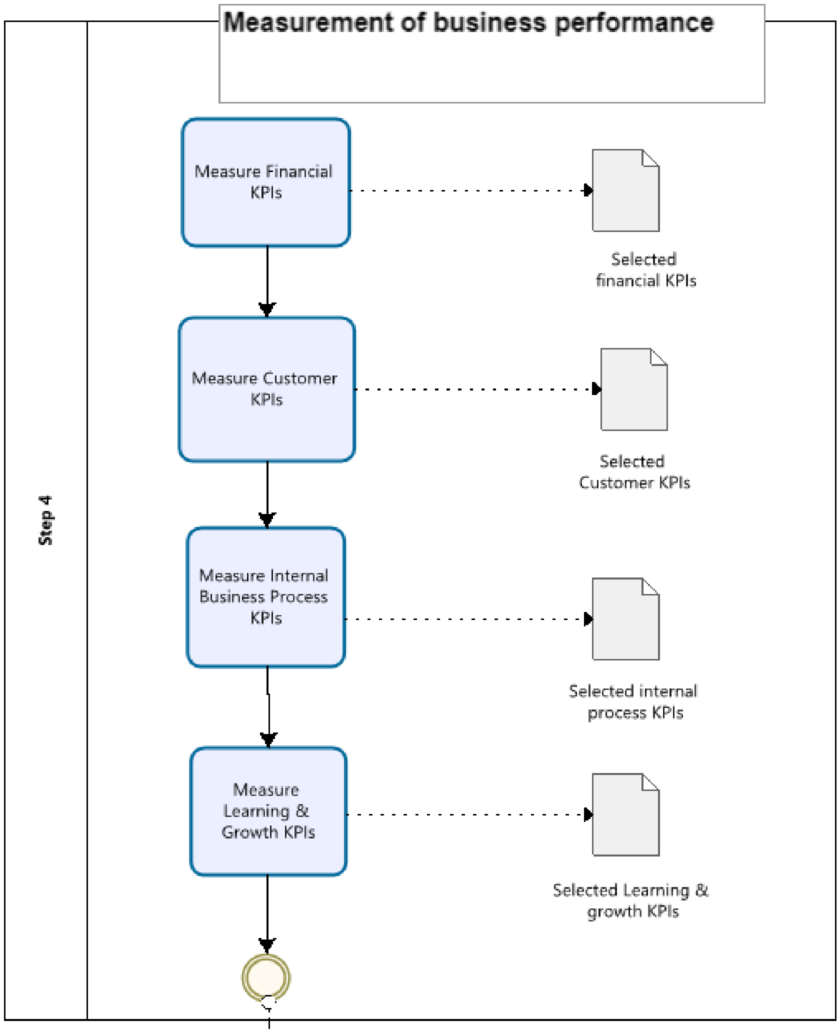


Figure 27. Fourth step of the method

3.2.5 Measurement of complexity metrics

The fifth step of the method is the measurement of the complexity in the organization. As shown in figure 28, this step covers the measurement of complexity metrics for different groups: architecture group, stakeholder group and model group.

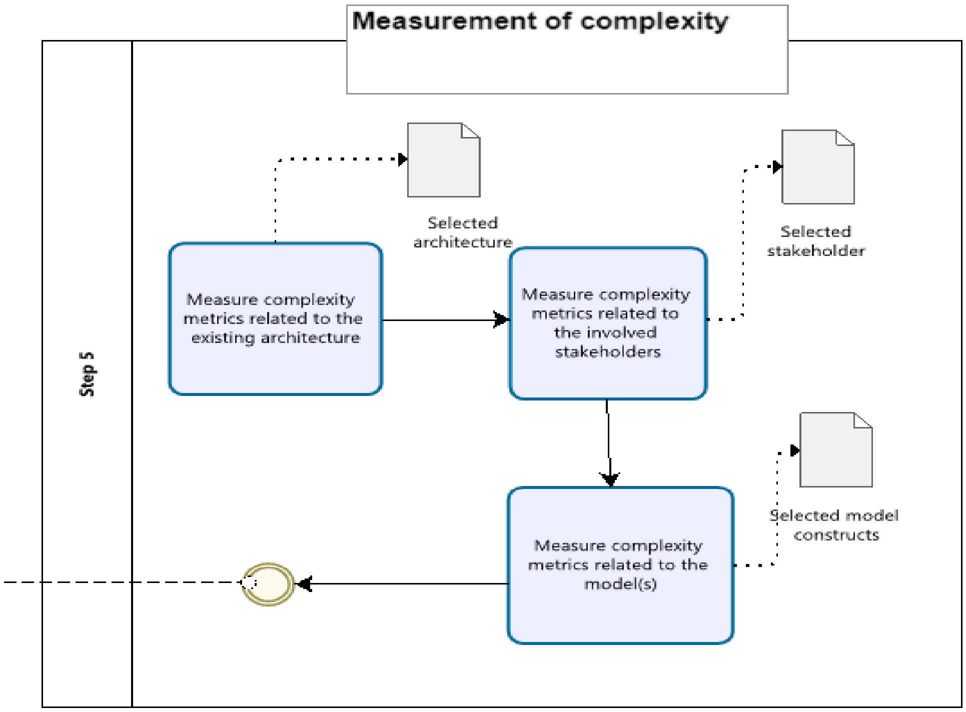


Figure 28. Fifth step of the method

Approach

The approach consists of using the complexity constructs (table 11) and the conceptual model (figure 26), as they serve as a guideline for the better enhancement of complexity.

Method

Similarly, to the measurement of KPIS (section 3.2.4), also for measuring these complexity metrics the input must be received directly from the company. Hence, interviews with the employees should be conducted, and the company should also provide the right information and documentation.

Deliverable

The deliverable of this step would be the measured complexity metrics, which will enhance the amount of complexity that the company is currently facing.

3.2.6 Analyzation of baseline architecture

The next step of the method (step 6) consists of the analyzation of the baseline architecture of the company.

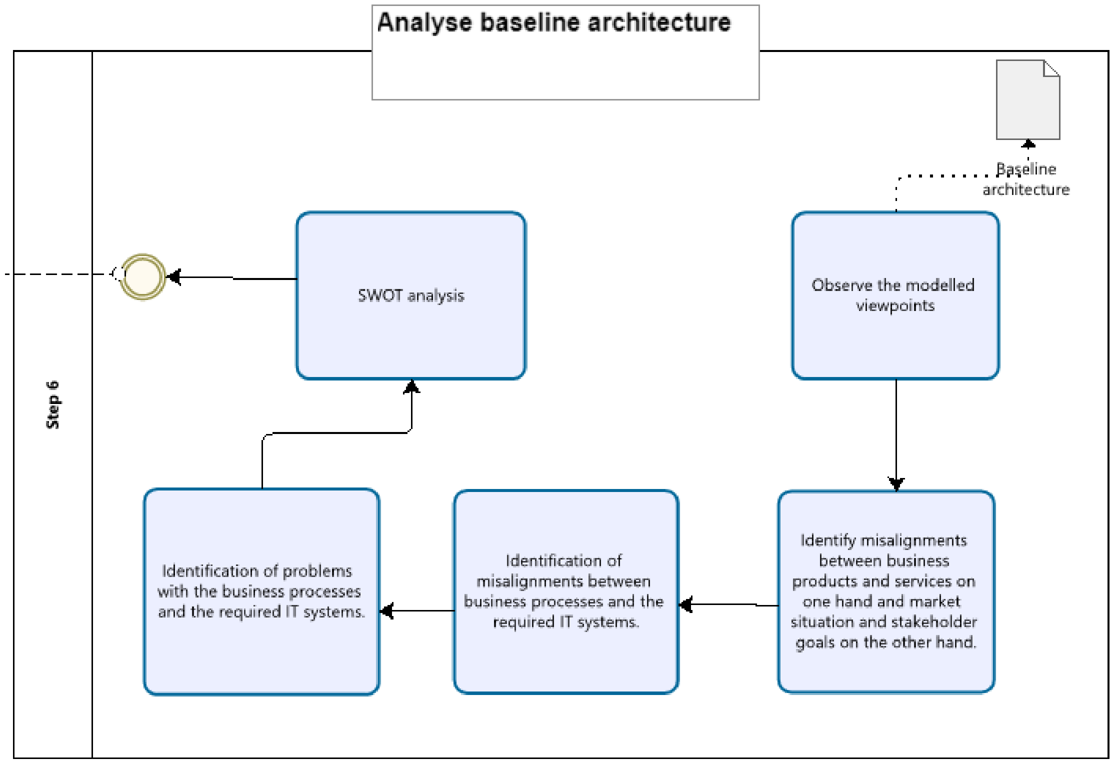


Figure 29. Sixth step of the method

Approach

As shown in figure 29, all the modelled viewpoints (in step 1) must be closely observed and critically analyzed. The aim of this step is the identification of misalignments that exist among the business products and service on one hand, and market situation and stakeholder goals on the other hand. In addition, this step aims to identify misalignments and/or problems among the current business processes and IT systems.

Method

The analyzation of the baseline architecture of the company will be addressed by using SWOT analysis (short for strengths, weaknesses, opportunities, threats), which is a business strategy tool that is used to assess how an organization is positioned in the market, compared to its competitors (Teoli et al., 2019). As part of the SWOT matrix there are internal and external considerations. "Strengths" and "weaknesses" are internally related because "strengths" represent facets of the organization which lend to being in advantage among the competitors, and "weaknesses" are seen as disadvantages against the competition (Teoli et al., 2019). On the other hand, "opportunities" and "threats" are part of the external consideration, because "opportunities" are seen as realities in the greater environment that the company can exploit to have more benefits, and “threats” are realities in the greater environment which might lead to big problems for the organization (Teoli et al., 2019).

