Enterprise architecture for small and medium-sized enterprises: CHOOSE

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FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

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Submitted to the Faculty of Economics and Business Administration of Ghent University
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I do not think that there is any other quality so essential to success of any kind as the quality of perseverance. It overcomes almost everything, even nature.

John D. Rockefeller

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- All the others whom I did not mention.

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List of Acronyms

0-9

4EM	For Enterprise Modelling method
7S	Strategy, Structure, Systems, Shared values, Skills, Staff, Style

A

A	Accuracy
ADM	Architecture Development Method
ARIS	Architecture of Integrated Information Systems

B

B	Business
BMM	Business Motivation Model
BPMN	Business Process Model and Notation
BRM	Business Reference Model

C

C4ISR	Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance architecture framework
CAIRO	Consulted, Accountable, Informed, Responsible, Out of the loop
CARP	Capability, Activity, Resource, Performer
CD	Cognitive Dimensions of notations
CDM	Conceptual Data Model
CE	Cognitive Effectiveness
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CHOOSE	keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise
CIM	Computation Independent Model

D

DBMS	DataBase Management System
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
DRM	Data Reference Model
DSR	Design Science Research
DYA	DYnamic Architecture

E

E2AF	Extended Enterprise Architecture Framework
EA	Enterprise Architecture
EAM	Enterprise Architecture Management
EASE	Enterprise Architecture Small and medium-sized enterprise Environment
EFQM	European Foundation for Quality Management
EKD	Enterprise Knowledge Development
ERP	Enterprise Resource Planning
EVA	Economic Value-Added

F

FEA	Federal Enterprise Architecture
FEAF	Federal Enterprise Architecture Framework
FTE	Full-Time Equivalent

G

GEAF	Gartner Enterprise Architecture Framework
GEAM	Gartner Enterprise Architecture Method
GMF	Graphical Modeling Framework
GORE	Goal-Oriented Requirements Engineering

I

i*	ISTAR: Intentional STrategic Actor Relationships
IAF	Integrated Architecture Framework
IFEAD	Institute For Enterprise Architecture Developments
IS	Information System
ISACA	Information Systems Audit and Control Association
IT	Information Technology
IU	Intention to Use

K

KAOS	Keep All Objectives Satisfied / Knowledge Acquisition in autOmated Specification of software systems

L

LDM	Logical Data Model
LEAP	Lightweight Enterprise Architecture Process

M

MDA	Model-Driven Architecture
ME	Mental Effort
MEM	Method Evaluation Model

O

OCL	Object Constraint Language
OMB	Office of Management and Budget
OMG	Object Management Group
OSM	Organization Structure Metamodel

P

PEOU	Perceived Ease Of Understanding / Perceived Ease Of Use
PES	Physical Exchange Specification
PEU	Perceived Ease of Use
PIM	Platform Independent Model
PRM	Performance Reference Model
PSQ	Perceived Semantic Quality
PU	Perceived Usefulness

R

RACI	Responsible, Accountable, Consulted, Informed
RAM	Responsibility Assignment Matrix
RASCI	Responsible, Accountable, Supportive, Consulted, Informed
RE	Requirements Engineering
REA	Resources, Events, Agents
Ref	Refinement

S

SBVR	Semantics of Business Vocabulary and Rules
SEAM	Systemic Enterprise Architecture Methodology
SEQUAL	SEmiotic QUALity
SME	Small and Medium-sized Enterprise
SRM	Service component Reference Model

T

T	Time
TAM	Technology Acceptance Model
TEAF	Treasury Enterprise Architecture Framework
TOGAF	The Open Group Architecture Framework
TRM	Technical Reference Model

U

UCM	Use Case Map
UEBQM	User Evaluations Based Quality Model for conceptual models
UML	Unified Modeling Language
US	User Satisfaction
USE	UML-based Specification Environment

Nederlandse samenvatting
-Summary in Dutch-

Enterprise architectuur (EA) is een samenhangend geheel van principes, methoden en modellen die worden gebruikt in het ontwerp en de realisatie van de organisatiestructuur van een onderneming, business processen, informatiesystemen en IT-infrastructuur. EA wordt gebruikt als een holistische benadering om de zaken binnen een onderneming gealigneerd te houden. Sommigen benadrukken het gebruik van EA om IT te aligneren met de business, anderen zien het breder en gebruiken het ook om de processen in lijn met de strategie te houden.

Recent onderzoek wijst op de noodzaak van EA in kleine en middelgrote ondernemingen (KMO's), belangrijke drijvende krachten van de economie, omdat ze worstelen met problemen in verband met een gebrek aan structuur en overzicht van hun bedrijf. Echter, bestaande EA raamwerken worden vaak gezien als te complex en tot op heden is geen van de EA benaderingen voldoende aan de KMO-context aangepast.

Daarom presenteren we in dit doctoraat de CHOOSE aanpak voor EA voor KMO’s. De aanpak bestaat uit vier artefacten: een metamodel, een methode, software tool ondersteuning en een visualisatie. De aanpak is eenvoudig gehouden, zodat het kan worden toegepast in een KMO-context en is gebaseerd op de essentiële dimensies van EA raamwerken.

Vijf stappen werden gezet: eerst werd het probleem van EA in KMO’s uitgebreid geanalyseerd. Vervolgens werd het CHOOSE metamodel ontwikkeld tijdens action research in KMO’s. Vervolgens werd action research in zes bedrijven gebruikt om een geschikte methode te ontwikkelen (bestaande uit richtlijnen, een stappenplan, en stop-criteria) en het CHOOSE metamodel ook verder te verfijnen, terwijl verschillende soorten software tools (PC, iPad, Android, ...) werden ontwikkeld om de evaluatierondes te faciliteren. Tenslotte werd een gepaste visualisatie ontwikkeld.

Abstract

Enterprise architecture (EA) is a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and IT infrastructure. EA is used as a holistic approach to keep things aligned in a company. Some emphasize the use of EA to align IT with the business, others see it broader and use it to also keep the processes aligned with the strategy.

Recent research indicates the need for EA in small and medium-sized enterprises (SMEs), important drivers of the economy, as they struggle with problems related to a lack of structure and overview of their business. However, existing EA frameworks are perceived as too complex and, to date, none of the EA approaches are sufficiently adapted to the SME context.

Therefore, in this PhD, we present the CHOOSE approach for EA for SMEs. The approach consists of four artifacts: a metamodel, a method, software tool support, and a visualization. The approach is kept simple so that it may be applied in an SME context and is based on the essential dimensions of EA frameworks.

Five steps were taken: first, the problem of EA in SMEs was extensively analyzed. Next, the CHOOSE metamodel was developed during action research in SMEs. Then, action research in six companies was used to develop an adequate method (consisting of guidelines, a roadmap, and stop criteria) and to further refine this CHOOSE metamodel, while different types of software tools (PC, iPad, Android, ...) were developed to enable the evaluation rounds. Finally, a proper visualization was established.

1 Introduction

1.1 Research Context

1.1.1 Enterprise Architecture

Have you ever had a house built or remodeled or are you planning to do so in the future? Most likely you will then contact an architect to draw plans. The architect in turn will contact the contractors, who use detailed plans to do their part of the job. The architect is responsible for a good match between your requirements and the work done by the contractors. For example, if three people simultaneously want to take a hot shower, the architect has to install a boiler with sufficient hot water capacity. In a company things are done in a similar way.

If you want to start or change a new business or a new business unit, you can ask an enterprise architect to help you. This architect will first work with you to model the business. You will specify who your customers are, what products and services you can offer, what processes you use to do this, and who is assigned. Subsequently, this architect will ensure, with or without the help of information system (IS) specialists, that your business is supported by IS (e.g. applications and data), which in turn requires a technological infrastructure (e.g. networks and devices) to run on (Figure 1.1) (Winter and Fischer 2007).

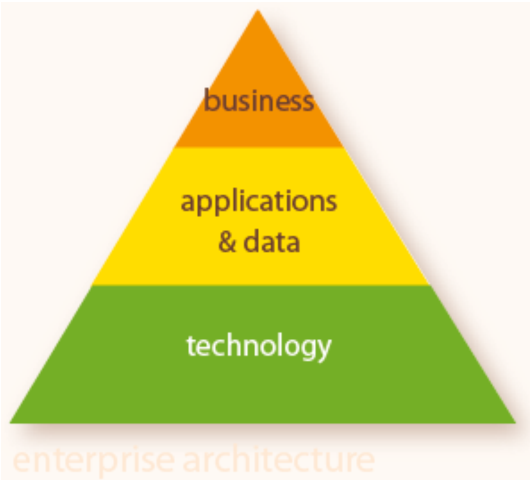


Figure 1.1: Enterprise Architecture (adapted from (Winter and Fischer 2007))

According to IEEE Computer Society (2000), architecture is “the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution”. Architecture could thus be defined as “structure with a vision”, providing an integrated view of the system being designed or studied. At the level of an entire organization, it is commonly referred to as enterprise architecture (EA).

EA is a key instrument in controlling the complexity of the enterprise and its processes and systems. Lankhorst (2013) defines enterprise architecture (EA) as “a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise’s organizational structure, business processes, information systems, and IT infrastructure”. An EA is typically developed because key people (stakeholders) have concerns that need to be addressed by the business and IS/IT systems within the organization (The Open Group 2012). Rather than specific solutions for specific problems, EA is assumed to capture the essence of the business, IT, and its evolution, as this essence is much more stable. In this respect, EA considers an enterprise as a system in which competencies, capabilities, knowledge, and assets are purposefully combined to achieve stakeholder goals. The tangible outcome of this line of reasoning is a blueprint or holistic overview of the enterprise in the form of an integrated collection of models. Hence, architecture can help maintain the essence of the business, while still allowing for optimal flexibility and adaptability (Jonkers et al. 2006).

The most important characteristic of an EA is that it provides a holistic overview of the enterprise. This enables optimization of the company as a whole instead of doing local optimization within individual domains. EA facilitates the translation from corporate strategy to daily operations. To achieve this quality, it is necessary to use an approach that is understood by all those involved from different domains (Lankhorst 2013).

A good EA can both give a static overview of the enterprise, as well providing a means of supporting change. A good architectural practice helps a company innovate and change by providing both stability and flexibility (Jonkers et al. 2006). Jonkers et al. further mentioned that it is important to realize that most stakeholders of a system are probably not interested in its architecture, but only in the impact of this on their concerns. An architect should be able to explain the architecture to all stakeholders with often completely different backgrounds. This points to one of the most important roles of EA: it serves as an instrument in the communication among diverse groups and interests and provides a common ground for discussion and decision-making. EA has become one of the top priorities of IT executives and is considered an important instrument for aligning the required changes in corporate strategy and business processes with an increasingly complex IT landscape (Luftman and Ben-Zvi 2011). Some of the most recognized benefits of EA are that IT can be used more efficiently and flexible, business and IT can be better aligned (Radeke 2011; Tamm et al. 2011; Daneva and van Eck 2007; Lindström et al. 2006), and a better fit between business and strategy can be achieved (Hoogervorst 2004; Veasey 2001). Braun and Winter (2005) underscore that in order to get business-IT and strategic alignment, EA must be constantly held up-to-date and easy to adapt.

1.1.2 Small and Medium-Sized Enterprises

An enterprise can be interpreted in a very wide sense. It could mean the whole enterprise, a smaller part of it (e.g., a business unit), or an area of activity of the enterprise (e.g., the purchasing). This research limits itself to small and medium-sized enterprises (SMEs), although the problems addressed and proposed solutions could be similar in larger organizations as well.

In the U.S., the Office of Advocacy defines a small business as an independent business having fewer than 500 employees (Small Business Administration 2012; Malone 1985). SMEs are important to the U.S. economy. They represent 99.7 percent of all employer firms, employ about half of all private-sector employees, pay 43 percent of total U.S. private payroll, and have generated 65 percent of net new jobs over the past 17 years from 1993 till 2009 (Small Business Administration 2011). Further, SMEs play a critical role in nurturing industrial innovation, constituting 40 percent of highly innovative firms in 2002 (CHI Research Inc. 2004). SMEs also play a significant role in enhancing the competitiveness of an economy through the process of economic renewal by creation, elimination, and restructuring of economic sectors.

Micro, small and medium-sized enterprises are often referred to as the backbone of the European economy. There were close to 20.8 million SMEs in Europe, which accounts for 99.8 percent of all companies. Furthermore the lion’s share of those SMEs are micro enterprises with a total of 19.2 million. Around 70 percent of European jobs are provided by the SMEs in the private sector and they account for 58.4 percent of total gross-value added production (European Commission 2011). The European Commission (2003) defines SMEs as companies that employ less than 250 employees and of which the annual turnover is less than 50 million euros or of which the total assets are less than 43 million euros.

There is a great need for more rigorous research that is relevant for this important sector of the economy (Devos 2011).

We further use the definition of SMEs as stated by the European Commission (2003): SMEs are companies that employ less than 250 employees and of which the annual turnover is less than 50 million euros or of which the total assets are less than 43 million euros.

1.2 Problem analysis of EA for SMEs

An important issue is that not all new SMEs make it through the first years (Jacobs et al. 2011). 70 percent survive 2 years, 50 percent 5 years, a third 10 years, and only a quarter stay in business 15 years or more (Bureau of Labor Statistics 2011; Census Bureau 2011).

Although there are many reasons for these numbers, some problems can be related to a lack of structure and overview in the company to pursue a superior competitive strategy (O'Gorman 2001).

In an SME, the entrepreneur (CEO) controls the enterprise. However, while most entrepreneurs have a good knowledge about their company, the overview tends to stay unspoken. This can cause some problems to occur:

- For ERP adoption, the most important criterion used by European SMEs in selecting an information system is the best fit with current business procedures (van Everdingen et al. 2000). This is also confirmed in the case studies of De Nil et al. (2012). However, in nearly all SMEs they visited, a clear overview of the business was lacking.
- In an enterprise, employees tend to know little about the structure of the company and why things are done. Although the entrepreneur knows the overview of the company, it is difficult for him to communicate with its employees about strategic issues without having an explicit overview (Kamsties et al. 1998).
- A concrete job description and overview of tasks and responsibilities of employees is difficult to keep track of, especially in a changing environment and enterprise (Kamsties et al. 1998). In (Chan and Chao 2008) it is said that the majority of the employees (88 percent) stated that they are required to spend a lot of time doing additional work that is not specified in their job description.
- A strategy is not static, neither are processes. Keeping processes at all time in line with the strategy is difficult to achieve (Dougherty 1992).
- In an ever-changing environment, assessing the impact of changes can help to prevent problems to occur. What if the economy changes? What if the strategy has to be adapted? What if an employee leaves the company? (Porter 1998)
- An SME has different stakeholders with different desires and goals. Balancing these goals as good as possible is not a simple assignment. (Heyse et al. 2012)
- If the CEO leaves the company for some reason (e.g., he/she sells the company or a child takes over), the knowledge about the overview of the company has to be transferred to the new CEO. (Yong et al. 2004; Bjuggren and Sund 2001)
- It is difficult to track all decisions made on different meetings. In the best case, reports of the meetings are made and stored at the same place, but most of the time this is not done. Transforming decisions towards real changes in how the company is organized and implementing these changes consistently is hard to achieve.

Furthermore, knowledge and more specifically entrepreneurial knowledge is important for SMEs. Knowledge cannot be reduced to its purely technical sense, as a collection of patentable inventions. Knowledge is fundamentally linked to an individual with an idea that is being realized (Devos 2011). This entrepreneurial knowledge gives SMEs a competitive advantage over larger companies. Larger companies are using capital and labor as resources and are trying to control their transaction and management costs (Jensen and Meckling 1976; Coase 1937).

Knowledge is very important for an SME, however, this knowledge is linked to a person with his idea (Audretsch et al. 2004). Next to capital and labor, this extra production factor, entrepreneurial capital, is important for SMEs to maintain and communicate, especially when the company is growing and the CEO tends to loose grip (Carree and Thurik 2005; Weick et al. 2005; Audretsch and Thurik 2000).

It seems obvious that EA could help to reduce these problems, however, EA is generally an unknown concept in SMEs. EA approaches are often experienced as complex, over-engineered, and difficult to implement. Because of the technical detail required for full-scale implementation, EA models tend to become very large, making them more difficult to understand and less effective to reflect on or design enterprises and their supporting systems (Balabko and Wegmann 2006). Due to their resource poverty, SMEs experience even more difficulties than larger enterprises in employing EA experts or hiring external consultants (Kroon et al. 2012). Yet, as some studies have confirmed, they may encounter several problems if they fail to implement EA (Bidan et al. 2012; Bhagwat and Sharma 2007).

1.2.1 Main Previous Research

EA is unknown and hardly used in SMEs. In literature, articles about EA for SMEs are very scarce, especially at the start of this PhD in 2009. A summary of the IS literature regarding SMEs is given in the literature study of Devos ((2011), pp. 41-87). Most of the articles are about E-business, Internet, E-mail, and ERP systems in SMEs. However, in this literature study of A1 papers found from 1979 to 2008 about SMEs and IT, no single paper discussed EA for SMEs.

In Belgium, an exploratory case study research by students of the University of Ghent in 27 SMEs delivered interesting insight in which factors determine whether an SME documents its processes, its strategy, and whether there is a link between both. While some companies have a link between their processes and strategy, nearly all of them missed a clear overview of their business organization, whereas none of them used EA or business architecture (De Nil et al. 2012).

Recently, Bidan et al. (2012) published a cross-sectional empirical study of information system architectures within 143 small to medium-sized enterprises in France. This study provides an empirically derived taxonomy of enterprise architectural variants of the types often described in the literature for large firms. The authors found three kinds of IT architectures in SMEs in France and the greater the size of the firm, the greater the IT architecture integration was in SMEs. They conclude that standardization of the processes through the company and industry is more important than the deployment of technology (ERP systems) to get improvement in organizational performance. This indicates the need for SMEs to get a structured view on their company.

Right now, existing EA frameworks are primarily used in large enterprises (Gartner 2012). Wißotzki and Sonnenberger (2012), among others, recognize the importance of EA and EA management (EAM) in particular, but noticed that EAM is still mostly unexplored and rarely used, especially in context of SMEs. Other research confirms these findings (Bernaert et al. 2014; Devos 2011). Yet, such specific research is crucial, as research findings based on large businesses cannot be generalized to small businesses due to the inherent differences between SMEs and large businesses (Aarabi et al. 2011). Previous and related research (Chew and Dehbokry 2013; Bidan et al. 2012; Jacobs et al. 2011) clearly indicated the need for EA to be used in SMEs and the unsuitability of existing EA approaches in an SME context.

Later during this PhD, some first efforts were made for investigating the use of EA in SMEs (Bernaert et al. 2014; Chew and Dehbokry 2013; Bidan et al. 2012; Wißotzki and Sonnenberger 2012; Aarabi et al. 2011; Bernaert and Poels 2011b; Jacobs et al. 2011). However, no concrete EA artifacts have ever been developed to be used in an SME context.

1.2.2 Benefits of Using EA in SMEs

Lybaert (1998) discovered that SME owners or managers with a greater strategic awareness use more information and that SMEs that use more information are generally more successful. Hannon and Atherton (1998) further revealed that for SMEs success is correlated with higher levels of strategic awareness and better planning of owners-managers. In addition, there is evidence to believe that companies that make strategic rather than just financial business plans perform significantly better financially than those that do not (O'Regan and Ghobadian 2004; Smith 1998). Jacobs et al. (2011) argue that from the perspective of change and complexity, EA could assist SME management during the growth of a small enterprise. For example, according to Aarabi et al. (2011), ERP (Enterprise Resource Planning) systems cannot be successfully implemented and utilized in SMEs if EA is disregarded. In fact, it is EA's integration of strategic goals, business processes, and technology planning methods that provides the standards, roadmap, and context for ERP implementation (Zach 2012). As Bidan et al. (2012) conclude, process standardization in SMEs is more important than the deployment of technology (e.g., ERP systems) to improve organizational performance. In short, SMEs need to get a structured view of their company, even before they start implementing an ERP solution.

1.2.3 Specific Research Problem

Hence, while EA might offer SMEs a solution to typical problems related to a lack of overview, strategic awareness, IT planning, and business-IT alignment, EA approaches that cater for the specificities of small businesses are still missing. This lack of an EA approach that can readily be used for SMEs is the problem that is addressed in the present research.

1.2.4 Importance from a Scientific/Practical Point of View

The impact of this research can be substantial as, to our knowledge, it is among the first efforts for bringing EA to SMEs (Bernaert et al. 2014; Bidan et al. 2012; Wißotzki and Sonnenberger 2012; Aarabi et al. 2011; Bernaert and Poels 2011b; Jacobs et al. 2011) by developing an EA approach specifically adapted to an SME context.

As already mentioned, SMEs are very important for economy. However, not all new SMEs make it through the first years. EA could help SMEs in overcoming the problems related to a lack of business overview and increase the survival rate.

1.3 Solution Design

1.3.1 Baseline Solutions to the Problem

As previously mentioned, it is a novel idea to develop an EA approach specifically for SMEs. Nevertheless, before starting, existing EA approaches were first analyzed. The identified frameworks were analyzed in order to determine the essential EA dimensions and are for instance used during the PhD to help select a suitable starting point to design the metamodel of a new approach dedicated to EA in SMEs.

Since the publication of the Zachman framework in 1987 (Zachman 1987), a multitude of EA frameworks have been proposed.

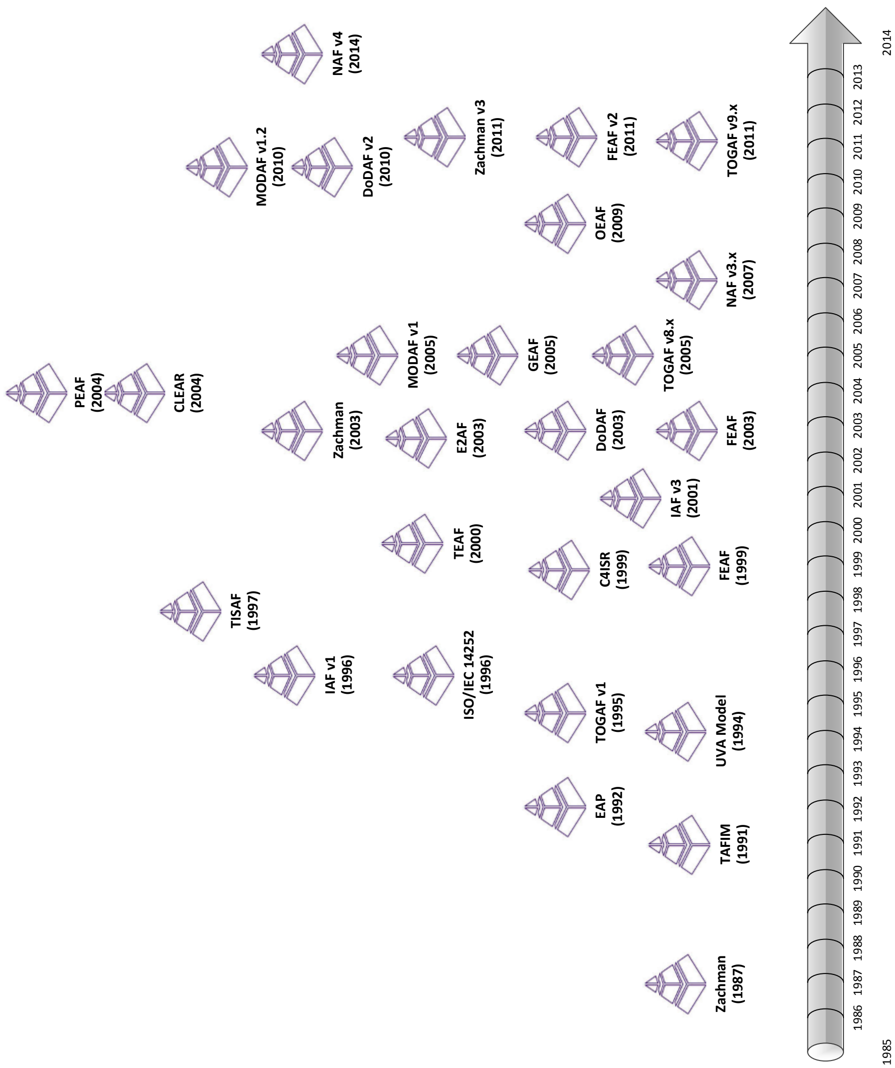


Figure 1.2: Historical overview of EA frameworks (updated by Georgadis (2015) from (Schekkerman 2006))

To identify the most important frameworks, we studied several reviews and historical overviews of EA frameworks, such as the one provided by Georgiadis (2015) (Figure 1.2). The overview by Schekkerman (2006) is less recent, but interesting for its explanation of the influences EA frameworks have had on each other (Figure 1.3). Based on these influence relationships, Zachman (Zachman International 2011), TOGAF (The Open Group 2009), DoDAF (DoD 2010), and E2AF (IFEAD 2006) appear to be important EA frameworks. Zachman gave rise to another EA framework, TEAF, which was created for the US Department of the Treasury. Yet, since it is subsumed in the Federal Enterprise Architecture (FEA), just like FEAF, it is better to include FEA instead of TEAF.