Deliverable

The main deliverable of this step would be identification of misalignment that currently exists, and these misalignments will be addressed in the next step of the method (in the target architecture). Another deliverable of this step is the SWOT analysis, which will demonstrate all the strengths and weaknesses, as well as the opportunities and threats of the company. Lastly, the SWOT elements will be also related to the motivation elements, hence the motivation viewpoint will be modelled by having all the SWOT elements as assessments.

3.2.7 Target architecture

Step seven focuses on the modelling of target architecture.

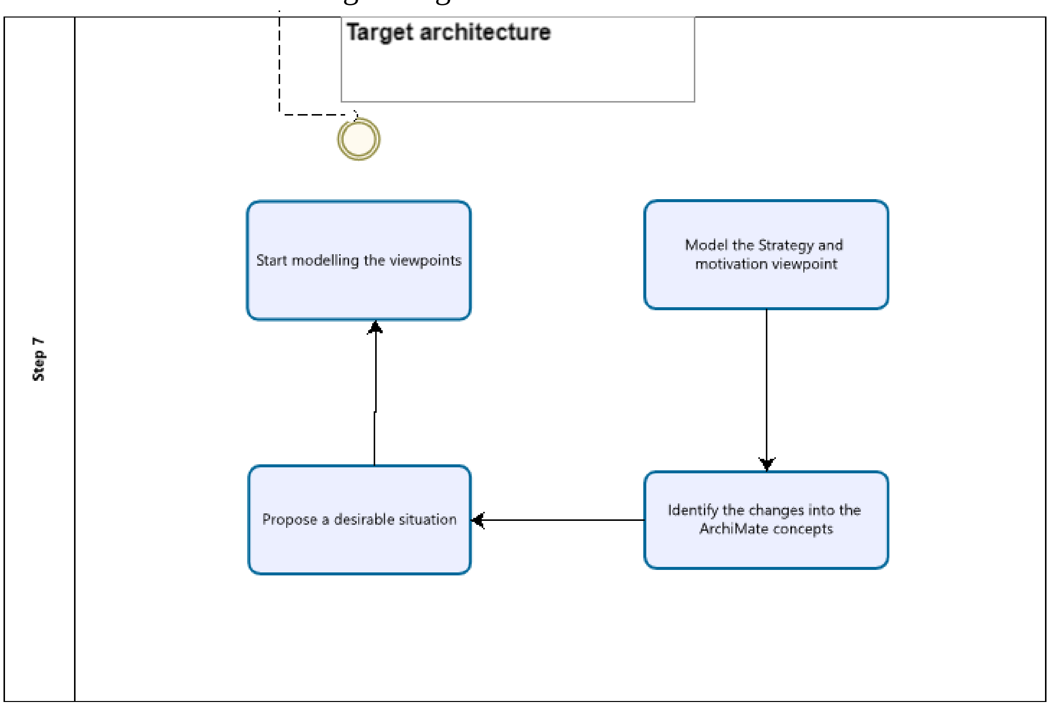


Figure 29. Seventh step of the method

Approach

As previously mentioned, according to Lankhorst (2009), the target architecture is very important as it decomposes the complexity of the organization into comprehensible and manageable business and IT components, and this allows a better understanding and communication between the various stakeholders of the organization (Smolander & Paivarinta, 2002). Armour et al., (1999) argue that the target architecture represents enhancements to the as-is (baseline) architecture of the company, which will add functions or make changes to support new operations. Hence in this step, the first process is to model a new viewpoint which will reflect the overall strategy for the new architecture and the motivation for changes based on the analysis of the baseline architecture, the second process is the identification of the optimal changes and how these changes will be reflected in ArchiMate concepts, the third process is to propose a desirable situation which is going to improve the as-is situation of the company and will lead to more benefits, the last process is the modelling of the viewpoints and lastly

Method

ArchiMate language will be used for modelling the target architecture, and the concepts will be selected accordingly to the proposal. This proposal will also address the weaknesses and threats that were identified in the SWOT analysis.

Deliverable

The deliverable of this step consists of the modelled viewpoint. Basically, the target architecture viewpoints will reflect the changes that must be made in the baseline architecture, and it will be shown via these viewpoints: overview, motivation viewpoint, application viewpoint, technology usage viewpoint and lastly strategy and motivation viewpoint.

3.2.8 Migration gap and impact analysis

The next step of the method (step 8) focuses on the implementation of the migration gap and the impact analysis.

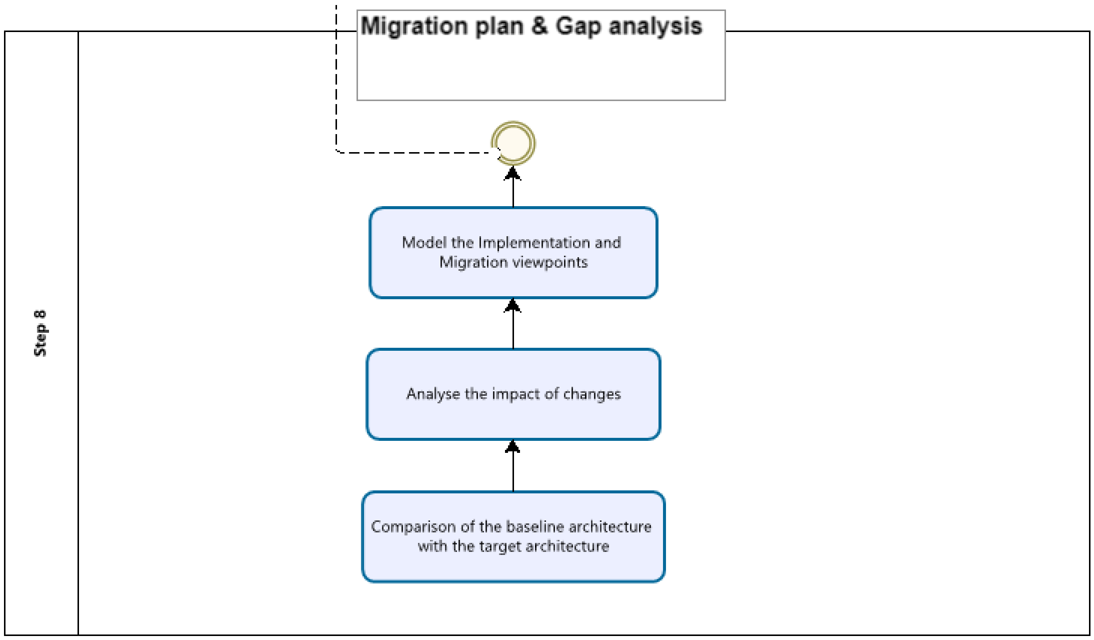


Figure 30. Eighth step of the method

Approach

The approach in this step starts by making a comparison between the baseline architecture and the target architecture in order to identify the changes that need to be made. Next, the impact of these changes must be analyzed in order to see if these changes are sufficient, if they are feasible and to predict their impact on the company. Lastly the implementation and migration viewpoint will be modelled.

Method

ArchiMate's implementation and migration elements will be used for modelling the implementation and migration viewpoint, as this viewpoint is used to relate the specific programs and projects that must be realized. Hence, the work package element will be used to represent a series of actions identified and designed to achieve specific results within specified time (The Open Group, n.d.), the deliverable concept will be used to show the outcome of a specific work package (The Open Group, n.d.), the plateau concept is used to show a specific stable stage (e.g., baseline architecture, target architecture) and the gap concept is used to show the difference that exist between two plateaus (The Open Group, n.d.).

Deliverable

The main deliverable of this step would be implementation and migration viewpoint, which will show the changes that must be made in order to achieve the target architecture. As shown in figure 32, the implementation and migration viewpoint will show the migration gap that exists among the baseline and target architecture, and it will also show the impact of the changes that must be made.

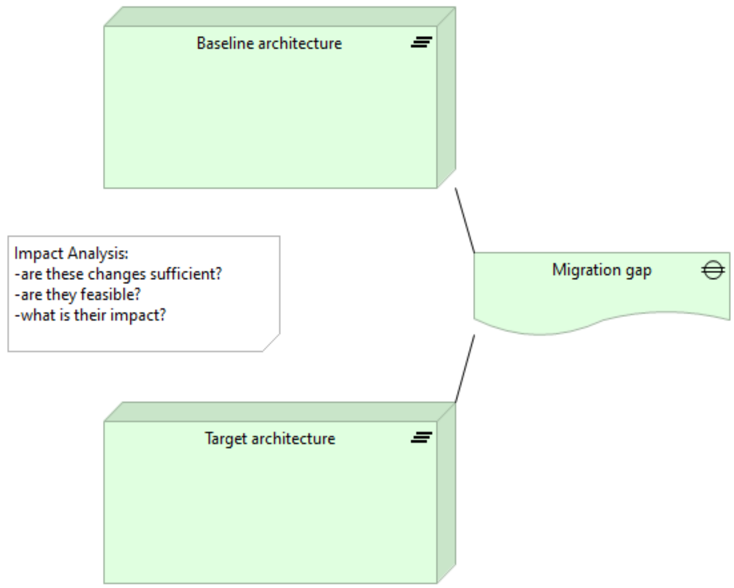


Figure 31. Deliverable of step 8

3.2.9 Re-measurement of business performance

The last step of method (step 9) consists of the re-measurement of the business performance in order to see what the contribution of these changes is.