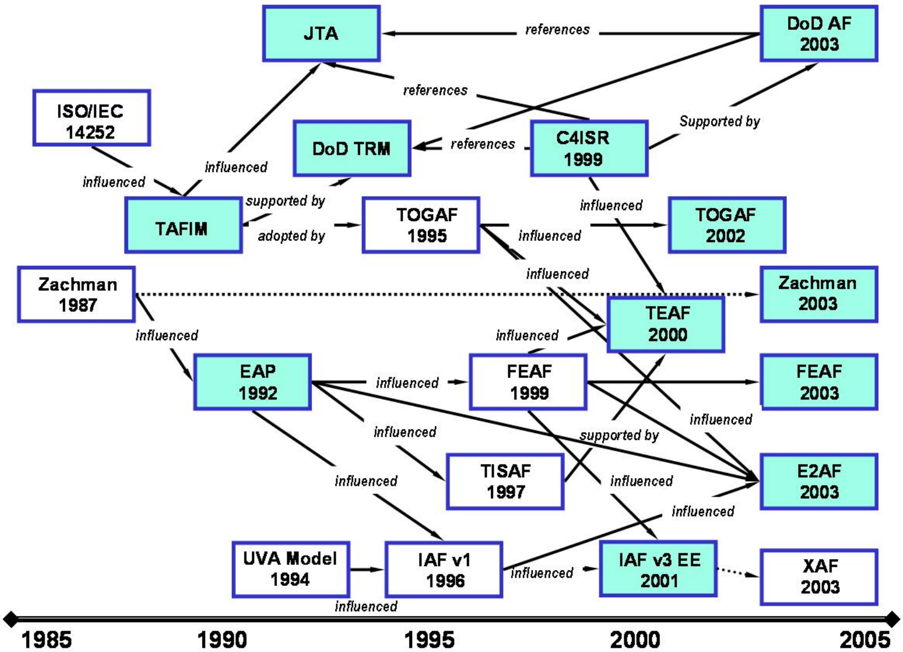


Figure 1.3: Overview of EA frameworks and their influence (from (Schekkerman 2006))

Zachman, TOGAF, DoDAF, FEAF, and TEAF are all analyzed in the study of Urbaczewski and Mrdalj (2006). Sessions (2007), on the other hand, compares the first two, Zachman and TOGAF, with FEA and Gartner's GEAM. Yet another study by Leist and Zellner (2006) juxtaposes Zachman, TOGAF, DoDAF, FEAF, TEAF, ARIS, and MDA (model-driven architecture). The last one, MDA, is more a general systems development approach, so it was not included in our further analysis.

In short, the most widely discussed EA frameworks that should also be included in the present analysis are Zachman (Zachman International 2011), TOGAF (The Open Group 2009), DoDAF (DoD 2010), E2AF (IFEAD 2006), FEA (The White House Office of Management and Budget (OMB) 2013, 2012), GEAM (Gartner) (Bittler and Kreizmann 2005; James et al. 2005), and ARIS (Scheer 2000).

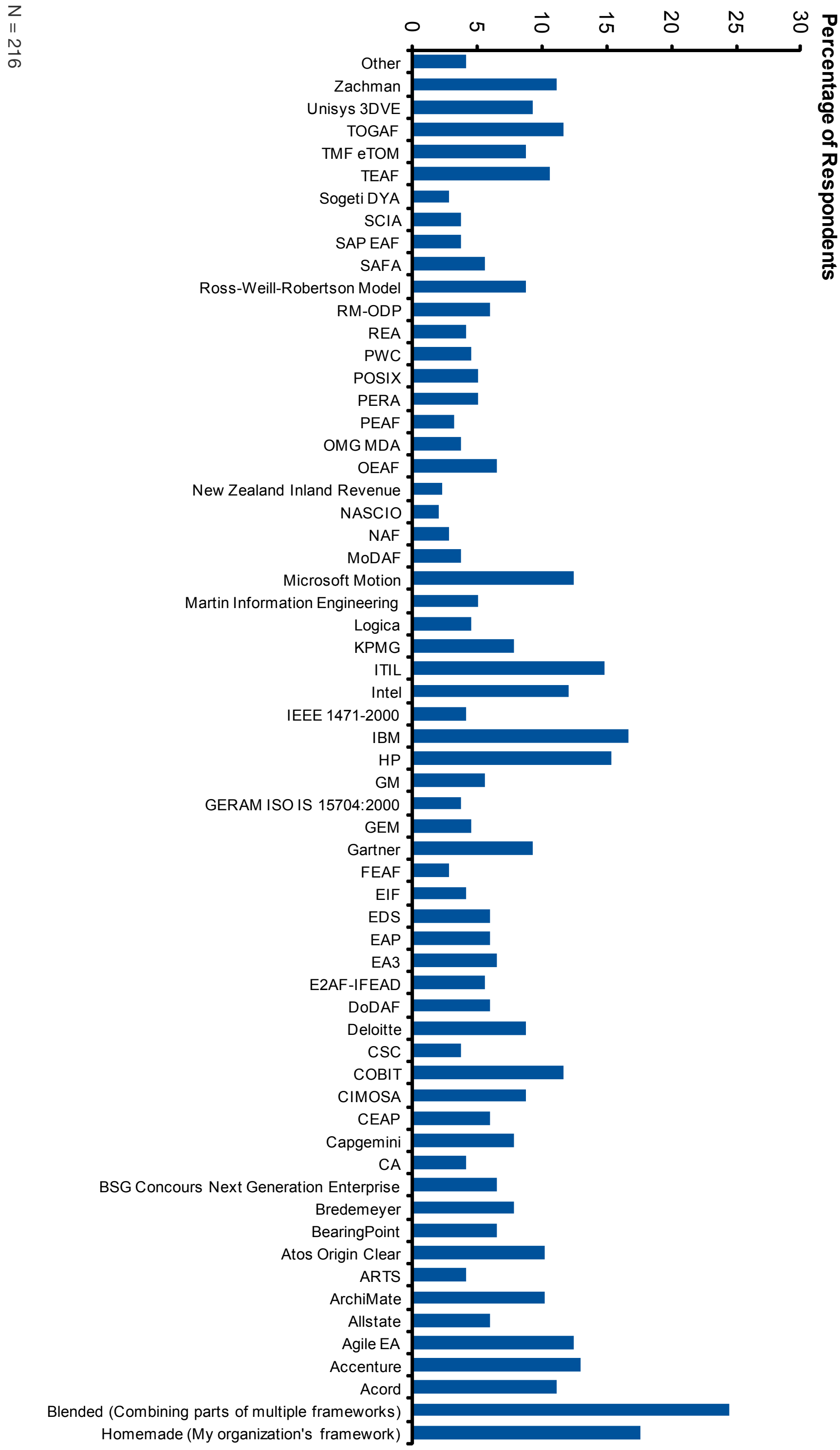


Figure 1.4: EA frameworks currently being used (from (Gartner 2012))

This selection of relevant EA frameworks is confirmed by the survey of IFEAD (2005) and, more recently, by the survey of Gartner (2012) on the use of EA frameworks in companies (Figure 1.4). However, a lot of companies also use a homemade EA framework or hire a consulting firm (e.g., IBM, Deloitte) to help them craft a best-of-breed framework. ArchiMate (Lankhorst 2013) was also included in our analysis, because it was recently adopted as a standard EA modelling language by The Open Group (2012) to be used in combination with TOGAF. Capgemini's IAF (van 't Wout et al. 2010) was also added because it was built based on experience in more than 3000 EA projects and it evolves faster than any standard ever can. As such, it lies at the basis of large parts of TOGAF 9's content framework. The Business Motivation Model (BMM) (OMG 2010) is also relevant for our study because of its emphasis on the motivational dimension. Yet it does not give a holistic EA overview and is not actually an EA framework. At the same time, though, BMM is often included in business architecture analyses (Glissman and Sanz 2009), so it should definitely be taken into account in our analysis. Finally, Sogeti's DYA (Wagter et al. 2005) offers a holistic view and should therefore also be included in our analysis.

To make sure that recently developed EA frameworks were not ignored, we also included several EA frameworks and enterprise modelling approaches developed in academia, namely CARP (derived from DoDAF) (Business Transformation Agency 2009), Enterprise Modeling (Bubenko 1993) and its successors Enterprise Knowledge Development (EKD) (Stirna and Persson 2007) and 4EM (Sandkuhl et al. 2014), REA extended with goal modeling (Andersson et al. 2009), SEAM (Wegmann et al. 2007b), and LEAP (Clark et al. 2011).

1.3.1.1 Zachman Framework

The Zachman framework (Sowa and Zachman 1992; Zachman 1987) (see Figure 1.5) is probably the first and most famous EA framework. This framework offers a structured way, based on two dimensions (focus and view), to classify and organize the representations of an organization. Each dimension consists of six parts, resulting in a matrix with 36 cells. The Zachman framework is only a classification framework and offers no method to develop EAs. Therefore, it is often used in conjunction with TOGAF.

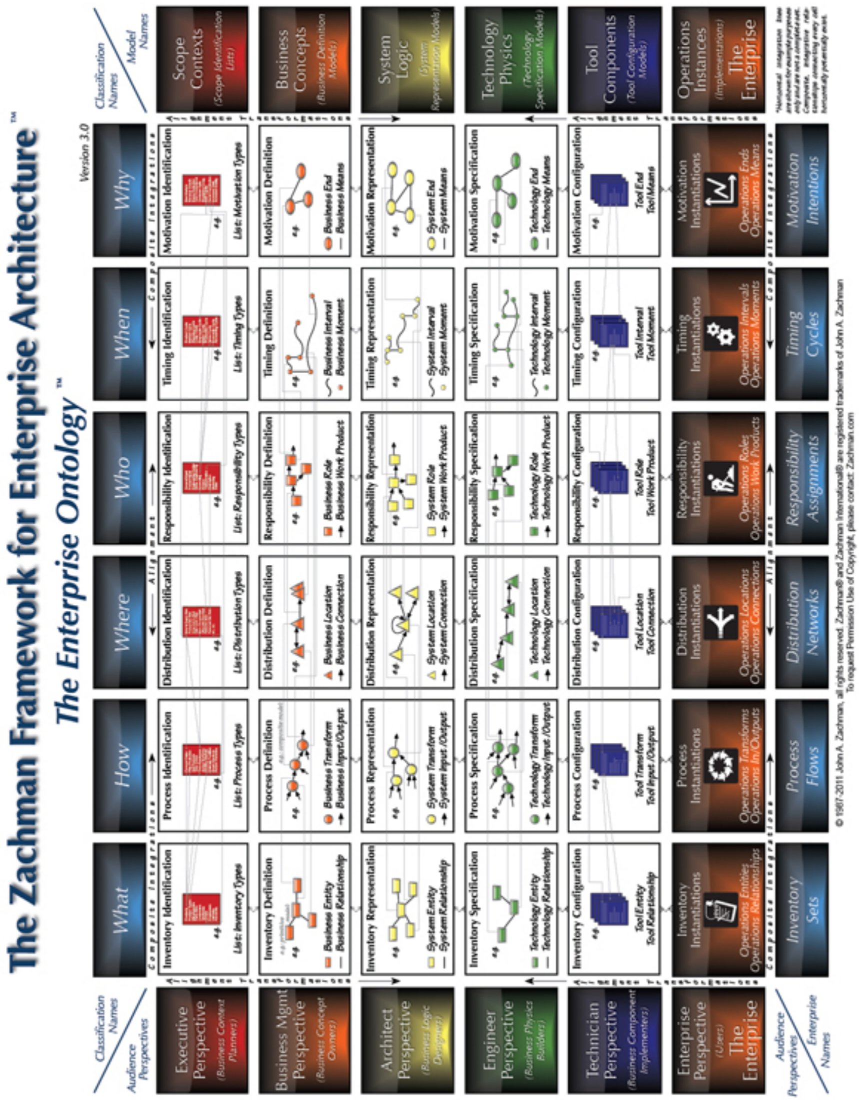


Figure 1.5: Zachman framework (from (Zachman International 2011))

1.3.1.2 The Open Group Architecture Framework (TOGAF)

The Open Group Architecture Framework (TOGAF) (The Open Group 2009) (see Figure 1.6) is a framework and method to develop and manage EAs. TOGAF consists of four major components, of which the Architecture Development Method (ADM) is considered the core. It describes an iterative method for EA development. The ADM states that the business architecture is first developed, followed by the information system architectures (applications and data) and the technology architecture. TOGAF is frequently used with ArchiMate.

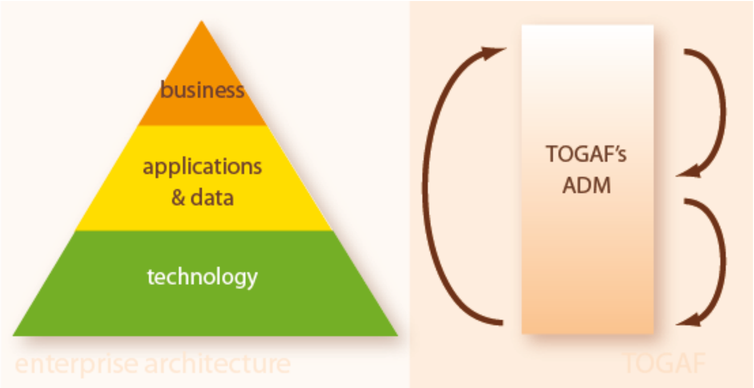


Figure 1.6: A simplification of TOGAF's ADM

The content metamodel (Figure 1.7) is the most interesting part for the research on developing an EA metamodel for SMEs, as it provides a definition of all the types of building blocks that may exist within an architecture, showing how these building blocks can be described and related to one another.

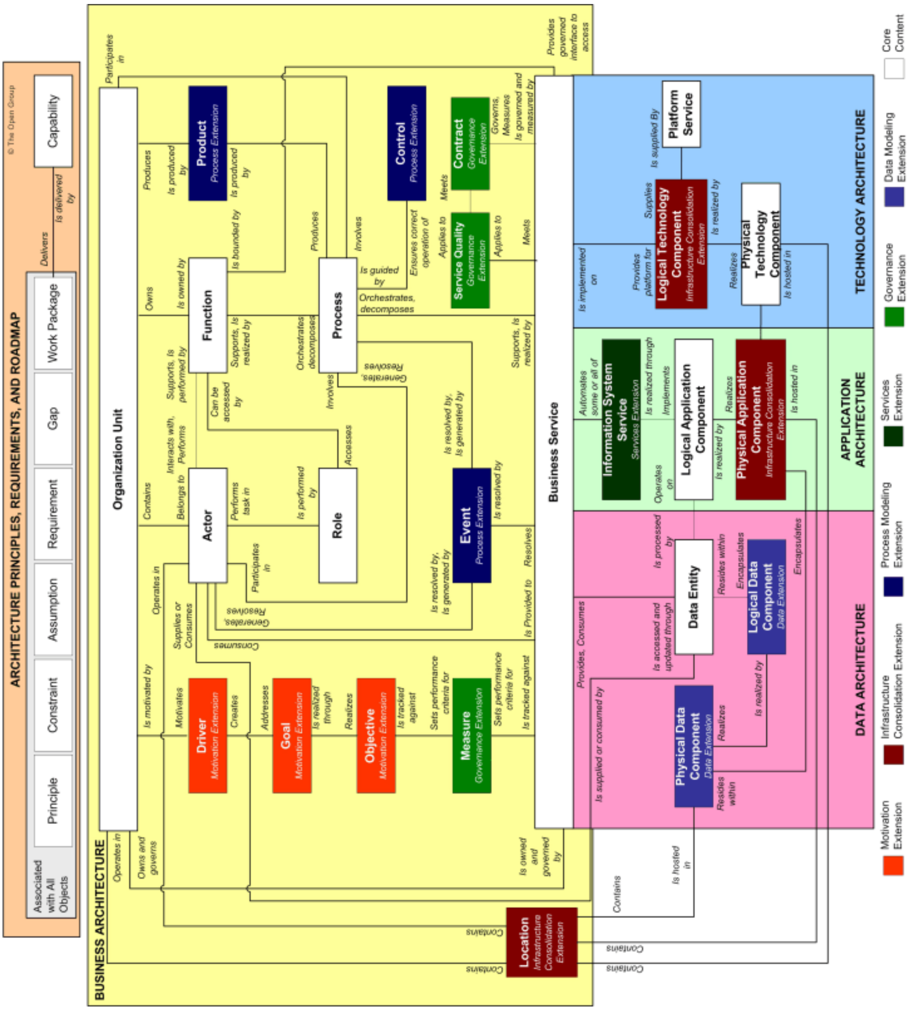


Figure 1.7: TOGAF's content metamodel (from (The Open Group 2009))

1.3.1.3 ArchiMate

ArchiMate (Lankhorst 2013; The Open Group 2012) (Figure 1.8) proposes a standard language and metamodel for describing EAs and is widely supported by tools and consulting companies. The metamodel shows that ArchiMate works with three layers of architectural models, namely a business architecture layer, an application architecture layer (includes applications and data), and a technology architecture layer. Within each layer there is a section that reflects behavioral or dynamic aspects and two sections representing structural or static aspects. The static aspects can be active (structure) or passive (information). The new version of ArchiMate (ArchiMate 2.0) provides a tighter alignment with TOGAF and also includes a strategic dimension (motivation) and implementation & migration dimension (Engelsman et al. 2011).

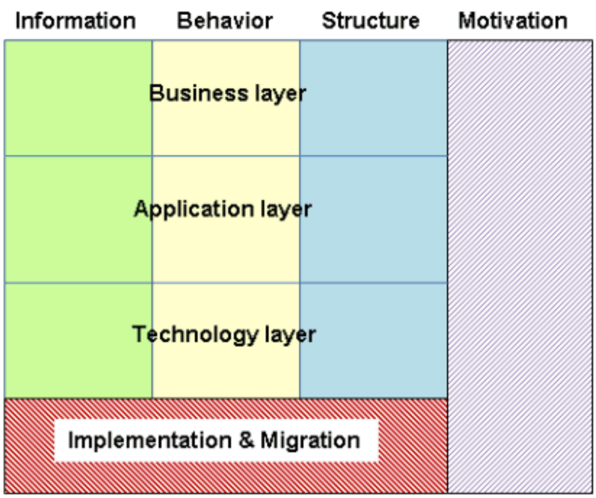


Figure 1.8: ArchiMate 2.0 (from (The Open Group 2012))

1.3.1.4 Department of Defense Architecture Framework (DoDAF)

DoDAF (DoD 2010) is an EA framework for the United States Department of Defense (DoD) (for the defense and intelligence community) that provides structure for a specific stakeholder concern through viewpoints organized by various views. The DM2 is DoDAF's metamodel and exists of a conceptual data model (CDM) (Figure 1.9) including the high-level data constructs, a logical data model (LDM) that adds technical information and the physical exchange specification (PES) with data types and implementation attributes.

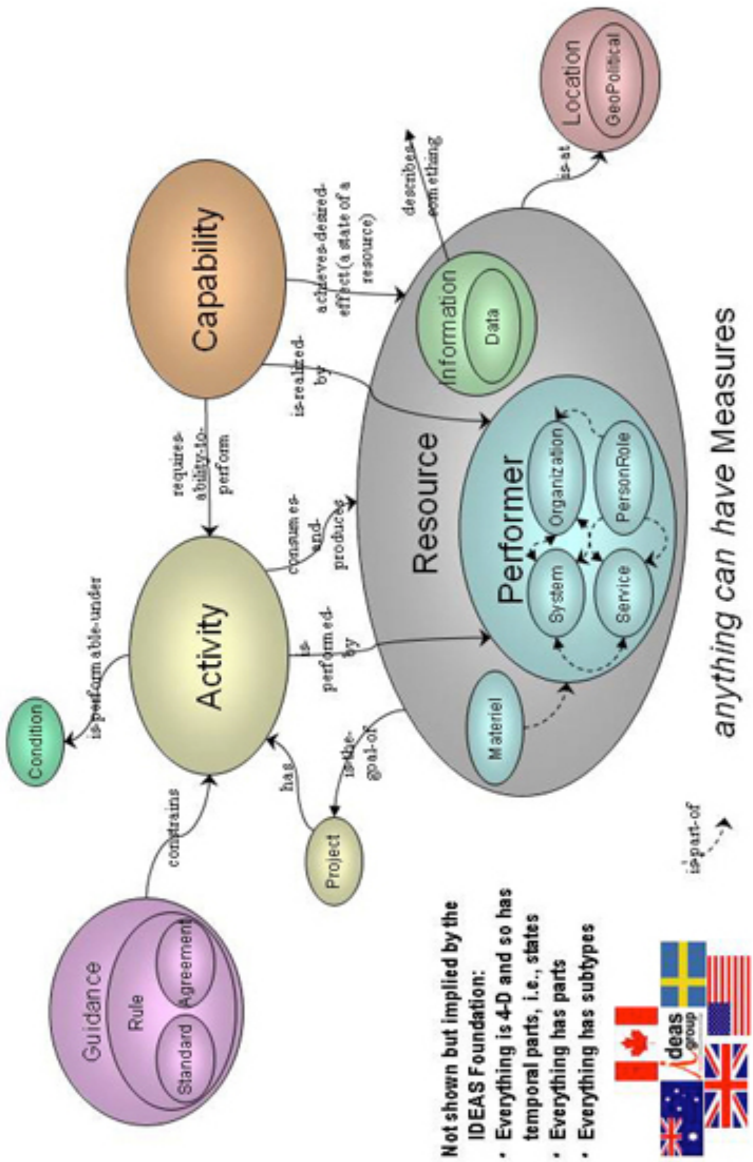


Figure 1.9: DM2 conceptual data model (from (DoD 2010))

1.3.1.5 Capability, Activity, Resource, Performer (CARP)

In his keynote on the Confenis 2011 conference, zur Muehlen (2011) talked about his vision on semantic EA. He introduced CARP (capability, activity, resource, and performer) (Figure 1.10) as a domain ontology for EA, based on the dimensions of DoDAF (DoD 2010). Some parts are already included in the DoDAF specification (Business Transformation Agency 2009).

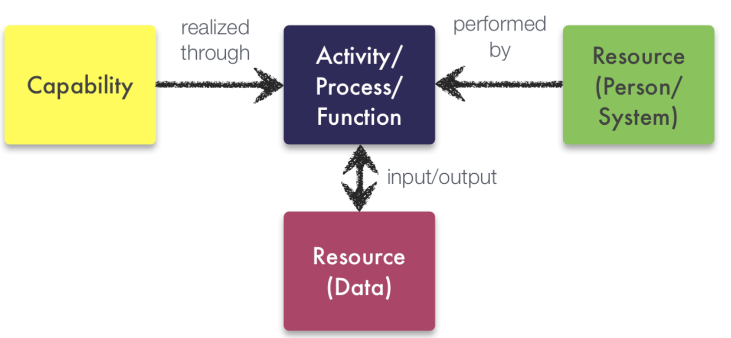


Figure 1.10: CARP (from (Zur Muehlen 2011))

1.3.1.6 Capgemini Integrated Architecture Framework (IAF)

IAF (Figure 1.11) has been developed by Capgemini since the 1990s (van 't Wout et al. 2010). This framework is the result of the experience of practicing architects on projects for clients across the group, so it has really evolved based on real-world experience. The framework includes four abstraction levels (why?, what?, how?, with what?) that separate problem from solution (from contextual to physical level). Four different aspect areas of EA (business, information, information systems, and technology infrastructure layer) cross the conceptual, logical and physical levels. Two additional aspect areas specifically address the governance and security perspective of the architecture.

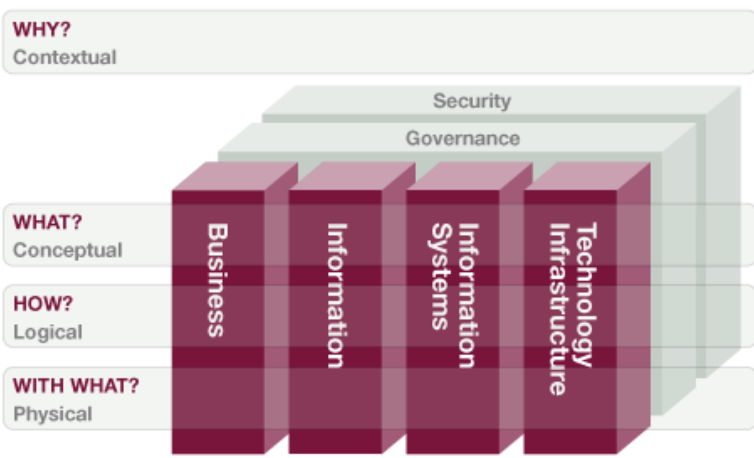


Figure 1.11: Capgemini's IAF (from (van 't Wout et al. 2010))

IAF does not include a metamodel, although some artifacts are proposed that are interesting for our research. The artifacts served as an input for the architecture content framework of TOGAF.

1.3.1.7 Extended Enterprise Architecture Framework (E2AF)

The institute for enterprise architecture developments (IFEAD) has created E2AF by translating the most important enterprise architecture environment rules and principles into a coherent framework (Figure 1.12) (Institute For Enterprise Architecture Developments 2006). This framework is the foundation of IFEAD's architecture world of thought.

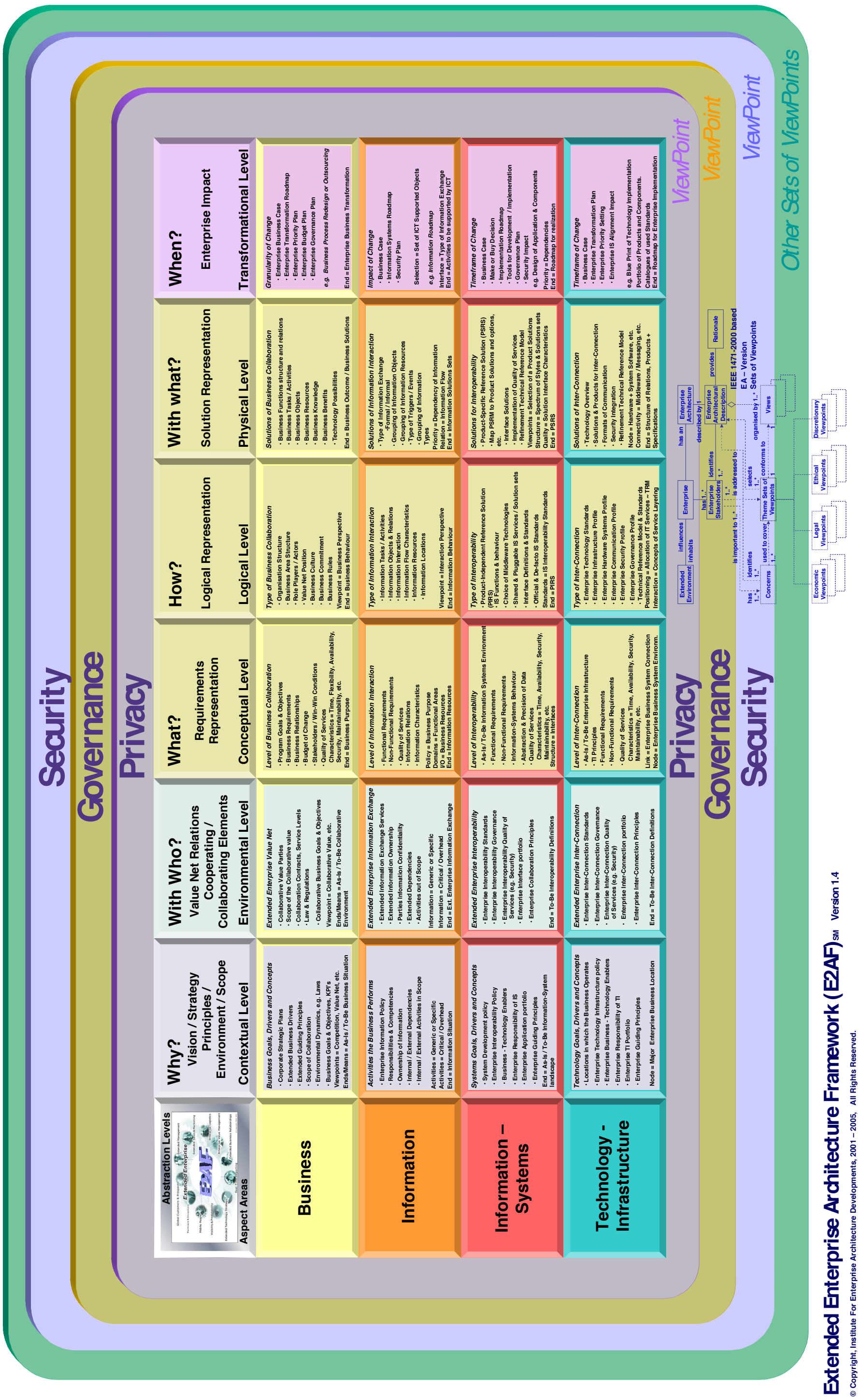


Figure 1.12: E2AF (from (Institute For Enterprise Architecture Developments 2006))

Like IAF, E2AF uses separation of concerns between problem and solution, this time in six main levels of abstraction: the contextual (why), environmental (with who), conceptual (what), logical (how), physical (with what), and transformational level (when). There are four different aspect areas that need to be integrated: business (or organization), information, information systems, and technology infrastructure.

1.3.1.8 Federal Enterprise Architecture (FEA)

The FEA is an initiative that aims to realize the value of enterprise architecture within the U.S. Federal Government (The White House Office of Management and Budget (OMB) 2013, 2012). Due to several laws and acts (in particular Clinger-Cohen Act), it became necessary for the different departments to have better documentation of the use and organization of their resources, IT in particular, documentation about their processes, etc.

The FEA includes a continual process from an as-is state to a to-be state. FEA consists of five reference models: performance reference model (PRM), business reference model (BRM), service component reference model (SRM), data reference model (DRM), and the technical reference model (TRM). The DoD enterprise architecture reference models are aligned with the FEA reference models. The references models are specific for government organizations, so are less interesting for this research. Federal enterprise architecture framework (FEAF), DoD C4ISR, and treasury enterprise architecture framework (TEAF) are supported by FEA. C4ISR has evolved into DoDAF (see section 1.3.1.4).

FEAF has been developed for civilian agencies. To classify the architectural information, the FEAF architecture matrix (Figure 1.13) has been developed, based on Zachman framework. It consists of three columns: data (what), application (how), and technology (where) architecture. The rows of Zachman have been preserved. Every cell consists of an EA model, which is the basis for managing and implementing change in the organization.

	Data Architecture	Application Architecture	Technology Architecture
Planner Perspective	List of Business Objects	List of Business Processes	List of Business Locations
Owner Perspective	Semantic Model	Business Process Model	Business Logistics System
Designer Perspective	Logical Data Model	Application Architecture	System Geographic Deployment Architecture
Builder Perspective	Physical Data Model	Systems Design	Technology Architecture
Subcontractor Perspective	Data Dictionary	Programs	Network Architecture

Figure 1.13: FEAF architecture matrix (from (The White House Office of Management and Budget (OMB) 2013))

TEAF is an architecture framework for treasury. In 2012 this framework has been subsumed by evolving federal enterprise architecture policy as documented in "The Common Approach to Federal Enterprise Architecture" (The White House Office of Management and Budget (OMB) 2012). The TEAF architecture matrix (Figure 1.14) is also related to Zachman framework and consists of four columns: functional (how, where, when), information (what, how much, how frequently), organizational (who, why), and infrastructure (enabler) view.

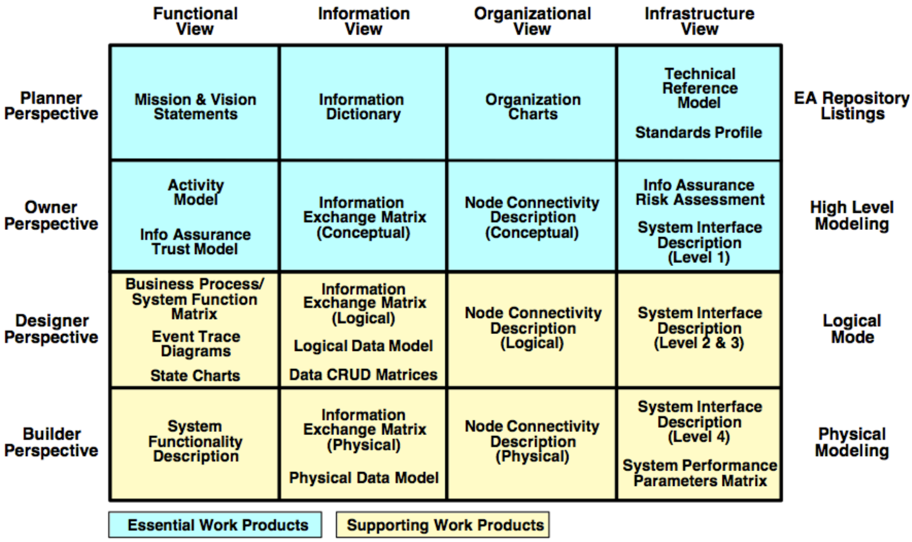


Figure 1.14: TEAF architecture matrix (from (The White House Office of Management and Budget (OMB) 2013))

1.3.1.9 Gartner Enterprise Architecture Method (GEAM)

GEAM is more an EA practice by one of the most well known companies in the field. With the acquisition of the Meta Group in 2005, including its enterprise architecture practice, Gartner has combined its approach with Meta's to create GEAM. The two major facets of GEAM are the Gartner enterprise architecture process model (Bittler and Kreizmann 2005) and the Gartner enterprise architecture framework (GEAF) (James et al. 2005). However, these documents contain little descriptive information.

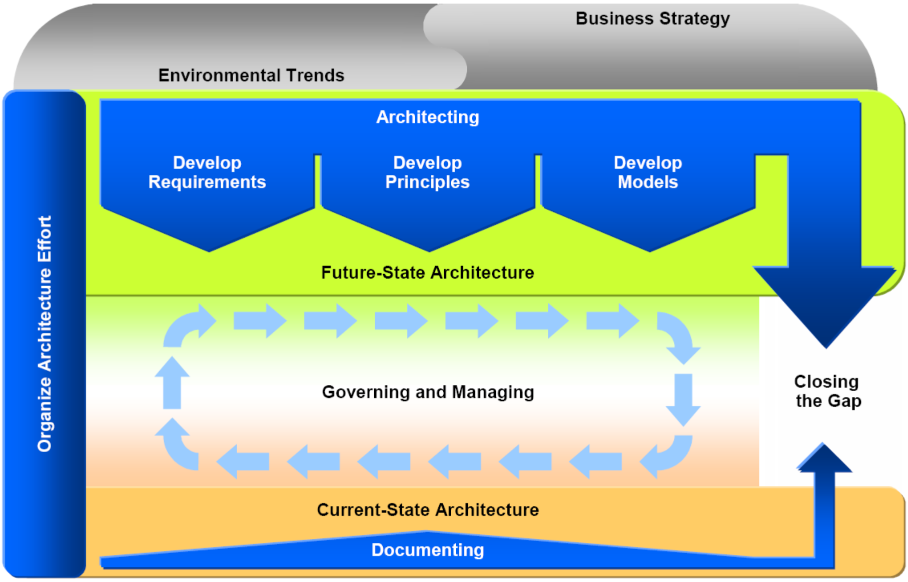


Figure 1.15: Gartner enterprise architecture process model (from (Bittler and Kreizmann 2005))

The Gartner EA process model (Figure 1.15) provides organizations with a logical approach to developing an EA. It is a multiphase, iterative and nonlinear model, focused on EA process development, evolution and migration, and governance, organizational and management subprocesses. It is most important to know where an organization is going (common requirements vision document) and how it will get there.

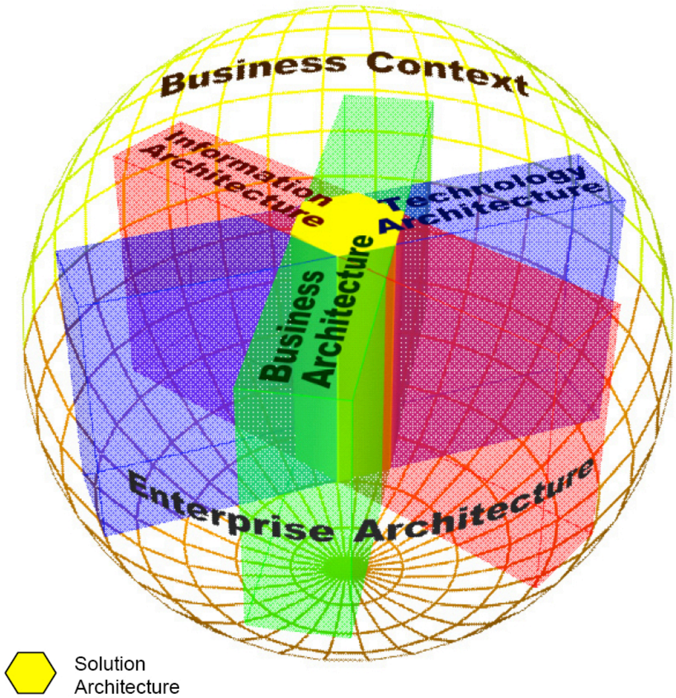
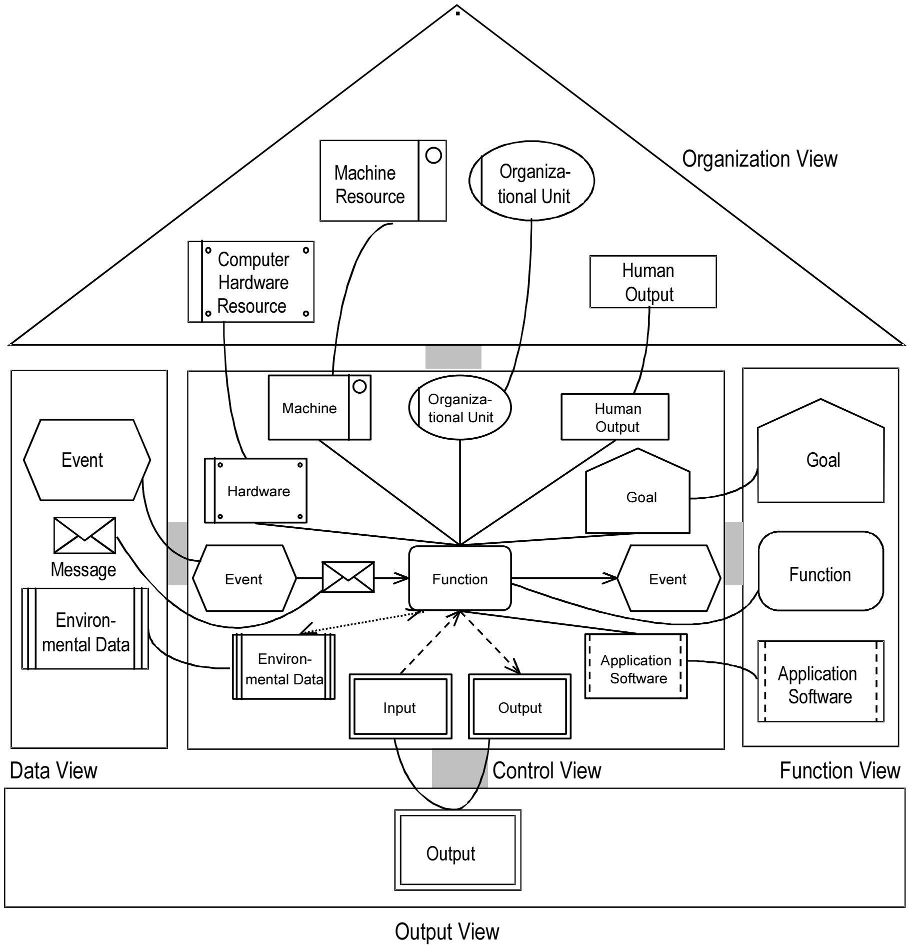


Figure 1.16: Gartner enterprise architecture framework (from (James et al. 2005))

The Gartner EA framework (Figure 1.16) includes three primary viewpoints (enterprise business architecture, enterprise information architecture, and enterprise technology architecture). It also introduces the enterprise solution architecture framework that deals with combining and reconciling the loosely coupled and often conflicting viewpoints into a unified architecture for an enterprise solution.

1.3.1.10 Architecture of Integrated Information Systems (ARIS)

ARIS started as the academic research of Scheer (Scheer and Schneider 2006; Scheer 2000) and offers methods for analyzing processes and everything related to processes to provide a holistic view. ARIS is supported by a well-known and widely sold business process modeling tool.



Organization View
Machine Resource
Organiza-tional Unit
Computer Hardware Resource
Human Output
Machine
Organiza-tional Unit
Human Output
Hardware
Goal
Event
Message
Environ-mental Data
Event
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Output
Application Software
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Function
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Data View
Control View
Function View
Output
Output View

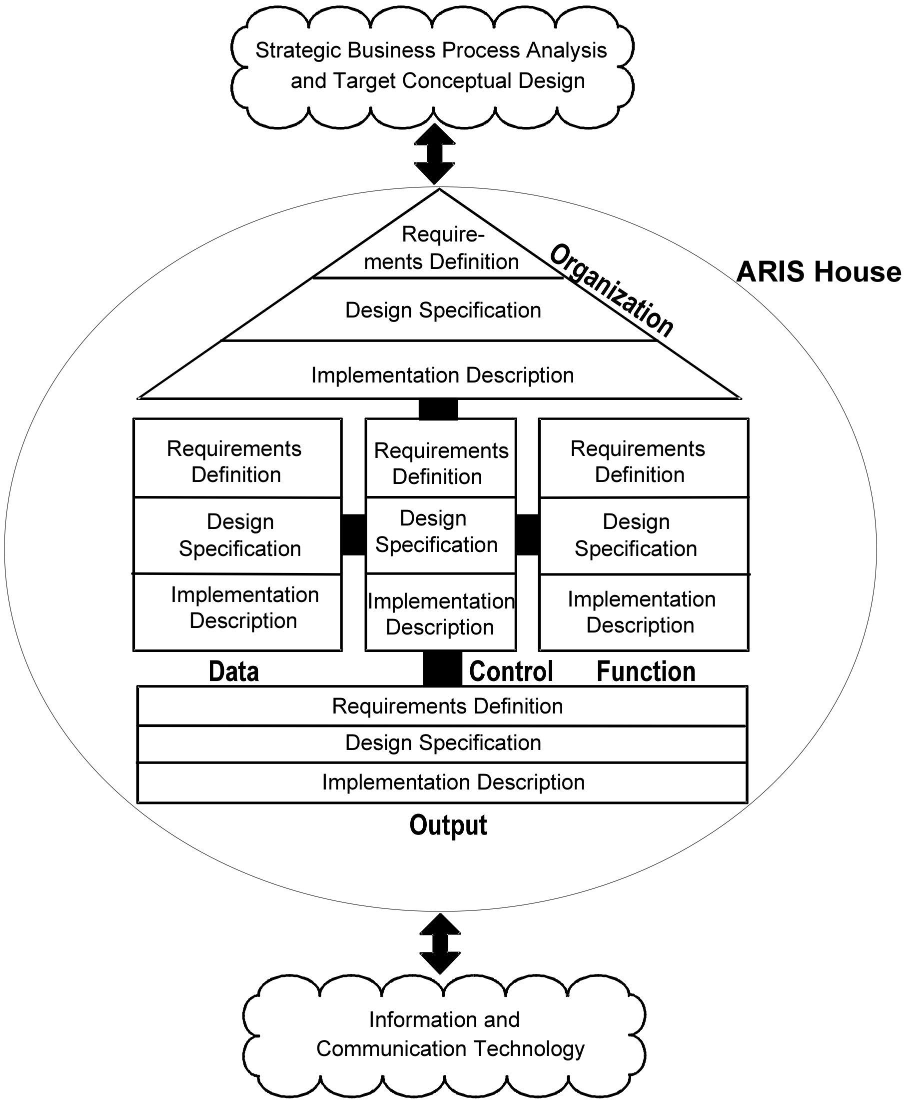

Figure 1.17: ARIS house (from (Scheer and Schneider 2006; Scheer 2000))

The ARIS house (Figure 1.17) has different related perspectives, with event-driven process chains in the center that connect all other views.

1.3.1.11 Business Motivation Model (BMM)

BMM (Figure 1.18) is a standard of the Object Management Group (OMG) (2010). It is designed to model the strategy, governance and the business network of a company. Business operations are not addressed by this model (The Business Rules Group 2010; Glissman and Sanz 2009).