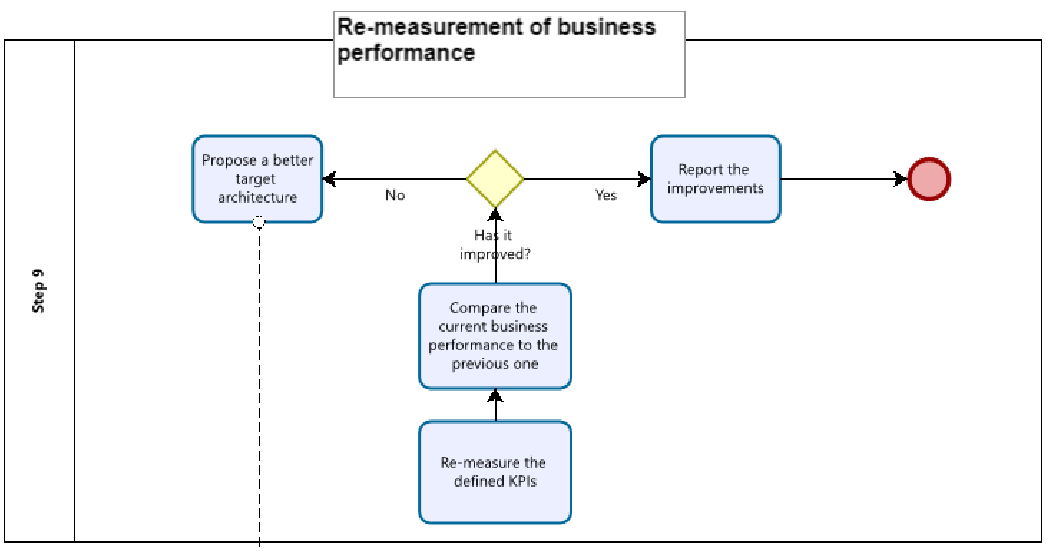


Figure 32. Last (ninth) step of the method

Approach

The first process on this step is to re-measure the KPIs that were selected in step 2, and then the current business performance is going to be compared to the previous business performance. Next, based on the comparison, it will be a reflection if the improvement were good or if there is a need to propose a better target architecture.

Method

To realize this step, the KPIs from the balanced scorecard have to be re-measured. The input will be gathered in collaboration with the company. Some interviews may be conducted and some documentation from specific softwares will be collected.

Deliverable

The main deliverable of this step will be the reflection on the target architecture by judging if this architecture has led to benefits and to improving the business performance and/or to reducing complexity, or if there is still a need for more improvements.

4. **Method Demonstration**

This chapter is restricted.

5.Method Validation

This chapter describes the treatment validation phase of the DSRM cycle (Wieringa, 2014). A panel of experts in the field of EA and/or complexity management is assembled and introduced to the method which is described in section 3. The panel of experts was asked to fill in a questionnaire which is based on the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT model is a unified theory which aims at predicting the usage behavior and user acceptance, and it consists of four determinants: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions (Venkatesh et al., 2003). As shown in figure 64, the UTAUT model consists also of four moderating factors on these determinants: Gender, Age, Experience, and Voluntariness of Use.

However, in our research the Social Influence determinant will not be considered as Social Influence is defined as the degree to which an individual believes that other important individuals believe he or she would use the new method (Venkatesh et al., 2003). The main reason why we have decided to not consider this determinant is related only three experts out of six are from the company, where the method is implemented, whereas the other experts are from the university or other companies. In addition, also the key moderating factors (Gender, Age, Experience, and Voluntariness of Use) will not be considered as in our research they are not determinant variables of user acceptance and behavior.
The constructs from the UTAUT model that have been selected to be asked in the questionnaire are listed in table 27.

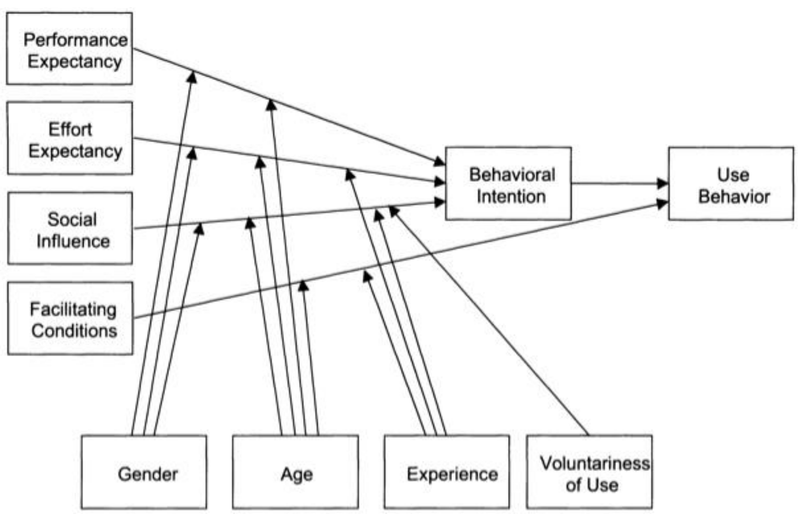


Figure 33. UTAUT Research Model (Venkatesh et al., 2003)

Construct	Definition	Item code	Item description
Performance Expectancy (PE)	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	U6	I would like to use the proposed method as it is considered helpful.
		RA1	Using the proposed method would improve my job performance in specific projects.
		RA5	Using the proposed method will increase my productivity.
Effort Expectancy (EE)	The degree of ease associated with the use of the system.	EOU6	I would find the proposed method easy to use.
		EOU3	My interaction with the proposed method will be clear and understandable.
		EU4	Learning to use the proposed method is easy for me.
		EU5	The rewards for implementing the method are worth the time.
Attitude Towards Use of Technology (ATUT)	An individual's overall affective reaction to using a system.	A1	Using the proposed method is a good idea.
		AF1	The proposed method makes my work more interesting.
		AF2	I am looking forward to those aspects of my job (or specific work projects) that require me to use the proposed method.
Facilitating Conditions (FC)	The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system.	PBC2	I have the necessary knowledge to use the proposed method.
		PBC3	The proposed method is compatible with other systems or tools that I use for my work.

Self-Efficacy (SE)	Judgment of one's ability to use a technology (e.g., computer) to accomplish a particular job or task.	SE4	I would use the proposed method if I could get help from someone (If I get stuck).
		SE7	I would use the method if there is a built-in guide for assistance.
Behavioral Intention of Use (BI)	An individual's perceived likelihood or subjective probability to use the system.	BI1	I intend to use the proposed method in the future for helping me in my job (or specific projects).
		BI2	I predict I would use the proposed method in the future for helping me in my job (or specific projects).
		BI3	I plan to use the proposed method in the future for helping me in my job (or specific projects).

Table 13. UTAUT constructs used in the questionnaire

5.1 Participants

The experts that agreed to take part in the validation process are:

- ❖ An assistant professor at the University of Twente, who has been teaching in graduation and post-graduation courses since 2008.
- ❖ Two senior consultants in Enterprise Architecture at Deloitte.nl.
- ❖ A senior complexity manager at the case company, who is currently leading a cross-functional team working with Marketing, Supply Chain, Manufacturing, R&D, Quality and IT.
- ❖ A senior IT project manager at the case company, who is responsible for IT in the company.
- ❖ A mould engineer at the case company, who is focused on the technology that the department uses as well as also in the identification of some financial outcomes related to produced products.

As noticed, the panel of experts is diverse. Among the selected experts most of them are familiar with all the used concepts in the method as shown in figure 65. However, the experts that are from the case company are not very familiar with Enterprise Architecture, but their expertise is mainly in IT and/or complexity management. The reason why we chose to have a diverse panel of experts is to have an extensive evaluation of the designed method, so the method is validated also outside the case study and all the results will be analyzed in the following section. Moreover, the experts who are from the case company make possible also the validation of the model of context (i.e., they validated the method demonstration in the Mould department).

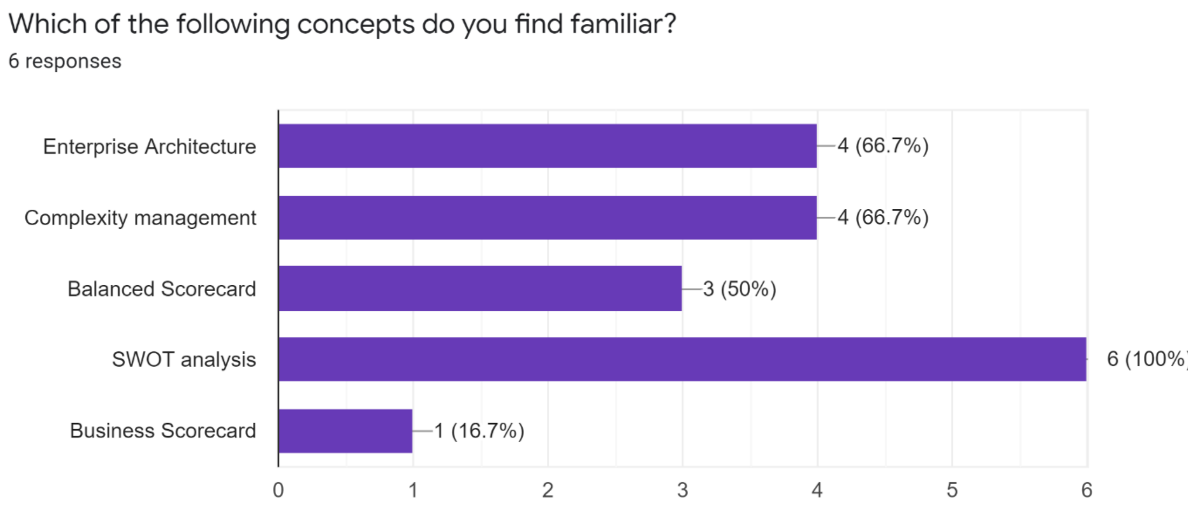


Figure 34. Familiarity with the concepts

5.2 Results

This section discusses the results of the questionnaire. Table 28 illustrates the evaluation of the method by each expert. This table allows comparisons between the different constructs of UTAUT and comparison about the score that each expert has given. The table is structured as follow: 'Construct ID' is the ID of each UTAUT determinant, 'E' is related to the expert (i.e. 'E1' is the score that the first expert has given), 'Min' is the minimum score that was given for a questions, while 'Max' is the maximum score, 'Sum' is the total score that was given in a question, 'Mean' is the average score that was given in a question, and lastly 'Stdev' is the standard deviation of the scores given by the experts. The standard deviation is used to measure the amount of dispersion among the data values. Hence, the higher the value of the standard deviation, the more the opinion of the participants differs among each other, and the lower the 'stdev' is, the more the opinions coincide.