The elements of BMM are divided into two groups. First, the ends and means define what an organization tries to achieve. The ends describe the planned accomplishments of an organization, whereas the means define the actions to achieve these goals. Second, in order to understand the context of the ends and means, the internal and external influencers are an essential part of the BMM. Business process, business rule, organization unit, asset, and liability are referenced by the BMM but defined in detail in other specifications.

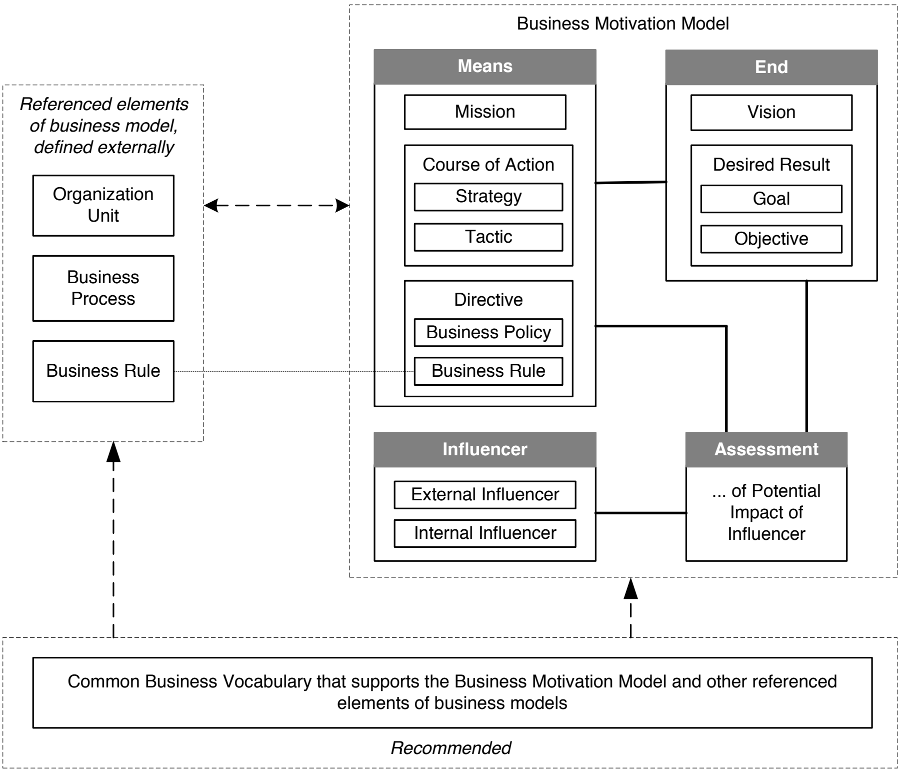

Figure 1.18: BMM overview (from (OMG 2010))

1.3.1.12 Dynamic Architecture (DYA)

DYA originates from Sogeti and consists of a process and an architecture framework (Wagter et al. 2005). DYA's architecture framework (Figure 1.19) has the objective to position the relevant component architectures and illustrate the coherence between them. The framework sets business objectives on top of the business, information, and technical architecture. Each of these architectures has different business objects, indicated by the columns in the framework. Each architecture can be further divided in three abstraction levels: general principles, policy directives, and models.

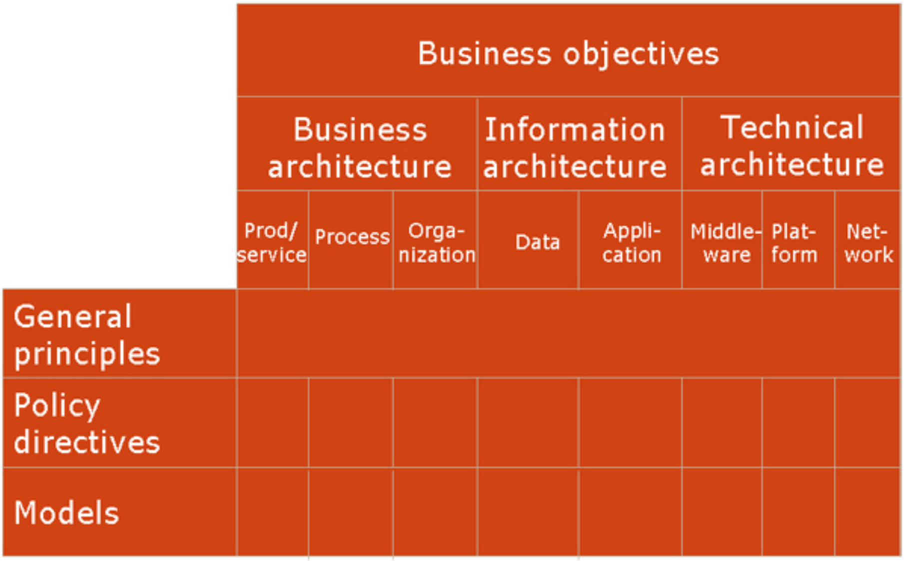

Figure 1.19: DYA's architecture framework (from (Wagter et al. 2005))

1.3.1.13 Enterprise Modeling, Enterprise Knowledge Development (EKD), and For Enterprise Modelling (4EM)

Enterprise Modeling has put a lot of effort in developing the enterprise model, in which different submodels are interrelated and describe four dimensions (Bubenko 1993). More recent work on the EKD method for enterprise modeling (Figure 1.20) defines six submodels, but agrees that its goals model, business process model, concepts model, and actors and resources model tend to dominate EKD usage (Stirna and Persson 2007).

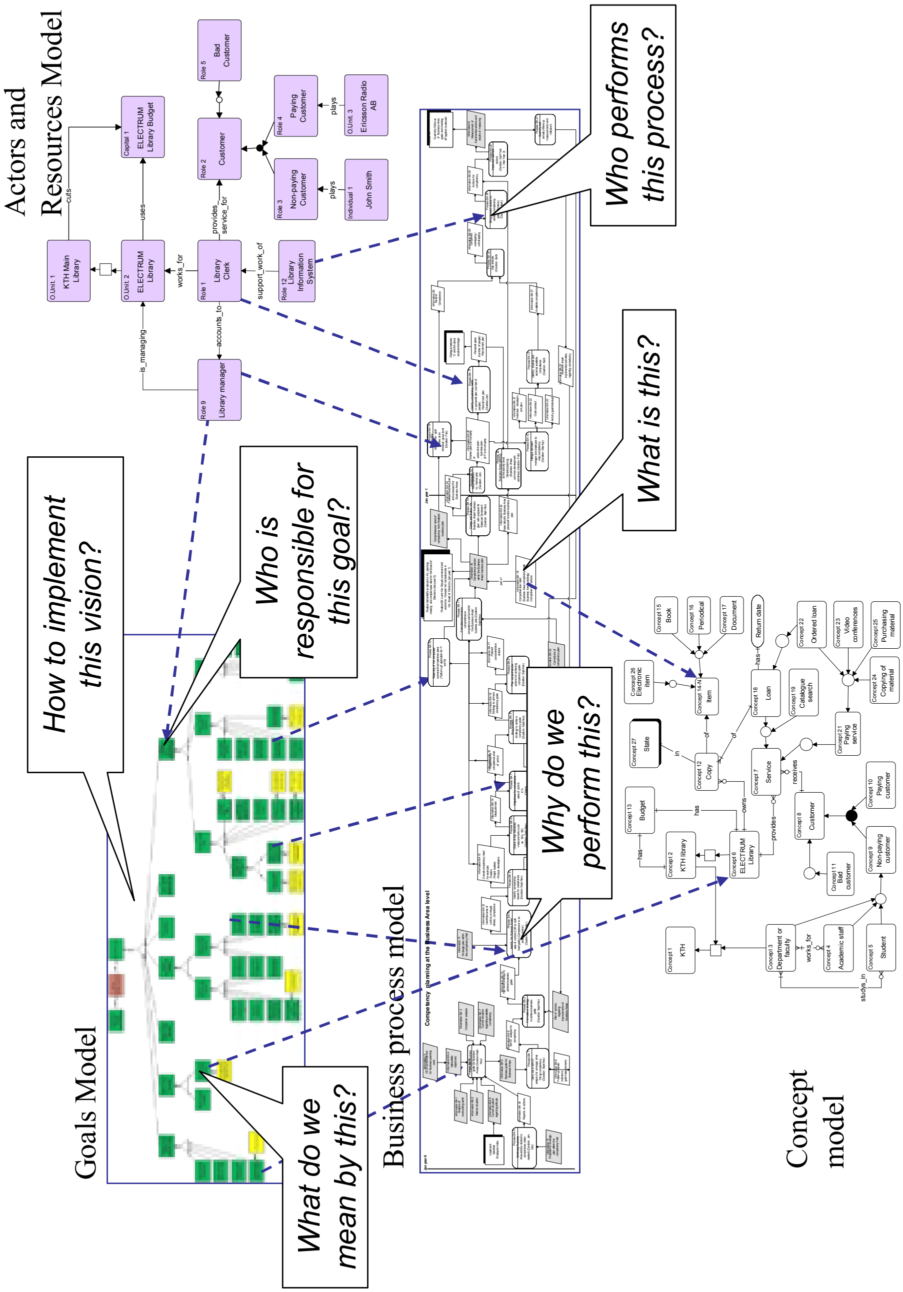

Figure 1.20: EKD (from (Stirna and Persson 2007))

1.3.1.14 Resources, Events, Agents (REA)

The REA ontology (Figure 1.21) was developed as a basis for accounting information systems (McCarthy 1982) and has been extended to form a basis for enterprise information systems architectures (Laurier et al. 2010). The core concepts in this ontology are resource, event, and agent. The REA ontology has been extended with goal modeling (Andersson et al. 2009).

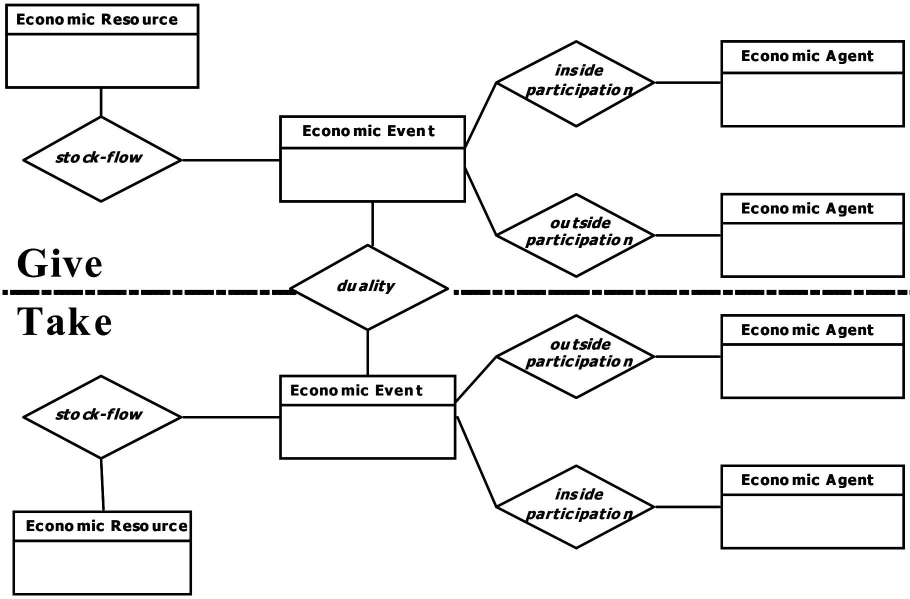

Figure 1.21: REA (from (McCarthy 2003))

1.3.1.15 Systemic Enterprise Architecture Methodology (SEAM)

SEAM (Figure 1.22) is a group of methods for strategic thinking, business-IT alignment, and requirements engineering (Laboratory for Systemic Modeling 2011). It is based on system thinking and distinguishes different levels, to analyze and design strategies at the business, inter-company, company, and IT system levels. SEAM exists in different versions: SEAM for business (Wegmann et al. 2007a), SEAM for enterprise architecture (Wegmann et al. 2007b), and SEAM for software. Each method is a specialization of the generic approach (Wegmann 2003).

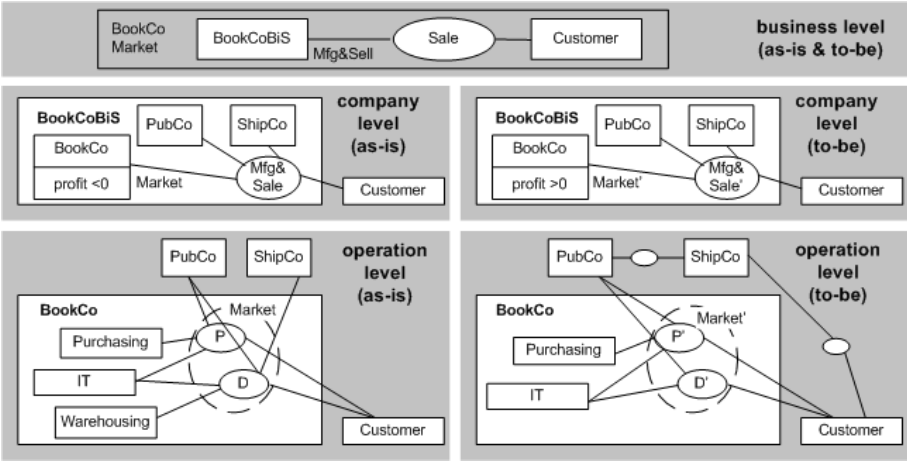

Figure 1.22: SEAM (from (Wegmann 2003))

1.3.1.16 Lightweight Enterprise Architecture Process (LEAP)

LEAP (Figure 1.23) is an EA framework that advocates for EA, and ArchiMate in particular, to be precisely defined through the use of UML and OCL to form the basis for a wide range of EA analysis techniques including simulation, compliance, and consistency checking (Clark et al. 2011). LEAP is more situated in (goal-oriented) requirements engineering, like KAOS (Van Lamsweerde 2009), than in the actual EA modeling, due to the formal specification of requirements. It is very precise, however not that lightweight.

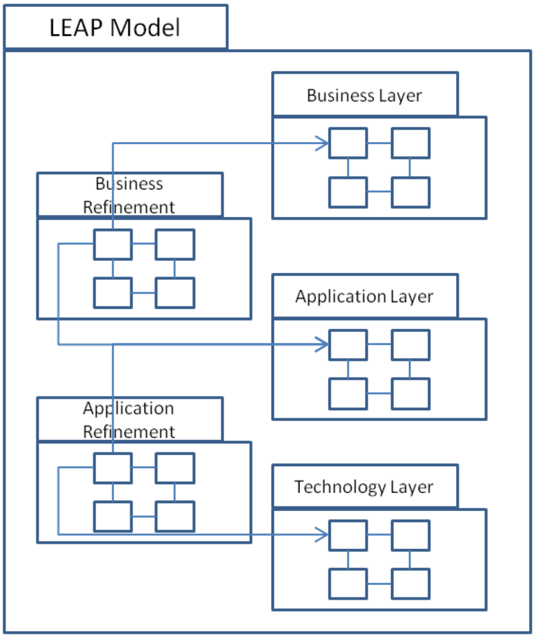

Figure 1.23: LEAP (from (Clark et al. 2011))

1.3.2 Solution Approach

1.3.2.1 Research Steps

The problem analysis advocates for the development of an EA approach that can be readily used by SMEs. First, Bernaert et al. (2014) investigated why EA has not yet been adopted by SMEs, despite its possible benefits. This article presented a research process (Figure 1.24) for developing an EA approach adapted to an SME context. They presented these research steps to be executed to design three artifacts: a metamodel, method, and software tool support. Our solution design can be situated in this context.

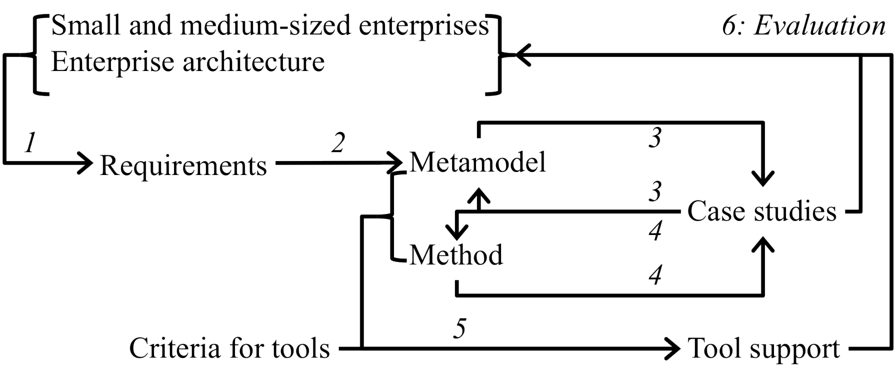

Figure 1.24: Summary of the research steps (Bernaert et al. 2014)

In step 1, both the literature on EA and IT use in SMEs were analyzed and relevant characteristics were examined. From these characteristics, requirements were extracted for EA in an SME context.

Step 2 was desk research based on a literature study and analysis, which involved choosing a suitable starting point to design the metamodel of the envisioned EA approach. While constantly keeping in mind the balance between comprehensiveness and simplicity, we analyzed a large number of existing EA frameworks in order to extract the essential dimensions of EA frameworks. In the end, an initial metamodel (i.e. the KAOS metamodel) was selected that matched these dimensions.

Step 3 was field research conducted primarily by means of action research in an initial SME and complemented with action research in five other companies. Through the action research programme, the metamodel was gradually further developed, with the initial metamodel as a starting point. The outcome of the action research was also used to evaluate the research results with respect to the EA essentials and the requirements for EA in an SME context (step 6).

After the start of the action research, five more action researches involving the use of the designed metamodel were initiated in companies with different characteristics (e.g., size, sector). These were primarily used to develop a method for using the metamodel for EA modelling (step 4). As the development of this method required us to instantiate the designed metamodel, the initial version of the metamodel that was available at that time in the action research programme was also tested in these other companies. Hence changes to the initial metamodel were also tested in other companies.

In step 5, the metamodel and method, in combination with criteria for developing software tool support, are being used to develop software tool support. This software enables both the evaluation in the case studies, as the validation by SMEs themselves that can use the tools.

Finally, a suitable visualization for the models was developed, in order to increase the chance of adoption by SMEs.

These steps have been divided throughout the different chapters of this PhD thesis:

- Step 1: EA and SME requirements: Chapter 2
- Step 2: EA metamodel: Chapter 3
- Step 4 (and 3 & 6): EA method: Chapter 4
- Step 5: EA tool support and visualization: Chapters 5 and 6

1.3.2.2 Research Method

In each part of the PhD, the most suitable set of research methods has been chosen. However, overall in this PhD, “Design Science” has been the main research method.

Design science (Hevner et al. 2004) is a well-known methodology to develop an artifact (construct, model, method, or instantiation). The different steps of design science can be applied to the research steps for the development of the different EA artifacts for SMEs (see Figure 1.25) (Hevner et al. 2004). The artifacts developed in this PhD, are an EA metamodel, method, software tool support and visualization.

The development and refinement of the EA artifacts are part of the build step. The action research during the case studies are part of the evaluate step, while the software tool support enables the evaluate step. The goal of design science is not the truth, but utility. Utility is found in the search for a higher adoption of EA in SMEs. The link to existing EA approaches enhances the rigor of our research, while the link to and action research in SMEs enhances the relevance of the research.

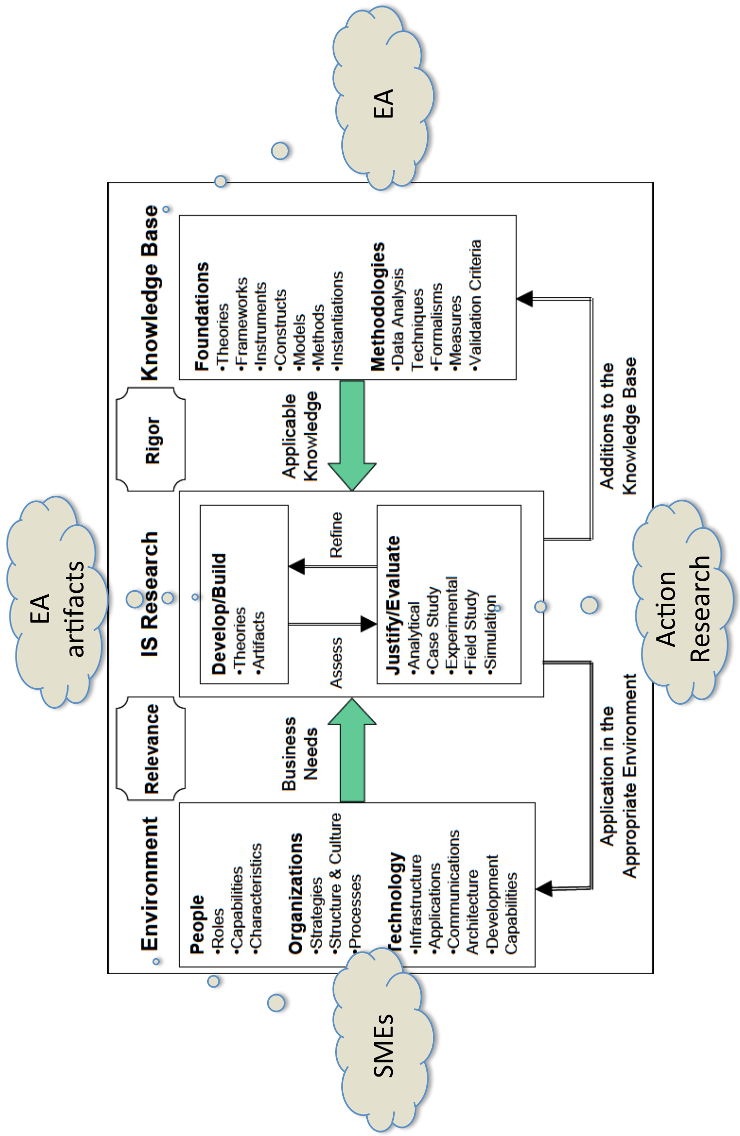

Figure 1.25: Information Systems Research Framework according to our research (from (Hevner et al. 2004))

The seven guidelines presented in (Hevner et al. 2004) can be applied to our research. The new EA metamodel, method, tool support, and visualization are created (guideline 1: creation of an artifact) for SMEs (guideline 2: for a specified problem domain). The new EA approach is evaluated during action research (guideline 3: thorough evaluation of the artifact). No specific EA approach for SMEs exists (guideline 4: innovative, novelty). The designed artifacts were formalized (guideline 5: the artifact must be rigorously defined, formally represented, coherent, and internally consistent). The action research is used to develop and refine the designed artifacts (guideline 6: search process). Finally, articles are written about the new EA approach for SMEs, both in academic journals as in journals for practitioners. Even more important, the approach was implemented and tested in practice (guideline 7: communication both to a technical and managerial audience).

Further, this introduction is structured according to the engineering cycle for world problems of Wieringa and Heerkens (2006). During a PhD three steps can be done. First, in a “problem investigation” step we investigate EA and SMEs. Second, in the “solution design” step, the different solution artifacts are designed, looking at existing EA frameworks and according to the requirements for EA and SMEs. Third, for the “solution validation” step, in the different companies, the proposed solution artifacts were evaluated against the requirements for EA and SMEs. Some more specific evaluations (method evaluation, model correctness, etc.) were performed per artifact.