In this survey, a five-Likert scale is used. Hence, possible answers range from 'Strongly disagree' to 'Strongly agree', and all these answers are then converted into numerical values. Values ranging between one ('Strongly disagree') and two ('Disagree) indicate negative feedback, three is a neutral opinion, while the values four ('Agree') and five ('Strongly agree') indicate positive feedback.

As seen in table 28, the method is evaluated positively with an average score of 4.18, and for most of the statements the standard deviation value is less than 1. It is worth to mention that all the experts agree that they would like to use the proposed method as it is considered helpful. However, we noticed that the highest dispersion among the answers exist at the statements that are related to 'facilitating conditions', as the panel of experts is diverse. Hence, as previously mentioned the selected experts are two EA consultants and one professor who have already knowledge and experience in working with EA, and on the other hand two expert are from the case company and they don't have an EA background. Therefore, the minimum value that is given is 2 at the statement of having enough knowledge for using this method, and the maximum is 5. Thus, the average standard deviation for this statement (FC2) is 1.471. On the other hand, for 15 statements out of 17 statements, the standard deviation is lower than 1, which indicates that the variation among the responses is low and that the experts mostly share the same opinion about the method.

Moreover, the average score value per statement ranges between 3.7 to 4.5 (figure 66). The most positive feedback is recorded for FC1 with a value of 4.5, while the lowest average value is 3.7 and it is given in 6 out of 17 statements (figure 66). A detailed analysis for each of the determinant is discussed in the next sections.

Construct ID	E1	E2	E3	E4	E5	E6	Min	Max	Sum	Avg	Stdev
PE1	4	4	4	4	4	5	4	4	25	4.166	0.408
PE2	5	4	4	4	4	5	4	5	25	4.166	0.408
PE3	4	4	3	3	4	4	3	4	22	3.666	0.516
EE1	5	4	4	5	3	4	3	5	25	4.166	0.752
EE2	5	4	4	4	4	4	4	5	25	4.166	0.408
EE3	5	4	4	4	4	4	4	5	24	4	0.632
EE4	4	4	3	3	3	3	3	4	22	3.666	0.816
ATUT1	4	5	4	4	4	5	4	5	26	4.333	0.516
ATUT2	3	4	4	4	4	5	3	4	22	3.66	0.516

										6	
ATUT3	5	4	4	5	4	3	4	5	26	4.333	0.516
FC1	5	2	5	5	5	4	2	5	27	4.5	1.224
FC2	5	2	4	5	2	5	2	5	23	3.833	1.471
SE1	3	4	4	3	3	5	3	4	22	3.666	0.816
SE2	3	4	5	5	4	5	3	5	25	4.166	0.752
BI1	4	3	4	4	4	4	3	4	23	3.833	0.408
BI2	4	3	4	4	3	4	3	4	22	3.666	0.516
BI3	4	4	4	3	3	4	3	4	22	3.666	0.516
Avg PE	-	-	-	-	-	-	-	-	97	4	0.062
Avg EE	-	-	-	-	-	-	-	-	97	4	0.179
Avg ATUT	-	-	-	-	-	-	-	-	96	4.111	0
Avg FC	-	-	-	-	-	-	-	-	96	4.166	0.174
Avg SE	-	-	-	-	-	-	-	-	97	3.916	0.045
Avg BI	-	-	-	-	-	-	-	-	94	3.9166	0.062
Avg Total score	-	-	-	-	-	-	-	-	577	4.018	0.066

Table 14. Questionnaire results

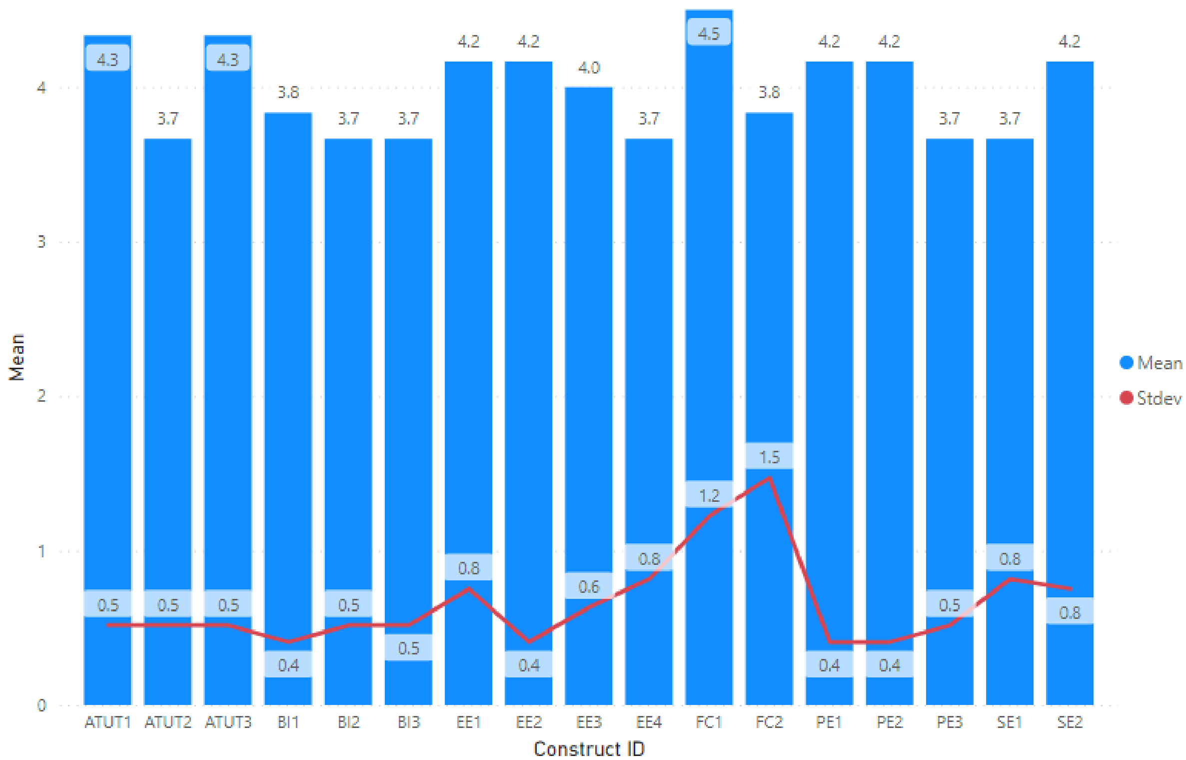


Figure 35. Questionnaire results

5.2.1 Performance expectancy (PE)

The determinant 'performance expectancy' indicates whether an individual using the proposed method would improve his performance in his working environment (Venkatesh et al., 2003). Table 29 illustrates how each expert has evaluated each of the statements. Overall, all the experts have stated they would like to use this method in their work or in specific project and the average score of this determinant results to be a 4 out of 5.

Statement		E1	E2	E3	E4	E5	E6	Avg
PE1	I would like to use the proposed method as it is considered helpful.	4	4	4	4	5	5	4.166
PE2	Using the proposed method would improve my job performance in specific projects.	5	4	4	4	5	5	4.166
PE3	Using the proposed method will increase my productivity.	4	4	3	3	4	4	3.666
Avg PE	-	-	-	-	-	-	-	4

Table 15. Performance expectancy questionnaire results

The experts have stated that the designed method is a good way to evaluate the requirements and the gap between the current architecture and the improved one, and that this method is a good approach as it is logical and includes the necessary steps to go from "As-is situation" via measures to the target and the implementation / evaluation. The standard deviation value in all the statements is between 0.4-0.5, which indicates that the experts agree in the performance expectancy of the method.

5.2.2 Effort expectancy (EE)

The determinant 'effort expectancy' indicates the degree of ease associated with the use of the method (Venkatesh et al., 2003). Table 30 illustrates how each expert has evaluated each of the statements.

Statement		E1	E2	E3	E4	E5	E6	Avg
EE1	I would find the proposed method easy to use.	5	4	4	5	3	4	4.166
EE2	My interaction with the proposed method will be clear and understandable.	5	4	4	4	4	4	4.166
EE3	Learning to use the proposed method is easy for me.	5	4	4	4	4	4	4
EE4	The rewards for implementing the method are worth the time.	5	4	3	3	3	3	3.666
Avg EE	-	-	-	-	-	-	-	4

Table 16. Effort expectancy questionnaire results

Similarly, also this determinant is evaluated positively by the experts, and it has an average score of 4 out of 5. The experts have stated that the steps of this method are clear and easy to follow and thus they view it as an easy method to use and apply. However, we can certainly say that this method is easy for an enterprise architecture, but organization without an EA department will find it a bit tricky as their employees may not be experienced with EA approaches. The standard deviation value in all the (EE) statements ranges between 0.4-0.8, which indicates that the experts share the same opinion in the effort expectancy that is expected for using and learning this method.

5.2.3 Attitude towards use of technology (ATUT)

The determinant 'attitude towards use of technology' indicates an individual's overall affective reaction to using a method or system (Venkatesh et al., 2003). Table 31 illustrates how each expert has evaluated each of the statements and as noticed the average score is 4.111.

Hence, the experts agree that the usage of this method is a good and an appealing idea to them and that they are looking forward to those aspects of their job where this method can be applied. If the complexity is a huge problem for the company than this method is definitively a good, logical way to determine it. Moreover, one of the EA consultants have stated that this method would tremendously help explaining what needs to be done to his junior colleagues and hence he sees it as a good time-saver. Interestingly, the standard deviation value in all the ATUT statements is 0.516, which demonstrates that the attitude towards using this method is positive.

Statement		E1	E2	E3	E4	E5	E6	Avg
ATUT1	Using the proposed method is a good idea.	5	5	4	4	4	5	4.333
ATUT2	The proposed method makes my work more interesting.	4	4	4	4	4	5	3.666
ATUT3	I am looking forward to those aspects of my job (or specific work projects) that require me to use the proposed method.	5	4	4	5	4	3	4.333
Avg ATUT	-	-	-	-	-	-	-	4.111

Table 17. Attitude toward use of technology questionnaire results

5.2.4 Facilitating conditions (FC)

The determinant 'facilitating conditions' represents the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the method (Venkatesh et al., 2003). Table 32 illustrates how each expert has evaluated each of the statements. As previously mentioned, some of the experts are not very familiar with EA and hence they don't have all the required knowledge in modelling all the viewpoints (minimum value is 2). That's why they have stated that they would need some training.

Statement		E1	E2	E3	E4	E5	E6	Avg
FC1	I have the necessary knowledge to use the proposed method.	5	2	5	5	5	4	4.5
FC2	The proposed method is compatible with other systems or tools that I use for my work.	5	2	4	5	2	5	3.833
Avg FC	-	-	-	-	-	-	-	4.166

Table 18. Facilitating conditions questionnaire results

The average value score for this determinant results to be 4.166, while the average standard deviation value per statement varies between 0.5 to 1.2. Therefore, we can say that most of the experts agree to have the necessary knowledge and that this method is compatible with other tools that they use in their work. On the other hand, one of the experts indicated that he does not have sufficient knowledge, or tools and that he would need some training.

5.2.5 Self efficacy (SE)

The determinant 'self-efficacy' represents the judgement of an individual's ability to use the method (Venkatesh et al., 2003). Table 33 illustrates how each expert has evaluated each of the statements. It's worth to mention that this determinant is somehow biased with the previous determinant. Hence, we can notice here that the experts who stated that he would need some training as is doesn't have the sufficient knowledge in using this method, also agrees with having some help from someone or having a built-in guide. Moreover, the experts have stated that a (simplified) guide would be very helpful for this method to ensure that the steps can be fully understood and followed as prescribed, and that the best assistance could be provided by an experienced user. The average score is 3.9, and the standard deviation values are lower than 1.

Statement		E1	E2	E3	E4	E5	E6	Avg
SE1	I would use the proposed method if I could get help from someone (If I get stuck).	3	4	4	3	3	5	3.666
SE2	I would use the method if there is a built-in guide for assistance.	3	4	5	5	4	5	4.166
Avg SE	-	-	-	-	-	-	-	3.916

Table 19. Self-efficacy questionnaire results

5.2.6 Behavioral intention of use (BI)

The construct 'behavioral intention of use' indicates an individual's perceived likelihood or subjective probability that he will engage in using the method (Venkatesh et al., 2003). Table 34 illustrates how each expert has evaluated each of the statements. The average score of this determinant is 3.91, as some experts state they agree to use this method in their job as consultant. Moreover, one of the experts states that he predicts to use this method for teaching EA in the future. The average standard deviation score per BI statement varies from 0.4 - 0.5, which indicates that the experts agree to use this method in the future.

Statement		E1	E2	E3	E4	E5	E6	Avg
BI1	I intend to use the proposed method in the future for helping me in my job (or specific projects).	4	3	4	4	4	4	3.833
BI2	I predict I would use the proposed method in the future for helping me in my job (or specific projects).	4	3	4	4	3	4	3.666
BI3	I plan to use the proposed method in the future for helping me in my job (or specific projects).	4	4	4	3	3	4	3.666
Avg BI	-	-	-	-	-	-	-	3.91

Table 20. Behavioral intention of use questionnaire results

5.3 The non-functional requirements

The method validation chapter consists also of validating the defined non-functional requirements, which are described in section 3.1. The first non-functional requirement considers the efficiency of the method and what would be the outcome of implementing it in the working environment. To validate this requirement, the panel of expert were asked about the performance expectancy of the method, and we can say that our method is expected to improve the business performance of an employee in his working environment (average PE score=4).

The second non-functional requirement is related to the cost effectiveness. Hence, when the method is implemented is must enhance improvements in the business performance of the organization. To validate this requirement, we have asked the panel of expert about sharing their opinion on this. Figure 67 shows the scores that each of the experts gave. As we can notice, the answers differ among the experts. All the experts have stated that this method is good, but the business performance will be directly influenced by the implementation of the proposed target architecture, and it can also be re-measured after this implementation is fully done.

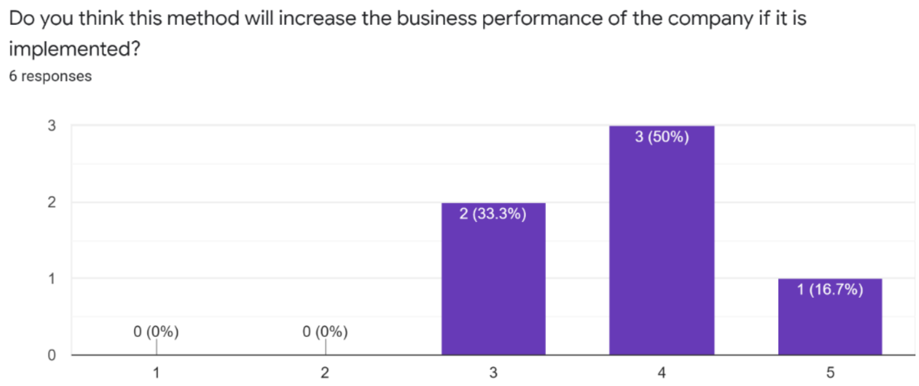


Figure 36. Business performance evaluation

The third non-functional requirement considers the implementation time of the method. The experts were asked to indicate what would be their effort expectancy, their facilitating conditions and what is their self-efficacy in using this method. As described in section 5.2, all these determinants have an average score around 4 and hence, we can say that the benefits gained from implementing this method are worth the spent time.

The last non-functional requirement is related to the usability of the method. The panel of experts were asked to indicate their behavioral intention in using this method and in average they agree to use this method (average BI=3.91). In addition, the experts were asked to indicate also their attitude towards using this method and all of them agree that the usage of this method is a good idea, and it would make their work more interesting. Thus, all of them have stated that they are looking forward to those aspects where they can apply this method in their job or in specific work projects.

6. Conclusion

The aim of this thesis is to show how an organization could use Enterprise Architecture for managing complexity and improving its business performance. As explained in section 1.4, the overall structure of this research follows the design science research methodology. Therefore, first the problem investigation has been done based on the formulated research questions (section 1.3). Next the treatment design phase has been carried out by starting with the specification of the functional and nonfunctional requirements and continuing with the method proposal which consists of nine steps. Each step has been elaborated by mentioning what would be the approach, what would be the method and what would be delivered of it. Next, this method has been implemented in the case study. In addition, the treatment validation phase has been carried out by building a group of experts in the field of EA and/or complexity.

This chapter discusses the results of this research, regarding the formulated research questions. Next, this chapter presents the contributions to the theory and to practice, and lastly it discusses the limitations and gives suggestions for future research.

6.1 Discussion

6.1.1 Research questions

As previously mentioned, the goal of this research is to propose a method that uses EA for controlling complexity and enhancing improvements in business performance. This goal is further defined in the context of the research questions. As described in section 1.3, the main research question is:

How can we improve business performance by reducing Enterprise Architecture complexity?

To assist in answering the main research question, some sub-research questions were raised and each of them will be discussed in the following paragraphs.

RQ1- What is the relationship between enterprise architecture and business performance?

To discover the relationship between EA and business performance, we have divided this research question into five knowledge questions and then we have performed a systematic literature review, which made it possible to identify relevant previous research that has been done in this field in the past two decades.

Enterprise architecture is viewed as a discipline that consists of principles, methods and models that are used in the design and realization of an enterprise's organizational structure, business processes, IT systems and infrastructure (Lankhorst et al., 2010; Rood, 1994). In addition, Lankhorst et al., (2010) argue that an enterprise architecture creates a holistic view of an organization and provides the useful insights for organizing IT systems and infrastructure in alignment with the business goals and it examines the key business, information, application and technology strategies as well as their impact on the business functions. EA aims to define a suitable operating platform which will serve in the supporting of an organization's current and future goals as well as it will provide a roadmap for moving towards and achieving this vision (Tamm et al., 2011).

By taking a look in the existing literature, we found that EA benefits do not have a direct influence on business performance, but EA benefit enablers do. Therefore, the next formulated research question looks at the impact of the EA benefit enablers on the business performance.

RQ2- What is the impact of EA benefit enablers to business performance?

In order to discover the impact of EA benefit enablers to business performance, we divided this research question into two knowledge questions. One knowledge question is the identification of the main EA benefit enablers and the second one is the identification of a good approach for measuring business performance.

The main EA benefit enablers that we have identified are: the 'Organizational Alignment', which is the extent to which the subunits of an organization share a common understanding, the 'Information Availability', which is the extent of useful, high-quality accessible information, 'Resource Portfolio Optimization', which is the extent to which an organization makes use of its existing resources and makes new investment, and lastly, 'Resource Complementarity', which is the extent to which the resources of an organization support the achievement of its goals (Tamm et al., 2011).