1.3.3 Solution

Bharati and Chaudhury (2006) noticed that simpler technologies and software packages have a much wider application in SMEs than more complex ones. A crucial element that was missing for SMEs to be able to use EA was simplicity. Therefore, an initial EA approach was developed according to Einstein’s principle: “Everything should be made as simple as possible, but not simpler”.

First, an extensive problem investigation of EA for SMEs was performed, after which the CHOOSE approach was developed. The approach is called CHOOSE to always keep in mind the requirements for EA for SMEs. CHOOSE is an acronym for “keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise”, incorporating the requirements for EA and simplicity as the main focus for adhering to the requirements for an SME context.

The CHOOSE approach started with an extensive study of EA and SMEs and finally consists of four main artifacts (Jonkers et al. 2009): the CHOOSE metamodel, the CHOOSE method (including step-by-step guidelines and heuristics), CHOOSE software tool support, and a CHOOSE visualization.

The combination of these parts forms the solution presented in this PhD. The study of EA and SMEs is presented in chapter 2, the CHOOSE metamodel is presented in chapter 3, the CHOOSE method is presented in chapter 4, CHOOSE software tool support is presented in chapter 5, and finally the CHOOSE visualization is presented in chapter 6.

1.3.3.1 Study of EA and SMEs

To explain the proposed approach to bridge the gap between small and medium-sized enterprises (SMEs) and enterprise architecture (EA), four main parts are discussed: SMEs, EA, EA for SMEs, and recommendations for EA approach developers.

In the first part, a definition of SMEs and SME characteristics related to IT adoption are given. These characteristics lead to the development of six criteria that can be of guidance for developing IS approaches that have a higher fit with SMEs. This part ends with a discussion of problems that SMEs are facing, due to a lack of structure and overview of the company.

The second part starts with describing what EA is, what it really means, and why it is used. Then, a broad spectrum of EA approaches and the key concepts are discussed. Afterwards, criteria for EA approaches are derived, which can be a guide for developing EA approaches. This part ends with a discussion of benefits EA can offer to companies, and more specifically a discussion of benefits EA can offer to the previously mentioned problems that SMEs are dealing with.

After discussing both SMEs and EA, it seemed obvious that EA can really offer benefits to SMEs. However, neither academia nor practice demonstrated the existence and use of EA in SMEs. This advocated for a third part on bridging the gap between EA and SMEs.

The third part begins with discussing adoption models. Since an EA method is an IS method, the adoption of an EA method in SMEs can be regarded as adoption of an IS method in an SME context. Therefore, the Method Evaluation Model (Moody 2003) is further used to get insight in bridging the gap between EA and SMEs. The third part continues with analyzing which actions are necessary to bring EA to SMEs, based on the adoption models.

Finally, the fourth part gives recommendations for developing EA approaches that are specifically adapted to an SME context. First, a plan with research steps is given to develop three artifacts: a metamodel explaining the syntax and semantics of EA models for SMEs, a method with detailed guidelines explaining the process of using this metamodel for building an EA model of an SME, and software tool support to facilitate the input and adjustment, and enhance the output of the EA models. Second, a design science approach is applied to these research steps. Third and finally, a basis and starting point for the dimensions of an EA metamodel for SMEs is proposed.

1.3.3.2 CHOOSE Metamodel

The CHOOSE metamodel, the first artifact of the design science research, was presented as part of an EA approach for SMEs. It includes the necessary information to get a holistic overview of the enterprise (EA requirements), while keeping it as simple as possible (SME requirements). The requirements for EA in an SME context proposed in (Bernaert et al. 2014) thus guided the metamodel development and were a means to evaluate the development of the CHOOSE metamodel. The metamodel from KAOS, a goal-oriented requirements engineering approach, was chosen as a starting point for the CHOOSE metamodel, because it matched the essential dimensions of EA. During multiple rounds of action research (Järvinen 2007) in a Belgian SME that complied with the characteristics of SMEs as proposed in (Bernaert et al. 2014), the metamodel was then adapted to form the CHOOSE metamodel. In further rounds of action research in five other case study companies (Bernaert et al. 2015a), the metamodel was further developed.

The CHOOSE metamodel eventually consists of four viewpoints (Figure 1.26). First, in a goal viewpoint, companies can identify goals by means of a goal hierarchy to model the motivational part (why). Second, these goals can in an actor viewpoint be linked to actors to identify the active performers (who). Third, the operation viewpoint gives an overview of the processes and projects to represent the behavioral part (how). Fourth, the object viewpoint lists all objects for the description of the concepts and relationships (what). In this way, the core part of the CHOOSE metamodel only consists of the bare minimum of concepts (only one main concept per viewpoint) to have a good balance between both comprehensiveness for EA and simplicity for SMEs. Since in KAOS all the viewpoints are tightly integrated, in the CHOOSE metamodel also a high traceability within and between the four viewpoints is achieved. These relationships make later analysis possible. The main benefit of the approach is that it offers an integrated way to get an overview of the company while aligning the operations with the goals of the company. This overview can be used to overcome the earlier defined problems that SMEs are facing.

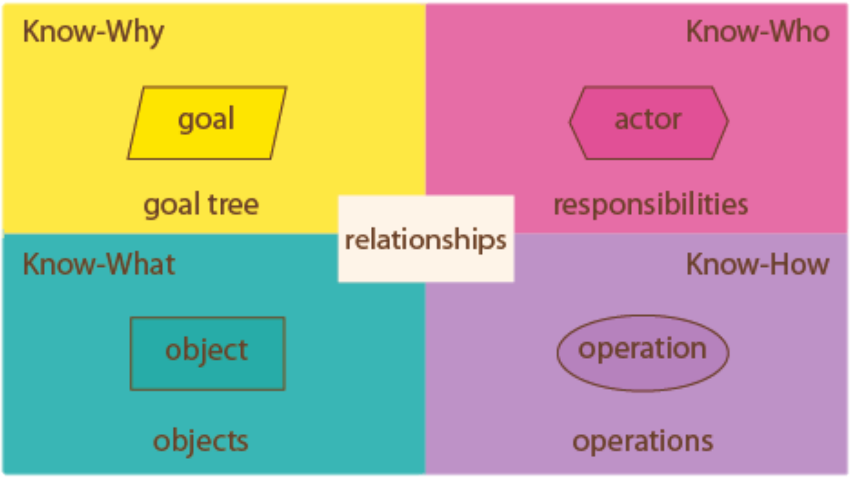

Figure 1.26: CHOOSE's metamodel overview (from (Bernaert and Poels 2011a))

1.3.3.3 CHOOSE Method

The second artifact developed during this PhD is a CHOOSE method, which guides the EA users in developing an EA model of their company. The method was developed, refined, and evaluated through an action research programme in different companies. Four SMEs with distinctive characteristics were selected. In addition, also an independent business unit of a large enterprise and one large enterprise were selected to test if applying the CHOOSE method would produce different results in larger enterprises.

The CHOOSE method eventually consists of a roadmap, an interview-method, and fourfold stop-criteria. The roadmap is a six-step procedure to implement the CHOOSE approach, the interview-method describes the best practice to structure the interviews, and the stop-criteria indicate when the input-phase of the EA model development process can be terminated.

As final step of the research, the CHOOSE method was evaluated by the CEOs of the action research companies and by an expert in SMEs with a good knowledge of EA.

1.3.3.4 CHOOSE Software Tool Support

In cooperation with numerous Master of Business Engineering students of Ghent University, a software tool support for different platforms was developed. Software tools were created and evaluated for PC (one using Access and Java, another using Eclipse GMF), Android tablets (two tools), iPad (two tools), and iPhone. Since each tool offered some specific benefits, the following overview will focus on the distinctive elements. In total, 7 tools were developed that are currently being compared against each other and evaluated in an ongoing master thesis research, in order to confirm the specific benefits and try to create a best-of-breed solution.

The EASE PC tool developed using Java in combination with Access is presented in (Ingelbeen et al. 2013) (see chapter 5) (Figure 1.27). This tool clearly shows different groups of functionalities (input, adjust, output) that should be supported.

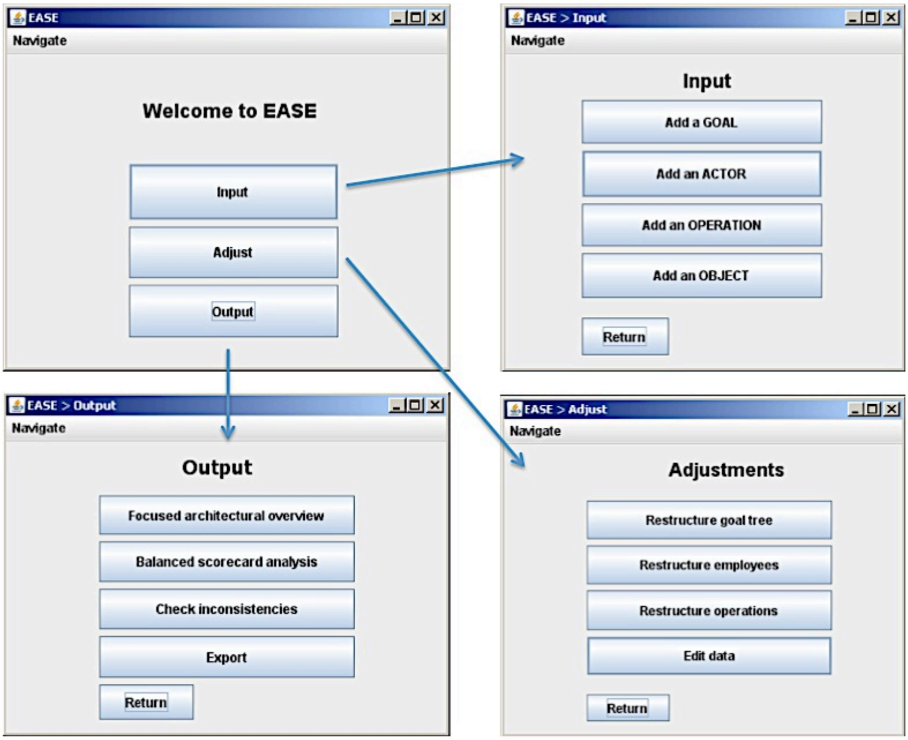

Figure 1.27: PC application (from (Ingelbeen et al. 2013))

The Eclipse GMF tool (Zutterman et al. 2013) used the Eclipse Graphical Modeling Framework (GMF) to create a visual tool by linking the CHOOSE metamodel to a graphical representation and a desired tool layout (Figure 1.28). This enables to instantly create a new tool if the CHOOSE metamodel changes and is thus particularly interesting for testing different versions of the metamodel and visualization.

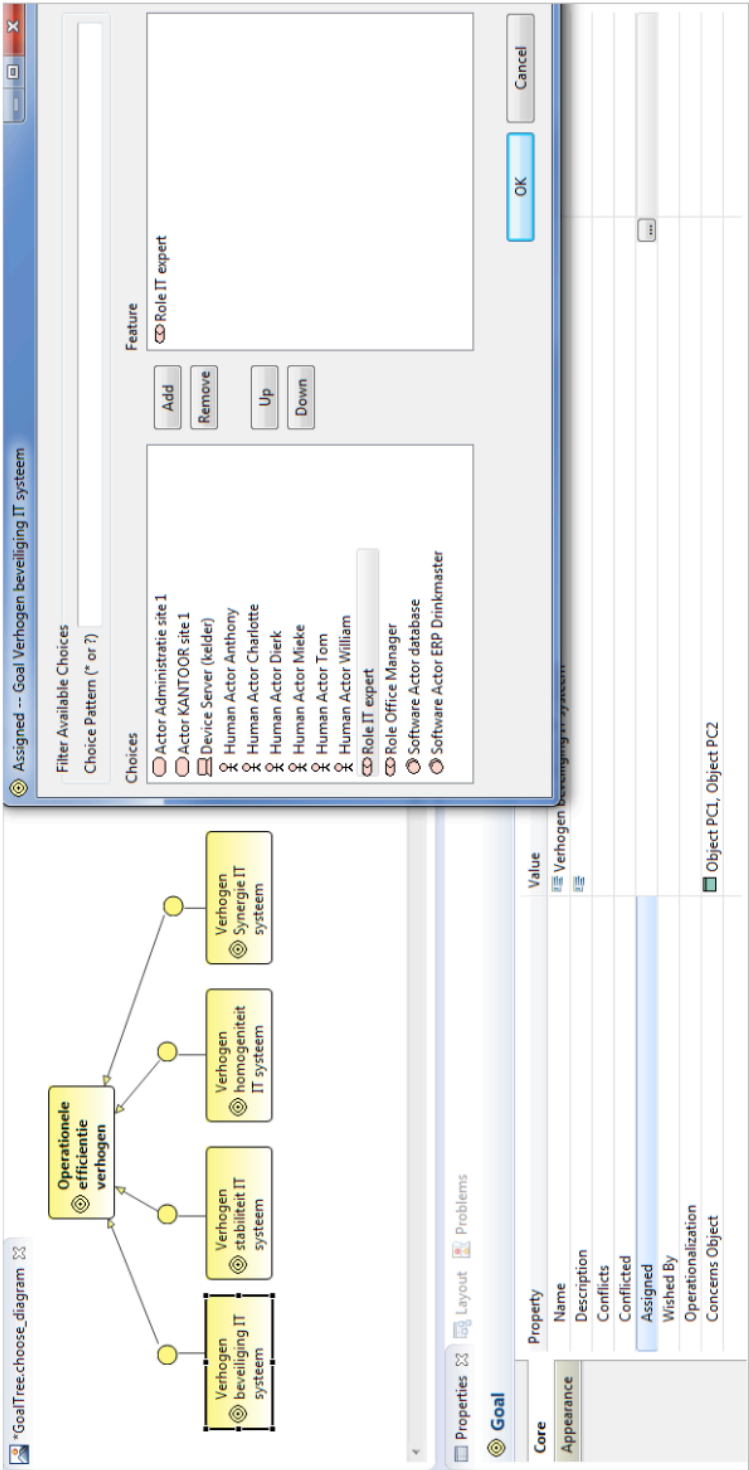

Figure 1.28: Eclipse GMF application (from (Zutterman et al. 2013))

In (Dumeez et al. 2013) (see Appendix B), an Android tablet tool is presented that explicitly incorporates the CHOOSE method and guides users in developing their CHOOSE model (Figure 1.29). In this way also the modeling process, i.e. the CHOOSE method, is supported.

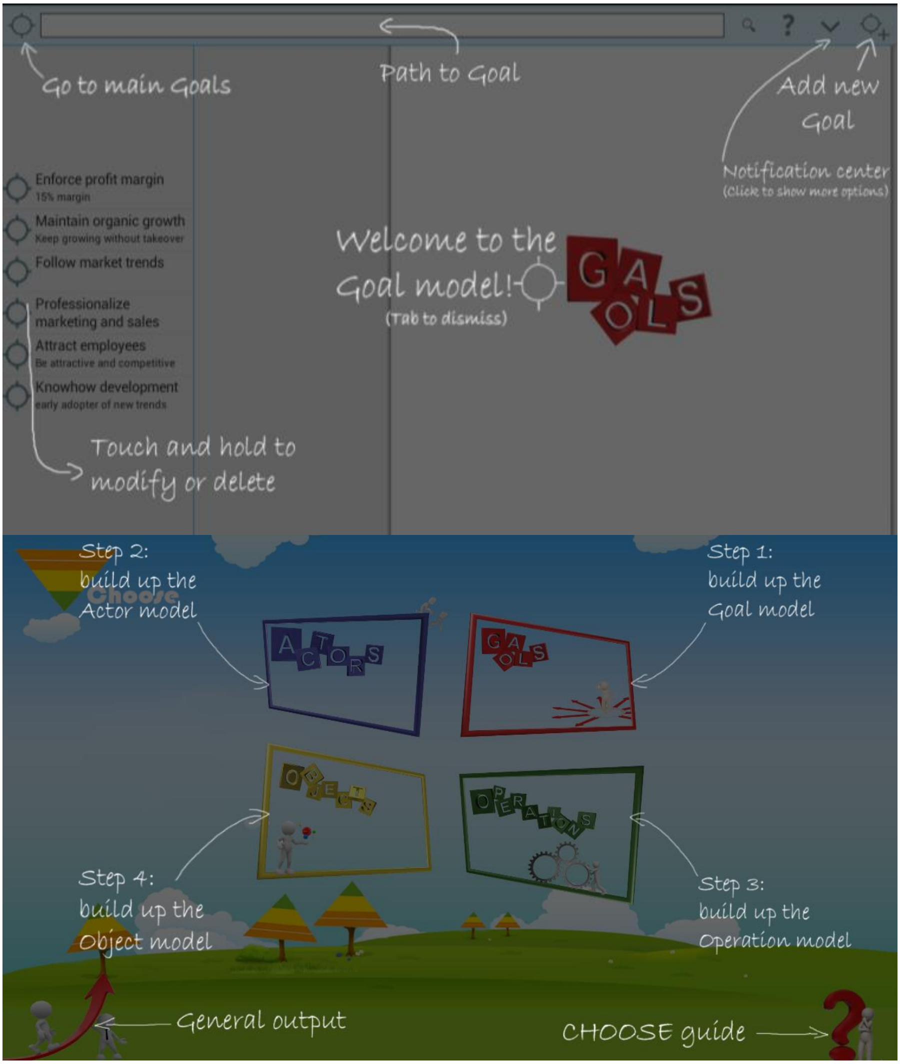

Figure 1.29: Android tablet tool (from (Dumeez et al. 2013))

(Bernaert et al. 2013) in its turn presents a more visually interactive Android tablet tool (see Appendix C) (Figure 1.30). The main advantage appeared to be the clear visual overview of the CHOOSE model and the ability to select different viewpoints.

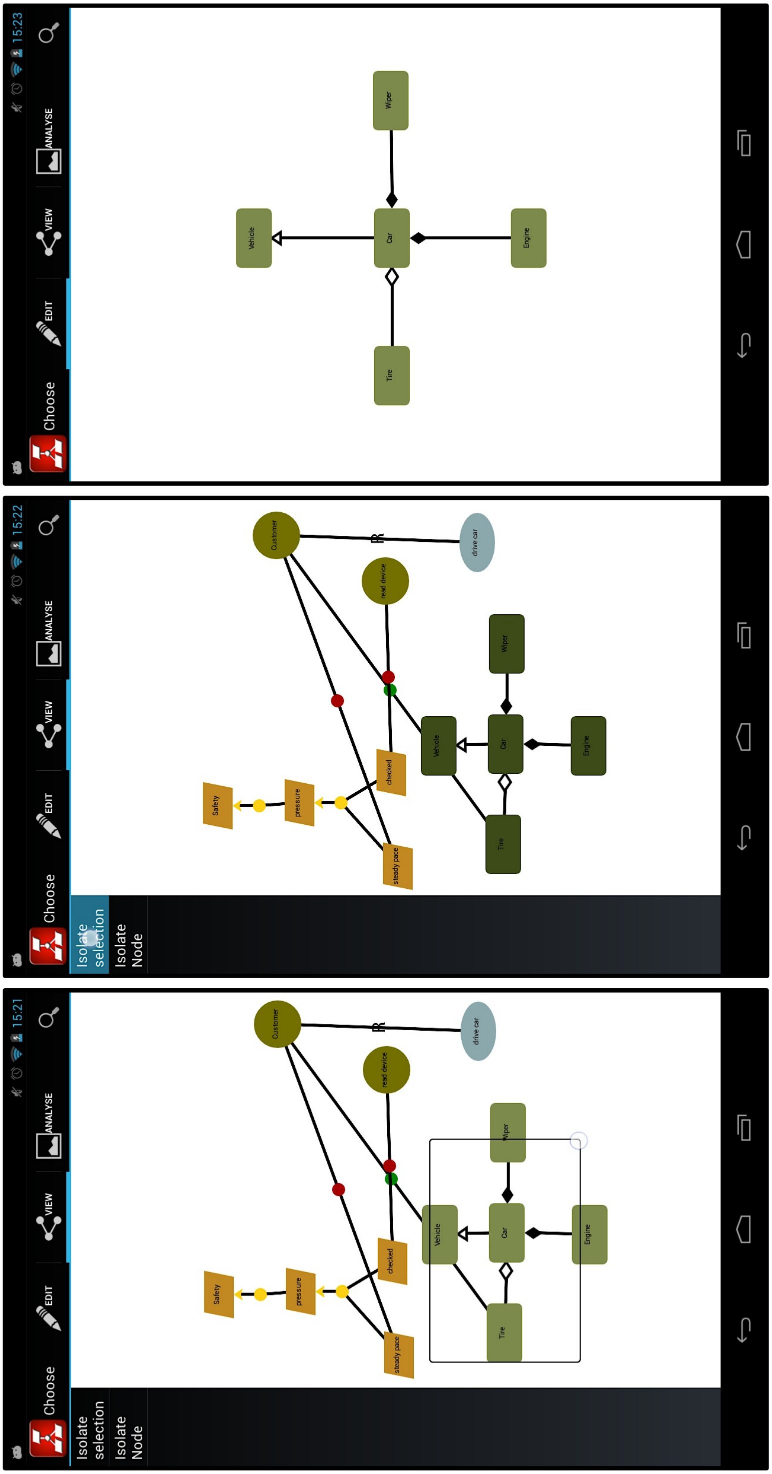

Figure 1.30: Android tablet tool (from (Bernaert et al. 2013))

The iPad application of (Otte et al. 2013) focuses on user support and analyses of the CHOOSE models (Figure 1.31). In this way, a clear analysis of the different hard and soft constraints of CHOOSE is supported by giving warnings to the users, as well as a user manual.

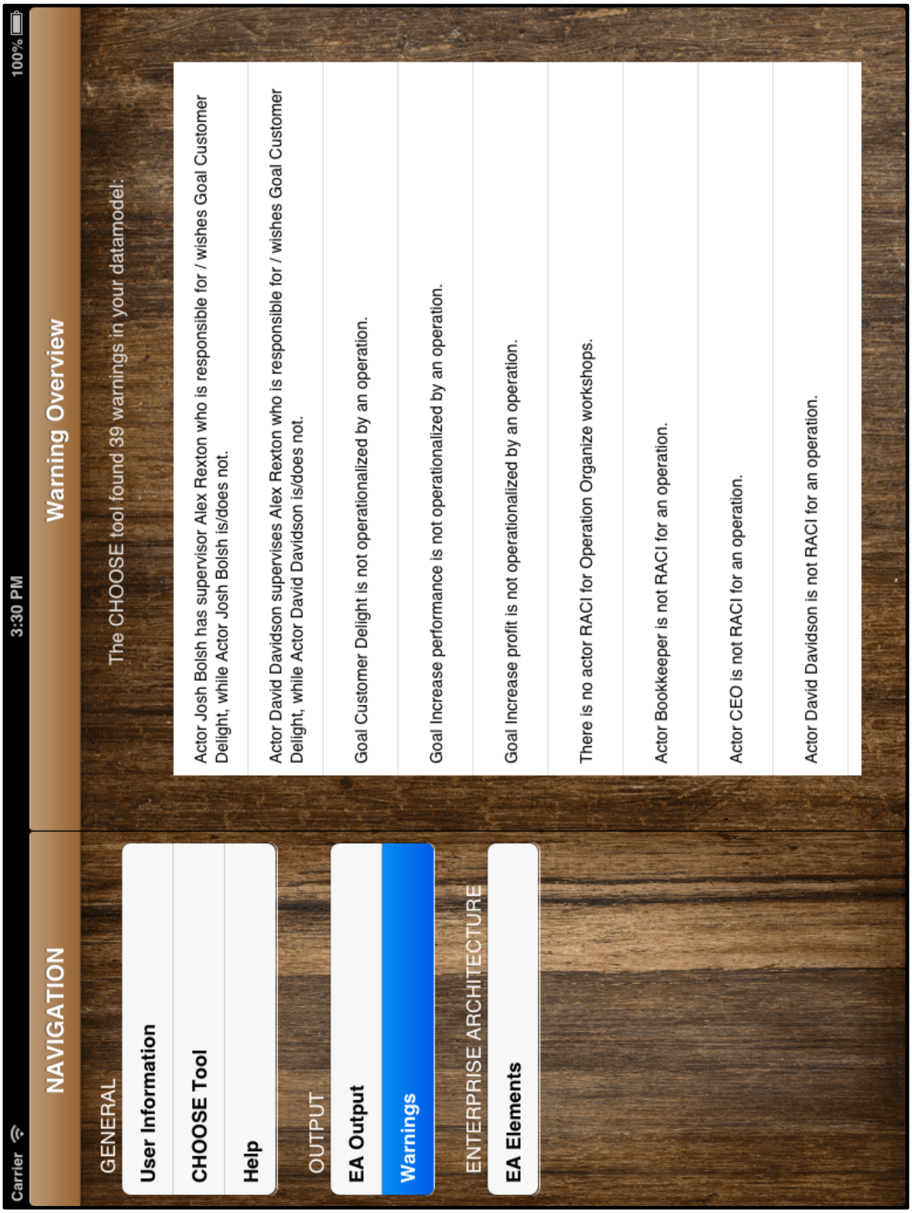

Figure 1.31: Analytical iPad application (from (Otte et al. 2013))

A second iPad application of (Verhulst et al. 2013) works with an automatic visualization, which shows the different CHOOSE model views whether as tree structures, or as listings (Figure 1.32). The main benefit is the ability to automatically create a consistent and clear visual overview.

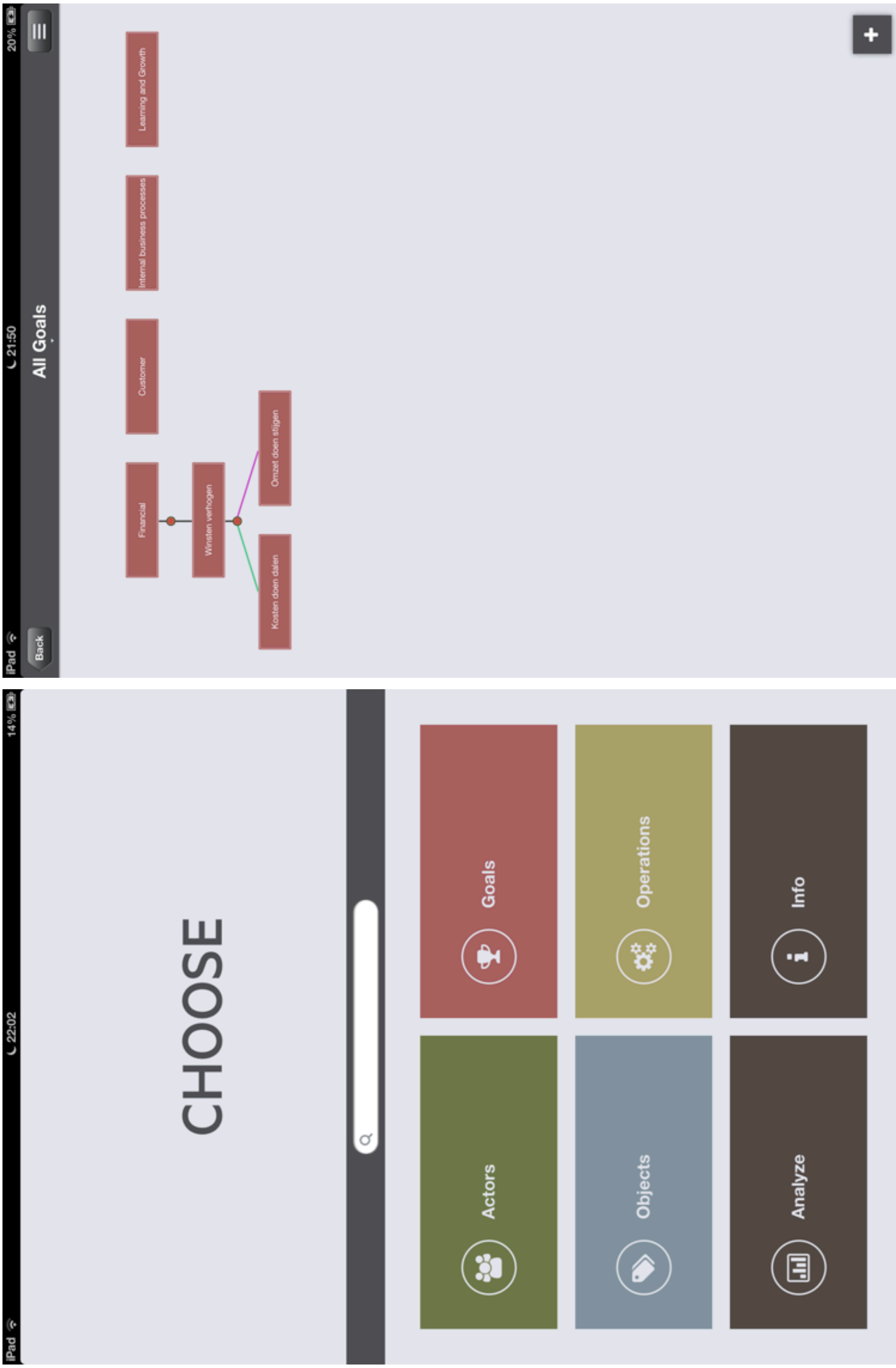

Figure 1.32: Visual iPad application (from (Verhulst et al. 2013))

Finally, an iPhone application (Puylaert et al. 2013) was developed complying with the screen size constraints of a smartphone (Figure 1.33).

The main advantage here was the inventive way in which users can easily make their own queries on the model.

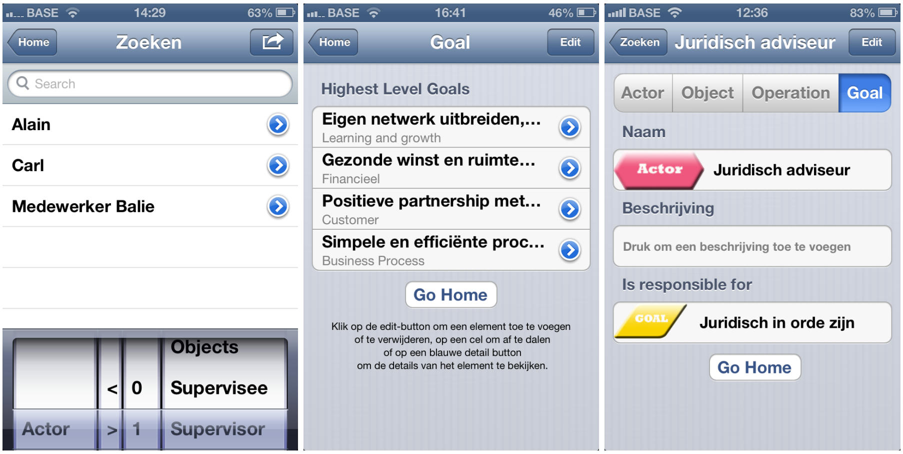

Figure 1.33: iPhone application (from (Puylaert et al. 2013))

1.3.3.5 CHOOSE Visualization

The fourth and last artifact which was created during this PhD, is an optimized visualization for CHOOSE (Boone et al. 2014). The form of representation has a great impact on the cognitive effectiveness of a diagram. Therefore, the visualization of CHOOSE used in the Eclipse GMF tool (Zutterman et al. 2013) was assessed, alternatives were described and an experimental comparison was conducted (Figure 1.34).

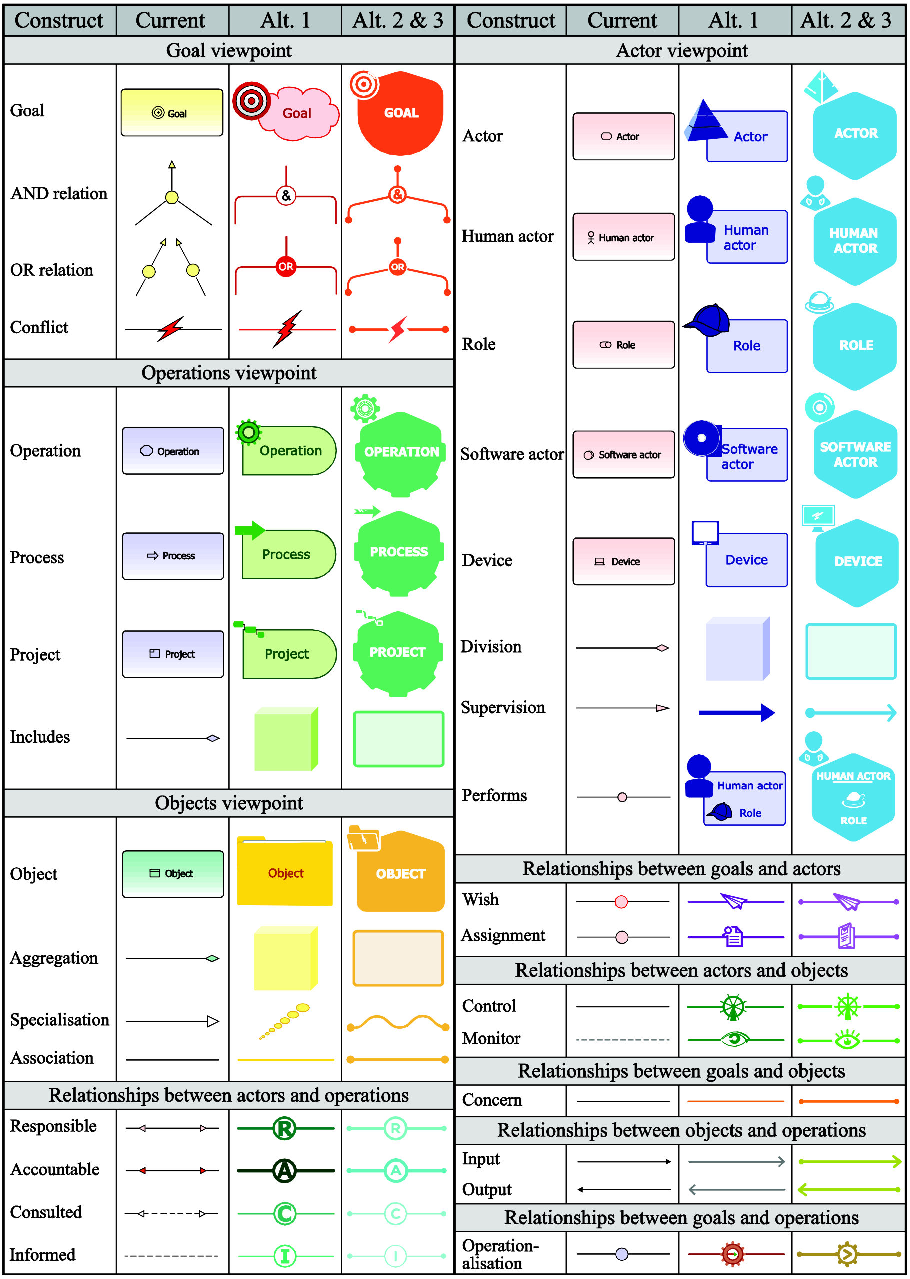

Figure 1.34: Symbols applied in the different visual notations of CHOOSE (from (Boone et al. 2014))

1.3.4 How and to What Extent Will the Research Provide a Solution to the Problem?

Our approach differs from the previously mentioned EA approaches in that the approach is specifically designed taking into account the characteristics of SMEs and their CEO. As Lankhorst (2013) mentioned, it is necessary to use an EA approach that is understood by all those involved from the different domains. SMEs have characteristics, some which are indeed different from larger companies (Bernaert et al. 2014).

CHOOSE is the first EA approach that is specifically developed for SMEs and provides SMEs with a language (metamodel and visualization), method, and software tool support to perform EA.

1.3.5 The Intended Scientific Contribution and its Originality/Novelty

In this research, we propose an EA approach that can be used by SMEs to develop their EA models and manage their EA. The approach differs from the existing EA approaches in that the approach is specifically designed taking into account the characteristics of SMEs. As such, it is the first effort to develop an EA approach specifically tailored to SMEs. A crucial element that was missing for SMEs to be able to use EA was simplicity in the existing approaches (Bernaert and Poels 2011b).

The practical implications follow from the solution that is provided for the problems of SMEs related to a lack of overview and structure of their company.

The implications for further EA research follow from the created possibility to implement EA in an SME context by using the CHOOSE artifacts. Other researchers can now for example assess the real contributions and pitfalls of using EA in SMEs. For instance, longitudinal research about the long-term effects of EA in SMEs could now be performed, similar to the recent research of Lange et al. (2015) about the factors and measures of EA management success.

1.4 Solution Validation

During the solution validation, we want to know if the developed EA artifacts conform to the requirements for EA and SMEs and if they are positively evaluated by SMEs. For each of the EA artifacts, a separate evaluation was performed, to know if the developed artifact is suitable for performing EA modeling in an SME context with a high chance of adoption. These evaluations are more deeply discussed within each of the sections of this PhD.

1.5 PhD Structure

The PhD consists of three big parts: the introduction (Chapter 1), the body of this PhD (Chapters 2-6), and conclusions (Chapter 7). The body of this PhD itself consists of five parts: a problem analysis of EA and SMEs and four parts each related to a particular CHOOSE artifact (metamodel, method, software tool support, visualization).

Each chapter of the body of this PhD was written as a self-contained research paper, so these chapters can be read independently from other chapters. This introductory chapter explains the relations between the chapters in this PhD.

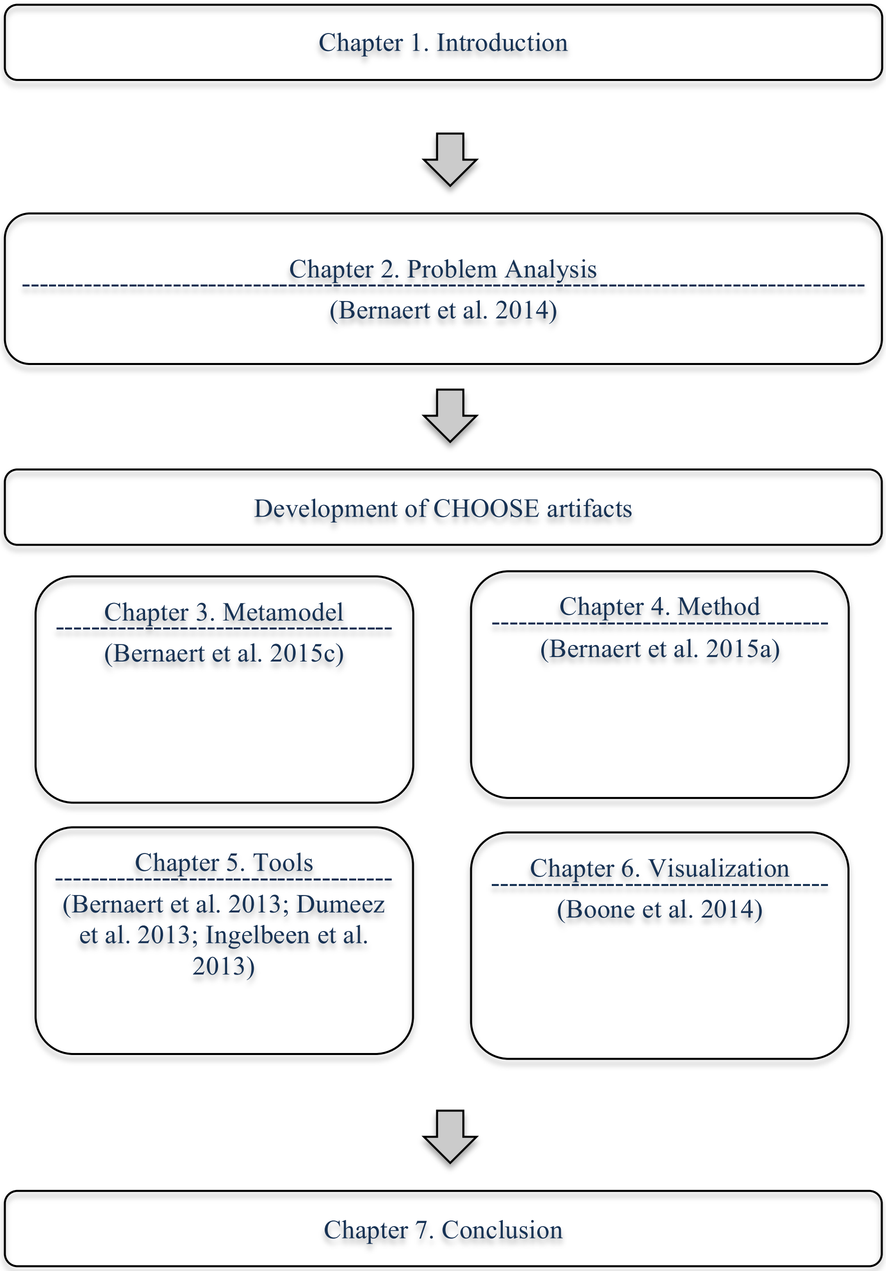

Figure 1.35: Overview of PhD structure

1.5.1 Chapter 1. Introduction

This chapter defines the structure of this PhD.

1.5.2 Chapter 2. Enterprise Architecture for Small and Medium-Sized Enterprises: A Starting Point for Bringing EA to SMEs, Based on Adoption Models

This chapter deals with the problem analysis of this PhD, by investigating EA for SMEs from an adoption perspective. The chapter refers to solutions that EA can bring to the problems regarding a lack of structure and overview in companies. However, it is clear that there still exists a gap between EA and SMEs. The main goal of this chapter is first investigating why EA is not yet adopted by SMEs, despite the benefits EA can offer. Adoption models offer insight in the adoption process. Second, this chapter offers a starting point to really adapt EA techniques to an SME context. The research steps for this PhD are given to start developing an EA technique for SMEs. The characteristics of SMEs emphasize the need of simple EA techniques.

1.5.3 Chapter 3. CHOOSE: Towards a Metamodel for Enterprise Architecture in Small and Medium-Sized Enterprises

This chapter elaborates on the construction of the first EA artifact for SMEs: the metamodel. The chapter presents the CHOOSE metamodel for EA in SMEs that is developed and evaluated during action research in SMEs. This metamodel is based on the essentials of EA frameworks and is kept simple to be usable in an SME context. The final CHOOSE metamodel includes only four essential concepts (goal, actor, operation, object), one for each most frequently used EA focus. An extract from the CHOOSE model from an SME is presented as an example. Finally, the CHOOSE metamodel is evaluated according to the EA essentials and the requirements for EA in an SME context.

1.5.4 Chapter 4. Enterprise Architecture for Small and Medium-Sized Enterprises: Action Research to Develop, Refine, and Evaluate the CHOOSE Method

This chapter mainly focuses on the action research programme to develop, refine and evaluate the second artifact of this CHOOSE approach. The CHOOSE method including step-by-step guidelines is developed from scratch and further refined. Four Belgian SMEs, a business unit of a large enterprise, and one complete large enterprise were used as companies in the action research programme. As a final step of this research, the method was independently evaluated by the CEOs of the SMEs and additionally by an expert in SMEs with a good knowledge of EA.

1.5.5 Chapter 5. Enterprise Architecture Software Tool Support for Small and Medium-Sized Enterprises: EASE

This chapter deals with a third, but crucial EA artifact to enable the application of EA by SMEs. The application and implementation of EA in general and the CHOOSE approach in particular, has after all proven to be a complex and challenging task. This chapter describes the development of one of the developed software tools called EASE in support of the CHOOSE approach in order to maximize the rate of adoption. Furthermore, the software tool is developed to guide the enterprise architect throughout the entire EA process and facilitate the implementation, management, and maintenance of the resulting EA. A brief overview is given of the main features illustrating the added value of this research-in-progress. Finally, validation is achieved by means of multiple case studies.

1.5.6 Chapter 6. Evaluating and Improving the Visualization of CHOOSE, an Enterprise Architecture Approach for SMEs

The fourth artifact of CHOOSE, its visualization, is elaborated in this chapter. First, the theoretical background is presented that is needed to conduct this research. The actual research consists of three major parts: first, the former visualization was assessed based on the principles of the Physics of Notations (Moody 2009a). Second, alternative representations were developed. Third, an experiment was conducted to verify which visualization has the best outcomes in terms of cognitive effectiveness on the one hand and perceived ease of use, perceived usefulness and intention to use on the other hand.

1.5.7 Chapter 7. Conclusion

This chapter summarizes the PhD research and discusses the implications of our findings for academics and practitioners.

1.6 Publications

This section gives an overview of all publications, which are realized during the PhD project. Parts of this dissertation have already been published in international journals or as a chapter in a book or have been presented at international conferences. After each reference, it is indicated which chapter of this dissertation contains the contents of these publications/presentations. The papers that were part of our research, but are not directly related to the research objectives central to this dissertation, are marked with the tag *[Not included]*.