A good approach for defining the business performance is the Balanced Scorecard (BSC), which consists of four perspectives: Financial perspective, Customer perspective, Internal Business Process perspective, and Learning & Growth perspective (Kaplan & Norton, 1993).
The balanced scorecard can be seen as the heart of an organization's efforts which shows how results are achieved, and defines and communicates the priorities to the managers, employees, investors and to customers (Kaplan & Norton, 1993). Evidence that the BSC is a good approach has also been provided by Sim and Koh (2011), who have conducted research in 83 electronics companies. According to Sim and Koh (2011), organizations should define their business performance by using the BSC, as the BSC tells the managers to make a commitment by introducing an array of measures or scorecards that will help with guiding better their decision

making, and will provide greater profitability, because in this approach the manager's position themselves to better serve their employees, customers and shareholders.

From the selected studies, we identified that the 'Organizational Alignment' (benefit enabler) has a positive influence on the financial and learning & growth-related business performance factors. 'Information Availability' is claimed to improve customer, internal and learning & growth-related business performance factors. To continue, the third benefit enabler 'Resource Portfolio Optimization' influences positively all the four perspectives of the BSC, and lastly 'Resource Complementarity' has a positive influence on the customer and internal business performance factors.

RQ3- How can we define complexity and how does it affect business performance?

In the conducted SLR study, we identified four dimensions of complexity: organized complexity vs disorganized complexity, qualitative vs quantitative complexity, subjective vs objective complexity and structured vs dynamic complexity (Schneider et al., 2014). On the other hand, Cant et al., (1995) classify complexity as: computational complexity, cognitive complexity, and representational complexity. Cognitive complexity is defined as the mental processes that a software engineer or another individual uses for interpreting code (Cant et al., 1995). In addition, Moodly (2009) has defined several principals that aim to maximize cognitive effectiveness of a user, e.g., perceptual discrimination, perceptual configuration, working memory, and long-term memory (table 4).

As described in section 2.2.2, an interesting SLR study on the identification of complexity metrics among different dimensions has been carried out by Iacob et al., (2018), who have identified 42 metrics as shown in table 5. However, most of the identified metrics (79% of them) are classified as objective-structural-quantitative-ordered. As the main focus of our research is on the objective and subjective dimension of the complexity, section 3.2.3 describes the complexity constructs as well as the complexity conceptual model which will be used for operationalizing the complexity metrics.

In order to identify the effect that complexity has on business performance, a design problem was formulated (section 1.3). As previously mentioned, this design problem (artifact) is the main contribution of our research. The artifact of this thesis is a method, as described in section 3. The method is further implemented at the case company. Part of the method steps are the measurement of business performance, and the measurement of complexity and final results show that the Mould department has a high complexity in the architecture code group as they are currently using many input sources and many databases. In addition, the department also uses duplicated systems for doing the same tasks (e.g., for E-mail). These complexity metrics also affect the KPIs, especially the ones that are related to time, and to the IT cost (i.e., the high number of input sources and the high number of databases effect the ‘throughput time’ indicator and the ‘cost’ indicator).

On the other hand, the complexity metrics in the stakeholder code group have different outcomes. The level of education metrics has an average score of 2 out of 5, which means that the average departmental academic knowledge is low. Surprisingly, the technology affinity metrics achieved a 3.72 score out of 5, which means that the mould engineers like learning new technologies and try to be as up to date as possible.

In addition, this method was validated by a group of experts in the field of EA and/or complexity management. Overall, the method received a positive evaluation with an average score 4.01, which indicates that the designed artifact is viewed as a good method for reducing EA complexity and for improving business performance.

6.1.2 General discussion and reflection

As described in chapter 5, the method was evaluated positively by the experts. These evaluations also lead to the identification of current changes and to future research. The main change in the designed method is related to step 7, which is the ‘target architecture’. One of the experts pointed out that the modelling of the target architecture must start with the overall strategy for the new architecture and the motivation for changes which is based on the analysis of the baseline architecture (step 6). In the beginning, we had suggested to have the modelling of strategy viewpoint after the modelling of the desirable situation, however this is not the best way. Therefore, the suggestion by the expert has been taken into account and now the ‘target architecture’ step starts with the modelling of strategy and motivation viewpoint.

It’s worth to mention that, the overall goal of reducing complexity is always present in the method. This is also shown in the motivation viewpoint in the case study by using the driver element of ArchiMate. Therefore, we believe that the last step of the method must consist on the re-measurement of business performance in order to evaluate how it was affected by the changes, and that there is no need to have a separate step of re-measuring complexity as this is the main aim of the proposed target architecture, and the impact of changes are described in the next step that is the migration gap and impact analysis step.

An interesting point for discussion is also the comparison of our method to TOGAF ADM Method. As described in section 2.1.3.2, TOGAF ADM is a cyclic process and consists of ten phases. Similarly, to our method, the first step of TOGAF ADM is the ‘Preliminary’ phase which clarifies the current baseline architecture of an organization. However, the next phases of

TOGAF ADM depict the architecture vision, the business architecture, the IS architecture and the technology architecture, while in our method only step 7 is focused on the target architecture of the organization and all the changes towards the desired situation are shown there. Another similar point between these methods is the migration plan phase which shows the prioritization and the implementation plan that the company must embark.

On the other hand, our method consists also in the selection and measurement of KPIs and complexity metrics which help in understanding and analyzing better the current situation, while TOGAF ADM is concerned with the 'Implementation Governance' about the EA projects, 'Change Management' which is focused on the future changes using surveillances processes in business and IT, and 'Requirements Management' which provides the place where all the requirements of the other ADM cycles are identified and stored. Hence, in conclusion, we can say that our method is similar to TOGAF ADM regarding the modelling of baseline, target architecture and migration plan, but our method is also implicitly concerned with the identification and measurement of the business performance and complexity, while TOGAF ADM is focused on the governance of EA projects and in change management.

6.2 Contributions

This section presents a summary of the contributions of this research. In the following paragraphs there is an elaboration on the contribution of this research to practice, as well as on the contributions to theory.

6.2.1 Contributions to practice

This research offers several contributions to practice. To start with, this method can serve as a guideline for organizations which are facing a high amount of complexity in their working environment and/or for organizations who want to measure their business performance. In addition, the designed artifact can be easily adapted by any organization without much effort as it has guidelines. Secondly, the designed method has been implemented to a company and it has been validated through the group of experts. Overall, this method was evaluated positively, and all the experts agreed towards the benefits that this method provides, and expressed their intention towards using it in the future. Hence, the proposed method is considered to be very useful for organizations that are dealing with a high amount of complexity and/or for organizations that are interested in the implementation of an enterprise architecture which will guide them towards future changes.

6.2.2 Contributions to theory

The findings of this research contribute to communities of academic research on EA, complexity management and business performance. Several prior research has been conducted in the field of EA or business performance for identifying the impact of EA on business performance (Bookholt, 2014; Boucharas 2010) or in EA complexity management where a conceptual complexity model has been proposed (Iacob et al., 2019). However, our research is the first one which presents how enterprise architecture could be used for managing complexity and for improving business performance. The delivered artifact of this research is a method which consists of nine steps and this method is concerned with the implementation of the EA in an organization by modelling the baseline architecture, the target architecture as well as by providing the migration gap and impact analysis. In addition, the designed method implicitly addresses the selection of KPIs and complexity metrics for measuring the business performance and the existing complexity. Hence, the 'as-is' situation of an organization is analyzed through the modelled viewpoints by using the ArchiMate language (e.g., overview, motivation viewpoint, business viewpoint, application viewpoint, technology usage viewpoint, etc.), through the SWOT analysis, as well as through the measurement of the selected KPIs and complexity metrics. Next, the 'to-be' situation is proposed by addressing a solution and improvements to all the identified misalignments, non-accurate processes or existing problems.

6.3 Limitations and Future research

There are several limitations in this research that have been identified, and that will guide towards future research. The first limitation is in regard to the profile of the case study. The designed method could only be demonstrated in a single department, which made the measurement quite limited. In the selection of the KPIs phase, we found out that only the financial perspective and internal business process perspective could be measured. The customer perspective could not be measured, because the department does not have any direct contact with customers. In addition, we could not measure the learning & growth perspective as currently the department is not considering any learning & growth developments for improving the end product (i.e., the end product of the Mould department are the mould drawings). In addition, most of the KPIs in the financial perspective and internal business process perspective have been reformulated or changed in order to be aligned with the scope of the Mould department (i.e., the department does not have any financial outcomes in term of money value and thus the 'Yearly recurring profit' could only be measured as the 'Number of finished projects per year'. Sales and profits of the company are handled by the Finance department).

The second limitation is related to the lack of collaboration from some employees in the department. As part of our research, we have distributed two surveys to the Mould department. The aim of the first survey was to become familiar and to better understand the problems that the mould engineers are currently facing regarding the complexity in their working environment. Even though this survey was quite short and anonymous only 5 out of 7 mould engineers filled out the questionnaire. In addition, the aim of the second survey was to get some input data for measuring some of the defined metrics, and sadly also this survey was completed only from 5 mould engineers. Therefore, this lack of collaboration results to having limited input towards the problem investigation and in doing the measurements.

In addition, the limitation on time that for this research effected the last step of the method (re-measurement of business performance). This step could not be completely done due to the time duration of this research which was done within 6 months. The implementation of changes that were identified in the target architecture require significant time, and in the case of the Mould department they also require the capabilities for the implementation of the ML pipeline and for the implementation of FAIR principles and FAIR Data Point. Therefore, in this step we have identified mostly the benefits that could be enhanced from these implementations, as it was difficult for us to determine exactly how much will be the savings on time spent per each mould workflow activity.

Another limitation is faced in the method validation phase. By considering the profile of the company where the method was demonstrated, we realized that the company does not have any employee who is experienced in EA. Therefore, the method had to be validated also outside the company, and thus the validation could be done by using the UTAUT model as this model makes possible the measurement of several user acceptance determinants. On the other hand, if the company had some EA experts, the validation would be done by having semi-structured interviews.

The last limitation is the change of the company supervisor in the middle of the research. Even though this is not really a limiting factor, but we see it as something that could have been avoided as it required some extra time for the side of the new company supervisor to become familiar with my research.