1.6.1 Publications in Peer-Reviewed International Journals and Conference Proceedings listed in Web of Science

- Bernaert, M., Poels, G., Snoeck, M., De Backer, M. (2015). CHOOSE: Towards a Metamodel for Enterprise Architecture in Small and Medium-Sized Enterprises. Information Systems Frontiers, DOI 10.1007/s10796-015-9559-0. *[Chapter 3]*
- De Clercq, D., Bernaert, M., Roelens, B., Poels, G. (2015). Simplicity Is not Simple: How Business Architecture in One of Belgium's Biggest Companies Can Be Simple and Easy-to-use. To be published in Lecture Notes in Business Information Processing. *[Future research]*
- Boone, S., Bernaert, M., Roelens, B.; Mertens, S., Poels, G. (2014). Evaluating and improving the visualization of CHOOSE, an Enterprise Architecture approach for SMEs. Lecture Notes in Business Information Processing, 197, 87-102. *[Chapter 6]*
- Bernaert, M., Maes, J., Poels, G. (2013). An Android Tablet Tool for Enterprise Architecture Modeling in Small and Medium-Sized Enterprises. Lecture Notes in Business Information Processing, 165, 145-160. *[Appendix C]*
- Dumeez, J., Bernaert, M., Poels, G. (2013). Development of Software Tool Support for Enterprise Architecture in Small and Medium-Sized Enterprises. Lecture Notes in Business Information Processing, 148, 87-98. *[Appendix B]*
- Bernaert, M., Poels, G. (2011). The Quest for Know-How, Know-Why, Know-What and Know-Who: Using KAOS for Enterprise Modeling. Lecture Notes in Business Information Processing, 83, 29-40. *[Related to Chapter 3]*

1.6.2 Publications in Other Journals

- Ingelbeen, D., Bernaert, M. (2013). EASE is de architect voor het MKB. Informatie, 55(6), 20-30. *[Related to Chapter 5]*

- Bernaert, M., Poels, G. (2011). De Zoektocht naar Know-How, Know-Why, Know-What en Know-Who: Architectuur voor Kleinere Bedrijven in Vier Dimensies. Informatie, 53(9), 34-41. *[Related to Chapter 2]*

1.6.3 Chapters in International Book Publications (VABB)

- Bernaert, M., Poels, G., Snoeck, M., De Backer, M. (2014). Enterprise Architecture for Small Medium-Sized Enterprises: A Starting Point for Bringing EA to SMEs, Based on Adoption Models. In: Devos, J., van Landeghem, H., Deschoolmeester, D. (Eds.): Information Systems for Small and Medium-sized Enterprises: State of Art of IS Research in SMEs. Springer, 67-96. *[Chapter 2]*

1.6.4 Publications in Peer-Reviewed International Conference Proceedings

- Ingelbeen, D., Bernaert, M., Poels, G. (2013). Enterprise Architecture Software Tool Support for Small and Medium-Sized Enterprises: EASE. Americas Conference on Information Systems (AMCIS), Chicago, USA. AMCIS 2013 Proceedings. *[Chapter 5]*
- Bernaert, M., Poels, G. (2012). Enterprise Architecture for Small and Medium-Sized Enterprises. SIKS Conference on Enterprise Information Systems (EIS), Nieuwegein, The Netherlands. Proceedings of the 7th SIKS Conference on Enterprise Information Systems (EIS 2012). *[Related to Chapter 2]*
- Bernaert, M., Poels, G. (2011). The Quest for Know-How, Know-Why, Know-What and Know-Who: Using KAOS for Enterprise Modelling. SIKS Conference on Enterprise Information Systems (EIS), Delft, The Netherlands. Proceedings of the 6th SIKS Conference on Enterprise Information Systems (EIS 2011). *[Related to Chapter 3]*
- Laurier, W., Bernaert, M., Poels, G. (2010). A Consolidated Enterprise Reference Model: Integrating McCarthy's and Hruby's Resource-Event-Agent Reference Models. International Conference on Enterprise Information Systems (ICEIS), Funchal, Portugal, pp. 159-164. Information Systems Analysis and Specification 3. *[Not included]*

1.6.5 Publications in PhD Symposia Related to International Reviewed Scientific Conferences

- Bernaert, M. (2012). Enterprise Architecture for Small and Medium-Sized Enterprises. International Conference on Research and Practical Issues of Enterprise Information Systems (CONFENIS), Ghent, Belgium. Proceedings of the Doctoral Consortium of the 6th

International Conference on Research and Practical Issues of Enterprise Information Systems. *[Related to Chapter 2]*

- Bernaert, M., Poels, G. (2010). Integrating the Semantics of Events, Processes and Tasks across Requirements Engineering Layers. International Conference on Advanced Information Systems Engineering (CAiSE), Hammamet, Tunisia, pp. 11-19. Proceedings of the CAiSE Doctoral Consortium. *[Not included]*

1.6.6 FEB PhD Day Contributions

- Bernaert, M., Poels, G. (2012). Enterprise Architecture for Small and Medium-Sized Enterprises. Fifth PhD Day, May 25. Ghent: Ghent University. *[Related to Chapter 2]*
- Bernaert, M., Poels, G. (2011). The Quest for Know-How, Know-Why, Know-What and Know-Who: Using KAOS for Enterprise Modelling. Fourth PhD Day, May 24. Ghent: Ghent University. *[Related to Chapter 3]*
- Bernaert, M., Poels, G. (2010). Integrating the Semantics of Events, Processes and Tasks across Requirements Engineering Layers. Third PhD Day, May 28. Ghent: Ghent University. *[Not included]*

1.6.7 Master Theses

- Scheldeman, Y. (2015). Van CHOOSE Modellen naar ArchiMate Modellen en Omgekeerd. Master Thesis in progress. Ghent: Ghent University. *[Future research]*
- Machtelinckx, N. (2015). Ontwikkeling van een Multiplatform Software Tool voor Enterprise Architecture in KMO's. Master Thesis in progress. Ghent: Ghent University. *[Related to Chapter 5]*
- Morina, A. (2015). Evaluating Enterprise Architecture Techniques Based on the Rule of 7. Master Thesis in progress. Ghent: Ghent University. *[Future research]*
- De Clercq, D. (2015). Simplicity is not Simple: Hoe Enterprise Architecture in een van de Grootste Belgische Bedrijven toch Eenvoudig en Bruikbaar Kan Zijn. Master Thesis. Ghent: Ghent University. *[Future research]*
- Rosez, G. (2015). Implementatie en Evaluatie van aan de UGent Ontwikkelde Software Tools voor Enterprise Architecture in KMO's. Master Thesis. Ghent: Ghent University. *[Related to Chapter 5]*
- Hollander, J. (2014). Welke architectuurelementen kunnen van toepassing zijn binnen het Midden-MKB? Oriënterend onderzoek naar Enterprise Architectuur binnen het Midden- en Kleinbedrijf. Master Thesis. Utrecht: Open Universiteit (OU). *[Related to Chapter 2]*

- Piens, S. (2014). From Strategy to Process Modeling in Small and Medium-Sized Enterprises in Flanders: A Large Scale Quantitative Research. Master Thesis. Ghent: Ghent University. *[Related to Chapter 2]*
- Carron, S. (2014). The Development of a Domain Ontology for Enterprise Architecture. Master Thesis. Ghent: Ghent University. *[Future research]*
- Moons, L. (2014). A Performance Management System for the CHOOSE Approach for Enterprise Architecture for Small and Medium-Sized Enterprises. Master Thesis. Ghent: Ghent University. *[Future research]*
- Boone, S. (2014). The Development of an Optimal Visualisation for Enterprise Architecture (CHOOSE). Master Thesis. Ghent: Ghent University. *[Chapter 6]*
- Paesschesoone, J. (2014). The Development of an Optimal Visualisation for Enterprise Architecture (ArchiMate). Master Thesis. Ghent: Ghent University. *[Related to Chapter 6]*
- Verhulst, P. (2013). Business Architectuur Modellering in CHOOSE: Een Gebruiksvriendelijke Applicatie Aangepast aan de User Interface van de iPad. Master Thesis. Ghent: Ghent University. *[Related to Chapter 5]*
- Otte, M. (2013). Next Generation Media: A User-Friendly iPad Application for Business Architecture Modelling. Master Thesis. Ghent: Ghent University. *[Related to Chapter 5]*
- Zutterman, S. (2013). Development of a Tool for Business Architecture Modeling in Eclipse. Master Thesis. Ghent: Ghent University. *[Related to Chapter 5]*
- Puylaert, O. (2013). Business Architectuur Modellering in CHOOSE: Een Gebruiksvriendelijke Applicatie voor de iPhone. Master Thesis. Ghent: Ghent University. *[Related to Chapter 5]*
- Callaert, M. (2013). Business Architectuur Modellering in KMO's: Case Study Onderzoek ter Verfijning en Validatie van de CHOOSE Methode en Metamodel. Master Thesis. Ghent: Ghent University. *[Related to Chapter 4]*
- Dumeez, J. (2013). Next Generation Media: A User Friendly Android Tablet Application for Business Architecture Modeling. Master Thesis. Ghent: Ghent University. *[Appendix B]*
- Maes, J. (2013). Business Architecture Modelling in CHOOSE: A Visual Application for Android Tablets. Master Thesis. Ghent: Ghent University. *[Appendix C]*
- Ingelbeen, D. (2013). Softwareondersteuning voor een Enterprise Architectuur in Access en Java. Master Thesis. Ghent: Ghent University. *[Chapter 5]*
- Roose, D., Vansteenlandt, J. (2013). Development of a Common Base for Enterprise Architecture: Building the Bridge Between

CHOOSE and ArchiMate. Master Thesis. Ghent: Ghent University. *[Future research]*

- De Nil, S., Deprost, E. (2012). Van Strategie tot Procesmodellering in Kleine en Middelgrote Organisaties: Een Exploratief Onderzoek. Master Thesis. Ghent: Ghent University. *[Related to Chapter 2]*
- Heyse, M. (2012). Keuzes Maken binnen Processen: Het Vermijden van een Russische Roulette voor de Organisaties. Master Thesis. Ghent: Ghent University. *[Not included]*
- Vancaeneghem, T. (2011). Het Realiseren van een Globaal Procesoverzicht bij Gedecentraliseerde Procesarchitecturen. Master Thesis. Ghent: Ghent University. *[Not included]*

1.6.8 To Be Submitted

- Bernaert, M., Callaert, M., Poels, G., Snoeck, M., De Backer, M. (2013). Enterprise Architecture for Small and Medium-Sized Enterprises: Action Research to Develop, Refine, and Evaluate the CHOOSE Method. Revised after submission to Enterprise Information Systems. *[Chapter 4]*

2

Enterprise Architecture for Small and Medium-Sized Enterprises: A Starting Point for Bringing EA to SMEs, Based on Adoption Models

Published as Bernaert, M., Poels, G., Snoeck, M., De Backer, M. (2014). Enterprise Architecture for Small and Medium-Sized Enterprises: A Starting Point for Bringing EA to SMEs, Based on Adoption Models. In: Devos, J., van Landeghem, H., Deschoolmeester, D. (Eds.): Information Systems for Small and Medium-sized Enterprises: State of Art of IS Research in SMEs. Springer, 67-96.

Abstract. On the one hand, small and medium-sized enterprises (SMEs) are important drivers of economy. SMEs face a number of problems due to a lack of structure and overview of the company. On the other hand, enterprise architecture (EA) can be used as a holistic approach to keep things aligned in a company. Some emphasize the use of EA to align IT with the business, others see it broader and use it to also keep the processes aligned with the strategy. This article refers to solutions that EA can bring to the problems regarding a lack of structure and overview in companies. While EA has gained importance in larger companies and EA can also provide similar benefits to SMEs, hardly any article discusses EA for SMEs. An exploratory research in Flemish SMEs confirms that in practice none of the SMEs knows or uses EA. It is clear that there still exists a gap between EA and SMEs. The main goal of this article is first investigating why EA is not yet adopted by SMEs, despite the benefits EA can offer. Adoption models offer insight in the adoption process. Second, this article offers a starting point for EA technique developers to really adapt EA techniques to an SME context. Research steps are given to start developing EA techniques, as well as a starting point for a metamodel based on only four concepts, because the characteristics of SMEs emphasize the need of simple EA techniques. These concepts refer to four dimensions that are present in a broad spectrum of EA techniques.

Keywords: *Enterprise architecture; Small and medium-sized enterprises; Business architecture; Adoption*

2.1 Introduction

To explain the proposed approach to bridge the gap between small and medium-sized enterprises (SMEs) and enterprise architecture (EA), this chapter is divided in four main parts: SMEs, EA, EA for SMEs, and recommendations for EA technique developers. The first two parts on SMEs and EA are descriptive, the third part is analytical and the fourth part is rather prescriptive.

In the first part, the definition of SMEs in Europe and the U.S. is explained. Then, SME characteristics related to IT adoption are given, out of which six well-documented characteristics can be derived. These characteristics lead to the development of six criteria that can be of guidance for developing IS techniques that have a higher fit with SMEs. The first part ends with a discussion of problems that SMEs are facing, due to a lack of structure and overview of the company.

The second part starts with an introduction of what the definition of EA is, what it really means, and why it is used. Then, a broad spectrum of EA techniques are being discussed. The key concepts of these techniques, which structure and dimensions they really have in common, are discussed in a subsequent section. Afterwards, similar to the part on SMEs, five criteria for EA techniques are derived from the definition of EA. These criteria can be a guide for developing EA techniques. The second part ends with a discussion of benefits EA can offer to companies, and more specifically a discussion of benefits EA can offer to the previously mentioned problems that SMEs are dealing with.

After discussing both SMEs and EA, it seems obvious that EA can really offer benefits to SMEs. However, neither academia nor practice demonstrate the existence and use of EA in SMEs. This advocates for a third part on bridging the gap between EA and SMEs.

The third part begins with discussing adoption models, starting with the technology acceptance model (TAM). This model has been extended by Moody to be used for IS method adoption, and is known as the method evaluation model (MEM). Thereafter, adoption models of IT in an SME context are being discussed. The adoption of EA in SMEs is about adoption of an IS method in an SME context. Therefore, the MEM is further used to get insight in bridging the gap between EA and SMEs.

The third part continues with analyzing which actions are necessary to bring EA to SMEs, based on the adoption models. The perceived efficacy (perceived usefulness and perceived ease of use) has to be increased, and the actual efficacy has to influence this perceived efficacy. This can only be done by stimulating implementation and research of EA in SMEs.

Finally, the fourth part gives recommendations for developing EA techniques that are specifically adapted to an SME context. First, a plan with research steps is given to develop three artifacts: a metamodel explaining the syntax and semantics of EA models for SMEs, a method with detailed guidelines explaining the process of using this metamodel for building an EA model of an SME, and software tool support to facilitate the input and adjustment, and enhance the output of the EA models. Second, a design science approach is applied to these research steps. Third and finally, a basis and starting point for the dimensions of an EA metamodel for SMEs is proposed.

2.2 Small and Medium-Sized Enterprises

2.2.1 What is a Small and Medium-Sized Enterprise?

An enterprise can be interpreted in a very wide sense. It could mean the whole enterprise, a smaller part of it (e.g., a business unit), or an area of activity of the enterprise (e.g., the purchasing). This research limits itself to small and medium-sized enterprises (SMEs), although the problems addressed and proposed solutions could be similar in larger organizations as well.

In the U.S., the Office of Advocacy defines a small business as an independent business having fewer than 500 employees (Small Business Administration 2012). SMEs are important to the U.S. economy. They represent 99.7 percent of all employer firms, employ about half of all private-sector employees, pay 43 percent of total U.S. private payroll, and have generated 65 percent of net new jobs over the past 17 years from 1993 till 2009 (Small Business Administration 2011). Further, SMEs play a critical role in nurturing industrial innovation, constituting 40 percent of highly innovative firms in 2002 (CHI Research Inc. 2004). SMEs also play a significant role in enhancing the competitiveness of an economy through the process of economic renewal by creation, elimination, and restructuring of economic sectors.

In Europe, micro, small and medium-sized enterprises are often referred to as the backbone of the European economy. There were close to 20.8 million SMEs in Europe, which accounts for 99.8 percent of all companies. Furthermore the lion's share of those SMEs are micro enterprises with a total of 19.2 million. Around 70 percent of European jobs are provided by the SMEs in the private sector and they account for 58.4 percent of total gross-value added production (European Commission 2011). The European Commission (2003) defines SMEs as companies that employ less than 250 employees and of which the annual turnover is less than 50 million euros or of which the total assets are less than 43 million euros.

This article uses the term SME. However, SMEs are not a homogeneous group. Therefore, it is important to focus on a clearly defined type of SMEs in research and development efforts. Distinctions can be made based on regional differences (e.g., U.S. versus Europe), on size (based on the number of employees or based on the definition), on industry (e.g., production, trade, services, and government), on growth, on family owned or not, on influence of the CEO, on education of the CEO, on number of years in business, and even based on workforce age (Meyer 2011).

2.2.2 Relevant Literature of SME Characteristics Influencing IT Adoption

In academia and practice, a lot of discussion arises on whether SMEs are different from large companies and whether a different IT approach is required for SMEs. In the next paragraphs, relevant literature is discussed and summarized in a set of six characteristics.

Literature regarding IT application in SMEs shows a substantial lack of empirically grounded explanatory models and emphasizes SMEs' technological lag with regard to IT tools adoption and implementation, disregarding the role played by contingencies (Mariano et al. 2003). This literature weakness has been ascribed to the use of unsuitable research methods, mostly conceived for large firms, and wrong assumptions concerning SMEs (Thorpe et al. 2005). As a matter of fact, the small size is interpreted as synonymous of the inability to commit financial and human resources, to rely on relevant external technical skills, to assign IT tools to something different from shortly-ranged operating issues, and to understand IT benefits.

Welsh and White (1981) identified important differences in the financial management of small and large businesses while Ballantine et al. (1998) identified unique characteristics of SMEs as lack of business and IT strategy, limited access to capital resources, greater emphasis on using IT and IS to automate rather than informate, influence of major customers, and limited information skills. Similar assertions and findings are given in other papers (Metaxiotis 2009; Grandon and Pearson 2004; Street and Meister 2004; Chen et al. 2003; Mariano et al. 2003; Poon and Swatman 1999; Cragg and King 1993; Raymond 1985).

The SME characteristics influencing the IT adoption can be grouped into six main characteristics. The low level IT adoption in SMEs is first ascribed to a lack of expertise and time on the management side (Malhotra and Temponi 2010; Yap et al. 1992; Berryman 1983; Welsh and White 1981) and second to a lack of financial resources and skilled manpower within SMEs (Malhotra and Temponi 2010; Lefebvre et al. 1996; Yap et al. 1992; Noori 1990; Montazemi 1988; Welsh and White 1981). Third, if management is not directly involved in the IT implementation process and if SMEs are not endowed with technical expertise, then the role played by external actors becomes of crucial importance. The problem then lies on the lack of good external technical skills, as SMEs only occasionally seek advice from IT vendors or external consultants (Sels et al. 2006; Fuller 1996). SMEs are more likely than large companies to suffer from resource poverty such as financial constraints, lack of professional expertise, and susceptibility to external forces (Kroon et al. 2012; Montazemi 2006; Thong et al. 1996). Furthermore, when relied upon, external consultants not only have to adapt to firm's way of thinking and working, but also see activities fading out when leaving the firm (Alstrup 2000). Furthermore, it frequently happens that an outsourced IT project becomes a failure (Devos 2011).

Fourth, most papers consider IT as a set of tools used to a large degree for solving short-term operating problems, rather than long-term strategic plans (Harvey et al. 1992; Khan and Khan 1992; Lincoln and Warberg 1987; Malone 1985; Deeks 1976), because of the unpredictability of SMEs strategic future. Fuller (1996) mentioned that strategic planning is described as an “emerging vision” or “strategic awareness”, “neither of which lend themselves easily to the explicit definitions required for systematic investment in information technology”.

Fifth, SMEs tend to have simple and highly centralized structures with the executive officers making most of the critical decisions (Montazemi 2006; Thong et al. 1996).

Sixth, top-management support has been found to be a key critical factor in IS effectiveness in SMEs (Montazemi 2006; Caldeira and Ward 2003; Yap et al. 1992).

Last, but less documented, some researchers link the delay in IT usage to presumed SMEs cultural delay (Rullani and Micelli 1998).

2.2.3 Six Well-Documented Characteristics

From the relevant literature on characteristics influencing IT adoption in SMEs, six characteristics can be distilled, some of which are different from larger companies:

1) Employees and management are typically overwhelmed with day-to-day business, leaving little time for themselves to look at strategic matters such as process management, not to mention quality and process improvement (Malhotra and Temponi 2010; Kamsties et al. 1998; Berryman 1983; Welsh and White 1981).
2) SMEs have limited IT knowledge and technical skills (Haug et al. 2010; Levy et al. 2001; Lefebvre et al. 1996; Thong et al. 1996; Thong and Yap 1995; Blili and Raymond 1993; Gable 1991; Noori 1990; DeLone 1988; Montazemi 1988; DeLone 1981; Welsh and White 1981). The main reason why European SMEs fail in utilizing IT is their lack of IT knowledge (Neidleman 1979).
3) Smaller companies have significantly fewer resources than larger companies, due to the highly competitive environment, financial constraints, lack of expertise, and sensitivity to external influences (Kroon et al. 2012; Ballantine et al. 1998; Thong et al. 1996; Thong and Yap 1995; Welsh and White 1981). The smaller the company, the fewer resources it has to hire experts, for example, employees with IT skills (Montazemi 2006; Levy et al. 2001; Ballantine et al. 1998; Fuller 1996; Lefebvre et al. 1996; Thong and Yap 1995; Blili and Raymond 1993; Alpar and Reeves 1990; Noori 1990; Montazemi 1988; DeLone 1981).
4) There is a big demand in these companies for knowledge regarding the performance of tasks and how things are done (Kamsties et al.

1998; Harvey et al. 1992; Khan and Khan 1992; Lincoln and Warberg 1987; Malone 1985; Deeks 1976).

5) By definition, SMEs are organizations with fewer employees than large companies. The manager or CEO, who is often the company's owner, is commonly the single person who decides on strategic issues. The CEO is the central figure who determines the direction of an SME (Levy and Powell 2008; Bharati and Chaudhury 2006; Montazemi 2006; Caldeira and Ward 2003; Thong et al. 1996; Thong and Yap 1995; Blili and Raymond 1993; Yap et al. 1992; Rizzoni 1991). His/her skills and preferences have a major impact on the extent to which the SME changes (Thong and Yap 1995; Birley 1982).
6) In SMEs, the CEO takes the decision whether or not to adopt a new approach (Levy and Powell 2008; Bharati and Chaudhury 2006; Levy and Powell 2005; Southern and Tilley 2000; Thong and Yap 1995). With every decision there is a degree of uncertainty. The expected returns must exceed the expected risks and costs (time, money, effort) in order to accept a new approach (Levy et al. 2001; Rogers 1983). Adoption will be covered in more detail later in this chapter.

2.2.4 Six Criteria for SMEs

From these characteristics it is possible to derive criteria that can be a guidance for developing IS techniques that have a higher fit with SMEs:

1) The approach should enable SMEs to work in a time efficient manner on strategic issues.
2) A person with limited IT skills should be able to apply the approach.
3) It should be possible to apply the approach with little assistance of external experts.
4) The approach should enable making descriptions of how things are done in the company.
5) The CEO must be involved in the approach.
6) The expected revenues of the approach must exceed the expected costs and risks. Later on in this chapter, the terminology perceived usefulness and perceived ease of use will be introduced.

2.2.5 Problems Faced by SMEs

SMEs are very important for economy, however, not all new SMEs make it through the first years. 70 percent survive 2 years, 50 percent 5 years, a third 10 years, and only a quarter stay in business 15 years or more (Bureau of Labor Statistics 2011; Census Bureau 2011). Although there are many reasons for these numbers, some problems can be related to a lack of structure and overview in the company to pursue a superior competitive strategy (O'Gorman 2001).