In regard to the identified limitations, for future research, it is recommended to demonstrate the proposed method in different cases, in order to determine what is the sensitivity in different contexts, and what is the effect that the artifact (our method) produces when implemented in different contexts. Therefore, the next three questions that have emerged for future research are:

-What are the effects that this EA complexity management method will produce in a long-term implementation?

-How can this EA complexity management method have a more cyclical nature of architectural work?

-Do we need ALL the method steps in ANY situation, or can the resequencing of the steps prevent extra time and workload?

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Appendix A

This section presents the Research Methodology of the SLR, which was part of the Research Topics.

Research Method

As mentioned also before, the goals of this paper will be realized by carrying out a systematic literature review (SLR) related to the evolution of the usage of enterprise architecture for dealing with complex IT systems. Thus, the systematic literature review has been chosen as the research method of this paper and it will be based on the guidelines that are proposed by Kitchenham and Charters (2007) who conducted a SLR in software engineering, as well as on the paper by Rouhani et al. (2015) who have carried a SLR on EA implementation Methodologies. According to Kitchenham & Charters (2007) and Rouhani et al. (2015), a SLR process is composed of three major phases: planning, execution and result analysis. In this study, the execution phase will be called the selection phase, as basically on this phase there will be the selection of the studies that were found in the scientific databases by using the inclusion and exclusion criteria.

3.1 The planning phase

The first phase in the SLR process is the planning which focuses on the definition of the objectives and the formulation of the research questions that will be addressed in this study, as well as on the specification of selecting the databases and the formulation of the search queries. Hence, all of these will be elaborated in the below sections.

3.1.1 Research questions

This section is focused on the formulation of the research questions that will be the focus of this study. Below there is the main research question and some knowledge questions which are listed under sub- research questions.

Main RQ:

How does the implementation of EA in an organization deal with complex IT systems?

Sub RQs:

1. Which is the most suitable framework for dealing with complex IT systems?
2. What benefits will the implementation of EA bring to the business performance of the organization?
3. What are some metrics for measuring complexity?

3.1.2 Scientific Databases

This section defines the scientific databases and sources that will help in performing this SLR study. The main databases that are selected for this review are:

- IEEE (https://ieeexplore.ieee.org)
- Google Scholar (www.scholar.google.com)
- Springer Link (http://www.springerlink.com).

These databases are chosen, because they provide a good coverage of all the publications and developments in the field of EA and in IT systems.

3.1.3 Search Queries

The search queries are formulated based on the group of keywords that are related to the research questions. The main keywords can be seen in Table 1.

Enterprise Architecture	Organization Structure	IT systems	Requirements
EA	Business	IT tools	Complexity
EA strategies	Enterprise	IT programs	Control
EA standards		Information systems	Efficiency
EA principles		Information technology	Management
EA frameworks		Systems architecture	

Table 1. Searching keywords

Based on these keywords (table 1), the next step in the process will be the formulation of search queries for each scientific database by clustering together the main keywords (that are in deep blue color in table 1), as well as their synonyms.

Searching queries in the scientific databases:

(“Enterprise Architecture” OR “EA” OR “EA strategies” OR “EA principles” OR “EA standards” OR “EA frameworks”)

AND

(“business” OR “enterprise”)

AND

("IT systems" OR "IT tools" OR "IT programs" OR "Information systems" OR "Information technology" OR "systems architecture")

AND

("complexity" OR "Control" OR "Efficiency" OR "management).

3.1.4 Inclusion and Exclusion Criteria

The last step in the planning phase is the formulation of inclusion and exclusion criteria. These criteria are very essential when doing a SLR study as these criteria will help in the reduction of the likelihood of having a biased search process and will help in a better selection of important and useful papers (Kitchenham & Charters, 2007). The articles that will be included in this study, are the ones that are focused on the EA field and on the implementation of EA. Moreover, the articles that are published in English language indicate that these studies could have been peer reviewed internationally and highly cited papers about EA and/or IT systems and/or EA frameworks indicate that these studies have had a high impact on the field of EA and IT systems. On the other hand, the papers that will not be considered are studies that are not in English, studies that are not related to research questions of this study as well as studies that are too short or incomplete. An overview of all these criteria can be seen in figure 3.

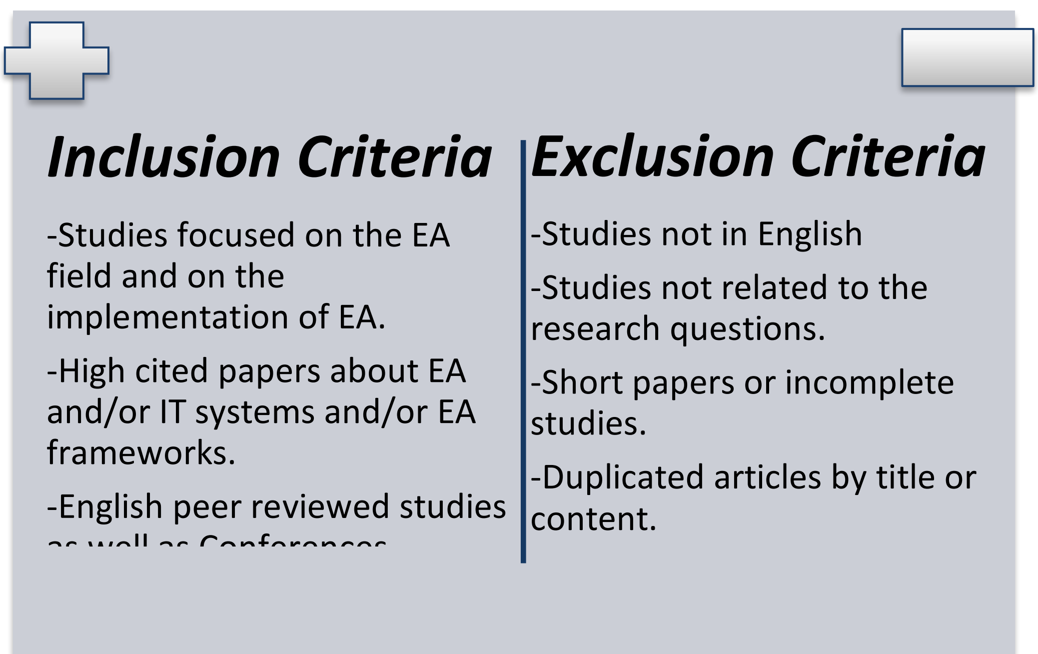

Figure 3. Inclusion and exclusion criteria

3.2 The selection phase

The second phase in the SLR process is the selection which focuses on the selection of the studies that were found in the scientific databases by using the inclusion and exclusion criteria. Once the potentially relevant studies have been found, they need to be assessed for their true relevance. According to Rouhani et al. (2015), the selection of studies should be performed through the following processes:

1. Search in the scientific databases for the identification of relevant studies using the searching queries or the searching keywords (table 1).
2. Apply the inclusion criteria (figure 3) to the studies that were found.
3. Exclude irrelevant studies based on the analysis of their titles and abstract.
4. Exclude duplicate studies across the scientific databases.
5. Evaluating the already selected studies by reading their whole text and removing short studies.
6. Exclude studies that are too general, or that are not able to answer any of the research questions.
7. Select primary papers.

The gathered results for each of these processes can be seen in figure 4.

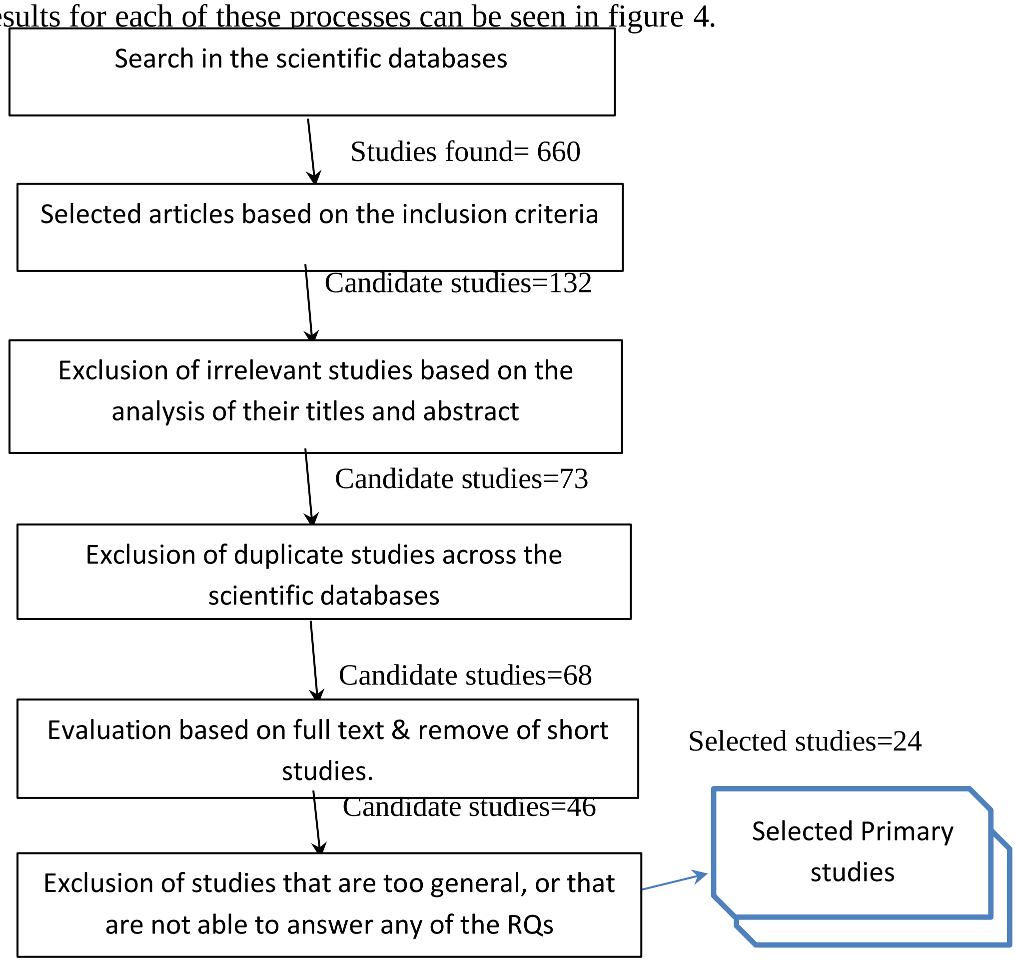

Figure 4. Processes for finding primary studies.

3.2.1 Synthesis

The seven step process helped a lot in selecting the primary studies which will serve for answering the research questions. More detailed information about the studies that were retrieved in step one based on the searching keywords and studies selected in step 7 of the process from each database can be seen in Table 2.

Source	Papers found	Candidate papers	Selected papers
IEEE	204	39	11
Springer Link	54	4	1
Google Scholar	302	30	12
Total	**660**	**73**	**24**

Table 2. Studies retrieved from the scientific databases.

3.3 Data extraction

After the selection of the primary papers, an extraction content that elaborates about the research purpose, research method and the output(s) of the papers should be done. The collected essential information can be seen in table 3, where the selected 24 papers are extracted. The research method in these papers could be: LR (literature review), S/I (survey or interviews) and/or E (experiment). In addition, different studies had different research purposes and goals and thus, the identification of the outcome(s) for each paper has also been done. In the output column, T stands for outputs in theoretical aspects, CM refers to conceptual models, A/F is the modeling of an architecture or the presentation of a framework and ER stands for empirical results and statistical analysis. As can be seen in table 2, most of the selected studies have used a literature review as their primary research method and have mostly outcomes in theoretical aspects. Interestingly, there are some studies that combine different research methods and/or have different outcomes (e.g the paper by Boh & Yellin (2014), Bookholt, E. (2014), Efatmaneshnik, M. & Ryan, M.J(2016), etc.).

Number	Reference	Research purpose(goals)	Research Method			Output(s)			
			LR	S/I	E	T	CM	A/F	ER

P 1	Fu et al., (2016)	They aimed to achieve these goals: to chart a landscape state-of-the-art relating to complexity cybernetics of EA and secondly to provide some suggestions for future work.	x			X			
P 2	Boh & Yellin (2014)	They conducted a firm-level survey in order to answer 2 key questions about the EA standards:(1) How do different governance mechanisms affect the use of EA standards? and (2) To what extent does the use of EA standards help organizations to improve the sharing and integration of IT resources across the enterprise?		x	X	X			x
P 3	Niemi, E. (2006)	The identification and classification of EA benefits.	x	x		X			
P 4	Shah& Kourdi (2007)	The identification of EA benefits and the specification of the role of EA frameworks	x			X			
P 5	Rojas et al., (2017)	The creation of a model to measure the complexity of EA			X		x		x
P 6	Iacob et al., (2018)	The incorporation of objective and subjective complexity metrics in a single EA complexity model	x				x		
P 7	Tam et al., (2011)	To address the knowledge gap of how does EA lead to organizational benefits	x				x		
P 8	Zachman, J. A. (1987)	The creation of a descriptive framework from disciples quite independent of IS, and the specification of IS architecture	x					x	
P 9	Rouhani et al., (2013)	To review 5 EA implementation methodologies and to compare them based on a designed framework.	x					x	
P 10	Bookholt, E. (2014)	To provide insight into the way EA yields benefits for business performance	x		X	X			x
P 11	Niemi & Pekkola (2019)	To clarify how EA benefits are realized by studying the EA benefit-realization model	x			X			
P 12	Lee et al., (2014)	Examination of complex IT services and complex management	x			X		x	
P 13	Lange et al., (2012)	The Identification of EA success factors and EA benefits and the proposition of a theoretical model explaining the	x			X			

		realization of EA benefits							
P14	Merwe et al., (2013)	To report on the research findings of a study that investigated the impact of managerial EA decisions on software developers in a software development company.	x			X			
P15	Gualtor et al., (2018)	To analyze the role of EA within other management tools, techniques, and frameworks that use different approaches for improving business governance.	x			X			
P16	Lakheouit, J. Baina, K.(2015)	To present a new method for evaluating EA complexity and facilitating decision between different TO-BE architecture scenarios.			X		x		
P17	Alwadain, A. (2019)	The development of an EA-benefit realization process model using an established theoretical foundation.	x				x		
P18	Niemi, E. Pekkola, S. (2013)	The identification of quality attributes for EA products and services		x					x
P19	van Steenbergen, M. (2011)	To give insights on how to implement and professionalize the practice of EA in organizations and what makes EA effective.	x			X		x	
P20	Lankhorst et al., (2005)	To model, to communicate at to analyze enterprise at work.	x			X	x		
P21	van der Raadt et al., (2004)	To provide a starting point for assessing architecture maturity and alignment within organizations.		x			x		x
P22	Schneider et al.,(2014)	To identify 8 aspects of complexity and to propose a framework for interpreting complexity	x			X		x	
P23	Efatmaneshnik, M. & Ryan, M.J(2016)	To introduce a concept of subjective complexity and a framework for measuring system's complexity	x		X	X		x	
P24	Boucharas et al., (2010)	A SLR on the literature concerning the potential contribution of EA to the achievement of various business goals.	x			x			

Table 3. Data extraction form.

3.3.1 Quality assessment

Once the primary papers have been selected based on the inclusion and exclusion criteria, the next phase is the assessment of their quality. According to the SLR guidelines in the paper by Kitchenham (2009), four quality assessment (QA) questions have been defined. These questions will help in the assessment of the research of each proposal and will also provide a quantitative comparison between them. The scoring procedure that was used by Kitchenham (2009) and also later by Rouhani et al. (2015) was: Yes(Y)=1, Partly(P)=0.5 and No(N)=0. Moreover, the quality assessment questions that were defined by them in these SLRs were:

1. How well are the practices or concepts defined?

   -Yes: It either explicitly describes enterprise architectures (the benefits, the complexity etc) or frameworks, the metrics or the implementation of them.

   -Partially: It briefly describes EA, EAF or the metrics.

   -No: It describes neither EA, EAF or the metrics.

2. How clearly is the research process established?

   -Yes: The research process and research methods are clear.

   -Partially: The research process is mentioned briefly

   -No: The process is not mentioned.

3. How clearly are the work limitations documented?

   -Yes: The limitations of the implementation of EA or EAF are clear.

   -Partially: The limitations are mentioned but are not explained.

   -No: The limitations are not mentioned.

4. How well have the diversity of context and perspective been explored?

   -Yes: It explicitly explains various perspectives of EA or EAF.

   -Partially: It mentions the various perspectives of EA but there is no detailed information.

   -No: It did not mention the various perspectives of EA.

These questions will help in checking the selected papers and the score that was achieved per each paper is shown in table 4. The indexes of the papers in table 4 are the same as the ones in table 3.

Paper	Reference	QA1	QA2	QA3	QA4	Total score
P1	Fu et al., (2016)	Y	Y	P	P	3
P2	Boh & Yellin (2014)	Y	Y	Y	P	3.5
P3	Niemi, E. (2006)	Y	Y	P	P	3
P4	Shah& Kourdi (2007)	Y	P	P	Y	3
P5	Rojas et al., (2017)	Y	Y	Y	P	3.5
P6	Iacob et al., (2018)	Y	Y	N	P	2.5
P7	Tam et al., (2011)	Y	Y	Y	P	3.5
P8	Zachman, J. A. (1987)	Y	Y	Y	P	3.5
P9	Rouhani et al., (2013)	Y	P	N	P	2
P10	Bookholt, E. (2014)	Y	Y	Y	Y	4
P11	Niemi & Pekkola (2019)	Y	Y	Y	P	3.5
P12	Lee et al., (2014)	Y	P	N	P	2
P13	Lange et al., (2012)	Y	Y	P	P	3
P14	Merwe et al., (2013)	Y	Y	P	P	3
P15	Gualtor et al., (2018)	Y	Y	N	P	2.5
P16	Lakhrouit, J. Baina, K.(2015)	Y	P	N	P	2
P17	Alwadain, A. (2019)	Y	N	N	P	1.5
P18	Niemi, E. Pekkola, S. (2013)	Y	Y	P	P	3
P19	van Steenbergen, M. (2011)	Y	Y	Y	Y	4
P20	Lankhorst et al., (2005)	Y	N	P	P	2
P21	van der Raadt et al., (2004)	P	Y	N	P	2
P22	Schneider et al.,(2014)	Y	P	P	P	2.5
P23	Efatmaneshnik, M. & Ryan, M.J(2016)	Y	P	P	P	2.5
P24	Boucharas et al., (2010)	Y	Y	Y	P	3.5

Table 4. Quality assessment form.

The scores are distributed from 0 to 4 points total. If a question is answered with Yes (Y) this is translated to 1 point, if the answer is Partially (P) it is 0.5 points and if the answer is No (N) it means 0 points. From the 24 selected studies, only two of them (the paper by Bookholt, E. (2014) and van Steenbergen, M. (2011)) have scored 4 points, which means that these studies have a very high quality. Moreover, around 63% of the selected studies have scored between 2.5 to 3.5 points, 23 % (6 studies) are qualified with 2 scores and only 1 paper (by Alwadain, A. (2019)) has scored 1.5 points, because it has good theoretical aspects and a process theory model but on the other hand it does not have a clear research method and the limitation section was missing.

Appendix B

This appendix is restricted.

Appendix C

This appendix is restricted.