In an SME, the entrepreneur (CEO) controls the enterprise. However, while most entrepreneurs have a good knowledge about their company, the overview tends to stay unspoken. This can cause some problems to occur:

- For ERP adoption, the most important criterion used by European SMEs in selecting an information system is the best fit with current business procedures (van Everdingen et al. 2000). This is also confirmed in the case studies of De Nil et al. (2012). However, in nearly all SMEs they visited, a clear overview of the business was lacking.
- In an enterprise, employees tend to know less about the structure of the company and why things are done. Although the entrepreneur knows the overview of the company, it is difficult for him/her to communicate with its employees about strategic issues without having an explicit overview (Kamsties et al. 1998).
- A concrete job description and overview of tasks and responsibilities of employees is difficult to keep track of, especially in a changing environment and enterprise (Kamsties et al. 1998). In (Chan and Chao 2008) it is said that the majority of the employees (88 percent) stated that they are required to spend a lot of time doing additional work that is not specified in their job description.
- A strategy is not static, neither are processes. Keeping processes at all time in line with the strategy is difficult to achieve (Dougherty 1992).
- In an ever-changing environment, assessing the impact of changes can help to prevent problems to occur. What if the economy changes? What if the strategy has to be adapted? What if an employee leaves the company? (Porter 1998)
- An SME has different stakeholders with different desires and goals. Balancing these goals as good as possible is not a simple assignment (Heyse et al. 2012).
- If the CEO leaves the company for some reason (e.g., he/she sells the company or a child takes over), the knowledge about the overview of the company has to be transferred to the new CEO (Yong et al. 2004; Bjuggren and Sund 2001).

Furthermore, knowledge and more specifically entrepreneurial knowledge is important for SMEs. Knowledge cannot be reduced to its purely technical sense, as a collection of patentable inventions. Knowledge is fundamentally linked to an individual with an idea that is being realized (Devos 2011). This entrepreneurial knowledge gives SMEs a competitive advantage over larger companies. Larger companies are using capital and labor as resources and are trying to control their transaction and management costs (Jensen and Meckling 1976; Coase 1937).

Knowledge is very important for an SME, however, this knowledge is linked to a person with his idea (Audretsch et al. 2004). Next to capital and labor, this extra production factor, entrepreneurial capital, is important for SMEs to maintain and communicate, especially when the company is growing and the CEO tends to loose grip (Carree and Thurik 2005; Weick et al. 2005; Audretsch and Thurik 2000).

2.3 Enterprise Architecture

2.3.1 Enterprise Architecture Introduction

Enterprise architecture (EA) is used as a holistic approach to keep things aligned in a company. Some emphasize the use of EA to align IT with the business, others see it broader and use it to also keep the processes aligned with the strategy. EA is a key instrument in controlling the complexity of the enterprise and its processes and systems. Lankhorst defines EA as "a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure". ((Lankhorst 2013), p. 3) As such, EA has to capture the essentials of the enterprise, because they are more stable than the specific solutions found for the problems currently at hand. The most important characteristic of an EA is that it provides a holistic overview of the enterprise. This enables optimization of the company as a whole instead of doing local optimization within individual domains. EA facilitates the translation from corporate strategy to daily operations. To achieve this quality, it is necessary to use an approach that is understood by all those involved from these different domains. (Lankhorst 2013)

2.3.2 Existing Techniques

Research on EA has primarily focused on integrating business with IT, often referred to as business-IT alignment (Henderson and Venkatraman 1993). An overview of some well-known EA frameworks, methods, metamodels, ontologies, and languages is given in the next paragraphs. However not exhaustive, this overview covers a broad spectrum of EA techniques: the initial EA framework (Zachman's Framework), the Open Group standards (TOGAF and ArchiMate), the U.S. Department of Defense Architecture Framework (DoDAF), a technique developed by a consulting firm based on best practices (Capgemini's IAF), and two techniques developed in an academic context (REA and EKD).

Zachman's Framework (Zachman 1987) (Figure 2.1) is probably the first and most famous EA framework. This framework is a structured way, based on two dimensions (focus and view), to classify and organize the representations of an organization. Each dimension consists of six parts, resulting in a matrix with 36 cells. Zachman's Framework is only a classification framework and offers no method to develop EAs. Therefore, it is often used in conjunction with TOGAF.

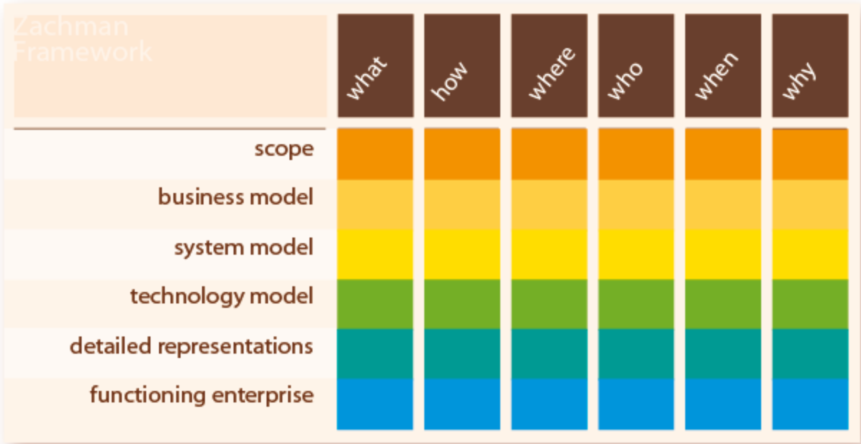

Figure 2.1: Zachman's Framework

The Open Group Architecture Framework (TOGAF) (The Open Group 2009) (Figure 2.2) is a framework and method to develop and manage EAs. TOGAF consists of four major components, of which the Architecture Development Method (ADM) is considered the core. It describes an iterative method for EA development. The ADM states that the business architecture is first developed, followed by the information system architectures (applications and data) and the technology architecture. TOGAF is frequently used with ArchiMate.

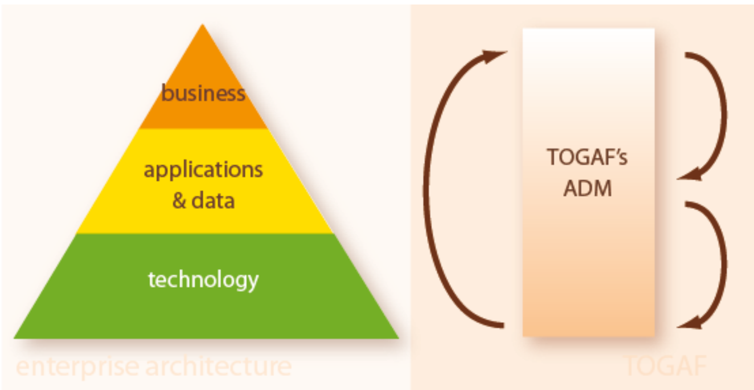

Figure 2.2: A simplification of TOGAF's ADM

ArchiMate (Lankhorst 2013; The Open Group 2012) (Figure 2.3) proposes a standard language and metamodel for describing EAs and is widely supported by tools and consulting companies. The metamodel shows that ArchiMate works with three layers of architectural models, namely a business architecture layer, an application architecture layer (includes applications and data), and a technology architecture layer. Within each layer there is a section that reflects behavioral or dynamic aspects and two sections representing structural or static aspects. The static aspects can be active (structure) or passive (information). The new version of ArchiMate (ArchiMate 2.0) provides a tighter alignment with TOGAF and also includes a strategic dimension (motivation) and an implementation & migration extension (The Open Group 2012).

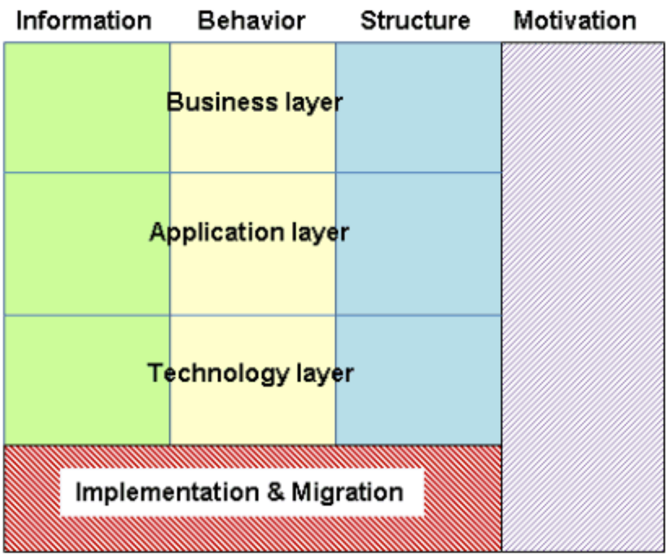

Figure 2.3: ArchiMate 2.0 (from (The Open Group 2012))

While being intensively elaborated to be as complete as possible, the previous approaches are becoming more difficult to implement. Extensive training and certification are needed to be able to start using these approaches.

The resource-event-agent (REA) ontology (McCarthy 1982) (Figure 2.4) was developed as a basis for accounting information systems and has been extended to form a basis for enterprise information systems architectures. The core concepts in this ontology are Resource, Event, and Agent. In (Andersson et al. 2009), the REA ontology has been extended with goal modeling.

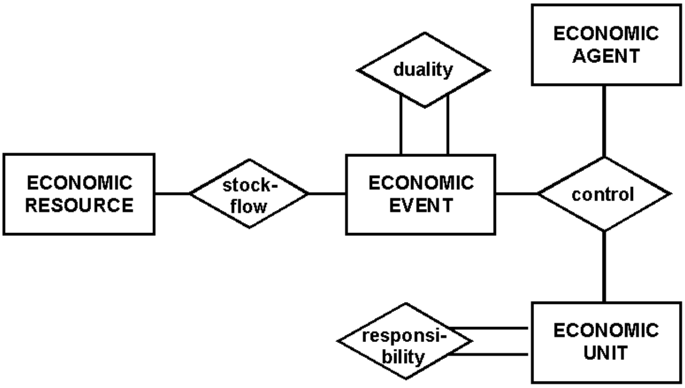

Figure 2.4: REA (from (McCarthy 1999))

In his keynote on the Confenis 2011 conference, zur Muehlen (2011) talked about his vision on semantic EA. He introduced CARP (capability, activity, resource, and performer) (Figure 2.5) as a domain ontology for EA, based on the dimensions of DoDAF (DoD 2010).

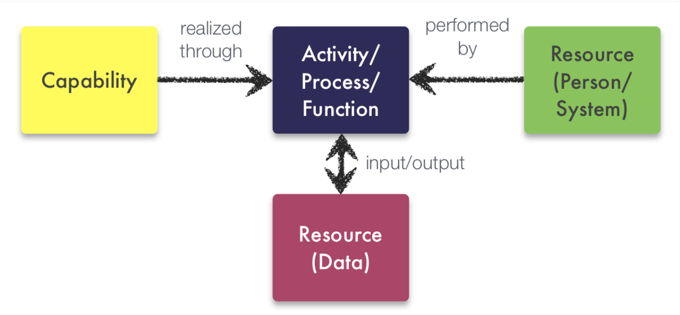

Figure 2.5: CARP (from (Zur Muehlen 2011))

Capgemini's Integrated Architecture Framework (IAF) (Figure 2.6) has been developed by Capgemini since the 1990s (van 't Wout et al. 2010). This framework is the result of the experience of practicing architects on projects for clients across the group, so it has really evolved based on real-world experience. The framework includes four questions (why?, what?, how?, with what?) across the different layers of EA (business, information, information systems, and technology layer).

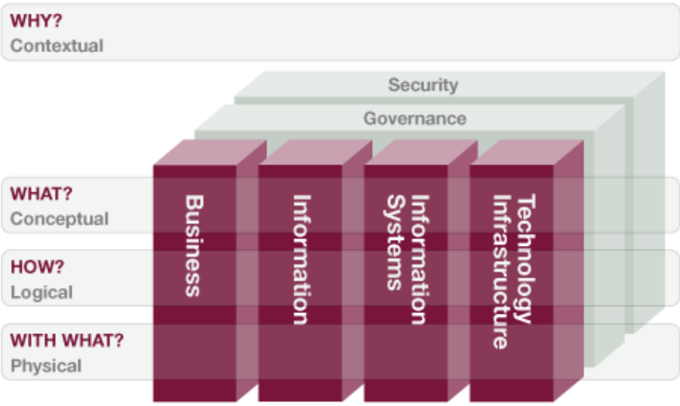

Figure 2.6: Capgemini's IAF (from (van 't Wout et al. 2010))

Enterprise modeling (Bubenko 1993) has put a lot of effort in developing the enterprise model, in which different submodels are interrelated and describe four dimensions. More recent work on the Enterprise Knowledge Development (EKD) method for enterprise modeling (Stirna and Persson 2007) defines six submodels, but agrees that its Goals Model, Business Process Model, Concepts Model, and Actors and Resources Model tend to dominate EKD usage.

2.3.3 The Key Concepts of Enterprise Architecture Techniques

Most EA techniques work with three layers of architectural models, namely a business architecture layer, an application architecture layer (includes applications and data), and a technology architecture layer. As EA is primarily developed by IT researchers, it focuses primarily on IT and its alignment with the business (business-IT alignment (Henderson and Venkatraman 1993)) (Figure 2.7). However, nowadays, the business architecture part gets more and more attention, because it is the basis where everything starts (Lankhorst 2013; Ross et al. 2006).

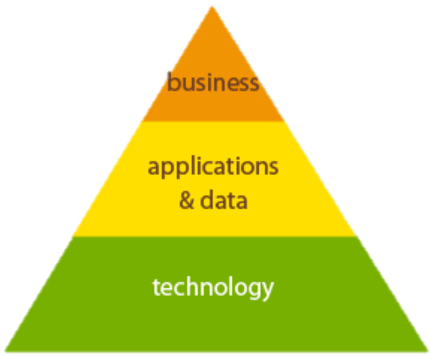

Figure 2.7: The three layers of a traditional enterprise architecture technique

In the business architecture layer we can distinguish four dimensions that are shared by all EA techniques. Either Zachman, ArchiMate 2.0, REA with goal modeling, CARP, Capgemini's IAF, enterprise modeling, and EKD include a strategic dimension, an active actor, an operation, and an object (input or output) (Figure 2.8).

	WHY	WHO	HOW	WHAT
Zachman	Why	Who	How	What
ArchiMate 2.0	Motivation	Structure	Behavior	Information
REA	Goals	Agent	Event	Resource
CARP (DoDAF)	Capability	Performer	Activity	Resource
IAF	Goal	Actor	Activity	Object
Enterprise modeling / EKD	Goals model	Actors and recources model	Business process model	Concepts model

Figure 2.8: The four dimensions of a traditional enterprise architecture technique

These four dimensions (why, who, how, what) can be used as a basis of an approach for EA in SMEs. Zachman's Framework also includes two additional dimensions: when and where. These dimensions can be seen as attributes of an operation (how).

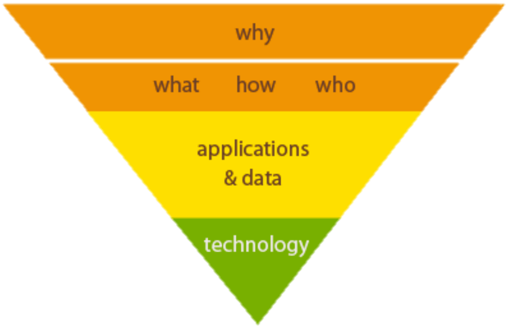

Figure 2.9: Enterprise architecture with more focus on the four core dimensions of the business architecture

Figure 2.9 is an inverted pyramid, unlike Figure 2.7, to emphasize that nowadays, it is assumed that the business architecture is the foundation of a good EA, and an EA technique has to start with a strategic question (why). Strategy is the most important part (Porter 1985), especially because different stakeholders have different goals. Most techniques for EA first made abstraction of this part, while this is the most important step. ArchiMate for instance now also incorporates this dimension in its new 2.0 standard (The Open Group 2012).

2.3.4 Five Criteria for EA Techniques

From Lankhorst's definition and description of EA ((Lankhorst 2013), p. 3), five criteria for an EA approach are derived:

1) Control: "EA is a key instrument in controlling the complexity of the enterprise and its processes and systems."
2) Holistic Overview: "The most important characteristic of an EA is that it provides a holistic overview of the enterprise.", "EA has to capture the essentials of the enterprise, because they are more stable than the specific solutions found for the problems currently at hand."
3) Objectives: "EA facilitates the translation from corporate strategy to daily operations."
4) Suitable for its target audience (here: SMEs): "It is necessary to use an approach that is understood by all those involved from these different domains."
5) Enterprise: "This enables optimization of the company as a whole instead of doing local optimization within individual domains."

Currently there are few EA approaches specifically adapted to be used in an SME context, which does not conform to criterion four. In the previous part on SMEs, it has however been shown that SMEs have some specific characteristics.

2.3.5 Benefits of Enterprise and Business Architecture

EA provides several benefits to companies, including the following: (Lankhorst 2013; Ross et al. 2006)

- Creating a common architecture means that the architect takes into account the needs of all stakeholders of the company, allowing the architecture to become an acceptable design for these stakeholders.
- The architecture provides an overview of the main areas of the company and it is possible to see only a part of this overview, without irrelevant details, using different viewpoints. For example, a marketeer can ask to just see the products of the company, its customers (groups), and the value proposition.
- The viewpoints can be used as documentation of the building blocks of the company. Changes in the company can for example first be tested on the EA model of the company, before implementing them in reality.
- The representation of and relationships between the elements of the EA can be used for analysis and optimization purposes. It is for example possible for a bank to calculate the network capacity required to process all transactions timely and accurately, based on the number of daily transactions.
- The representation of and relationships between the elements can also enable change impact analysis. If, for example, it is decided to fully automate the payment process through formatted numbers on invoices, it could be examined to what extent these changes affect the other elements of the EA. For example, an application will have to be developed or purchased to be able to identify these formatted numbers and be able to link the payment automatically to the correct invoice. This analysis will make it also possible to draw up a good budget.
- The survey of van Everdingen et al. (2000) revealed that for ERP adoption, the most important criterion used by European SMEs in selecting an information system (ERP adoption) is the best fit with current business procedures. By developing a business architecture, a clear overview of the business can help selecting the most appropriate ERP system for the company.

Besides these general advantages, EA could help reducing the previously mentioned problems from SMEs. First of all, EA makes it possible to clearly define a competitive strategy (Porter 1985) as part of the business architecture and to align the company with this strategy to achieve a competitive advantage. Second, a clearly defined EA model could make it easier to find an ERP system that best fits the current business. Third, an explicit business architecture model can show the links between operations and strategy and enables an entrepreneur to communicate with the employees. Fourth, a job description can be queried from the relationships of employees with operations. Fifth, by explicitly linking strategic and operational items, it becomes easier to achieve and maintain alignment of the processes with the strategy. Sixth, these links make it possible to perform change impact analysis. Seventh, linking goals in a goal tree and including goals from different stakeholders makes it possible to develop a global goal tree and see which goals are conflicting. These conflicts can be resolved by balancing the different desires and goals (Heyse et al. 2012). Eighth, relevant knowledge of the company and the entrepreneurial knowledge can be made explicit in the EA model by modeling these concepts in the business layer, making it easier for employees and successors to gain insight in this knowledge.

EA could help to reduce the previously mentioned problems from SMEs, however, EA is generally an unknown and unused concept in SMEs. In literature, articles about EA for SMEs are very scarce. In fact, in a literature study of Devos ((2011), p. 41-87) of A1 papers found from 1979 to 2008 about SMEs and IT, no single paper discussed EA for SMEs. Furthermore, an exploratory case study research in 27 SMEs in Belgium (De Nil et al. 2012) delivered interesting insight in which factors determine whether an SME documents its processes, its strategy, and whether there is a link between both. While some companies have a link between their processes and strategy, none of them uses an EA or business architecture method.

2.4 Enterprise Architecture for SMEs

In the next part, we will discuss the most important adoption models for IS and IS methods. These models will help us to propose guidelines for EA technique developers in order to be able to develop EA techniques that are easier adapted by SMEs. User acceptance of information systems has become an important issue in the IS field (Hu et al. 1999; Brancheau et al. 1996; Gaynor 1996; Hartwick and Barki 1994; Markus and Keil 1994; Alavi and Carlson 1992; Keen 1991; Cooper and Zmud 1990; Davis et al. 1989). Regardless of the technical superiority or potential benefits of a particular information system, if it is not used or is under-utilized, the benefits cannot be realized (Chau 1996).

2.4.1 Adoption Models

2.4.1.1 Technology Acceptance Model

Of all the models that have been proposed for user technology acceptance, the Technology Acceptance Model (TAM) has been the most influential (Altaf and Schuff 2010; Lederer et al. 2000; Hu et al. 1999; Igbaria et al. 1997; Chau 1996; Szajna 1996; Venkatesh and Davis 1996; Taylor and Todd 1995; Subramanian 1994; Szajna 1994; Hendrickson et al. 1993; Adams et al. 1992; Mathieson 1991; Davis 1989; Davis et al. 1989).

Davis (1989) introduced the TAM, a well-known and widely referred model regarding the adoption of technology. He developed and validated a measurement scale for predicting user acceptance of technology, based on two variables, perceived usefulness and perceived ease of use, which are hypothesized to be fundamental determinants of user acceptance.

People tend to use or not use an application to the extent they believe it will help them to perform their job better. This first variable is called perceived usefulness. However, even if potential users believe that a given application is useful, they may, at the same time, believe that the system is too hard to use and that the performance benefits of usage are outweighed by the effort of using the application. This second variable is called perceived ease of use. Both variables have an impact on the intention to use (Figure 2.10).

Perceived usefulness is “the degree to which a person believes that using a particular system would enhance his or her job performance”. Perceived ease of use, in contrast, refers to "the degree to which a person believes that using a particular system would be free of effort”. The intention to use is “the extent to which a person intends to use a particular system”.

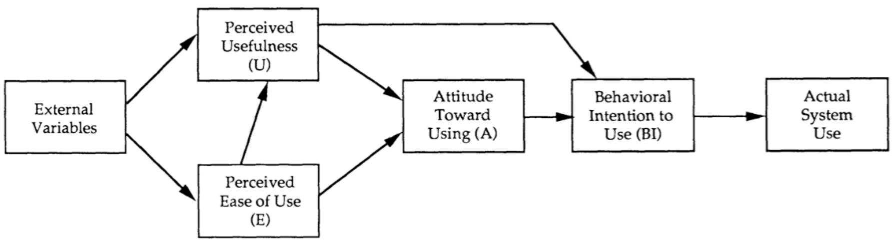

Figure 2.10: Technology Acceptance Model (from (Davis et al. 1989))

Davis (1989) refined the measures and streamlined them, which resulted in two six-item scales for perceived usefulness and perceived ease of use.

Perceived usefulness:

1) Work more quickly
2) Improve job performance
3) Increase productivity
4) Enhance effectiveness
5) Make job easier
6) It is useful

For perceived usefulness, notice that the items fall into three main clusters. The first cluster relates to job effectiveness (2,4), the second to productivity and time savings (1,3), and the third to the importance of the system to one's job (5,6).

Perceived ease of use:

1) Easy to learn
2) Controllable (get it to do what I want it to do)
3) Clear and understandable
4) Flexible to interact with
5) Easy to become skillful
6) Easy to use

These items also fall into three main clusters. The first relates to physical effort (2,4), while the second relates to mental effort (3,6). The third cluster is somewhat more difficult to interpret but appears to be tapping perceptions of how easy a system is to learn (1,5).

In both studies performed by Davis, perceived usefulness was significantly more strongly linked to usage than was perceived ease of use. Users are driven to adopt an application primarily because of the functions it performs for them, and secondarily for how easy or hard it is to get the system to perform those functions. For instance, users are often willing to cope with some difficulty of use in a system that provides critically needed functionality. Although difficulty of use can discourage adoption of an otherwise useful system, no amount of ease of use can compensate for a system that does not perform a useful function. Ease of use may in this way be an antecedent to usefulness, rather than a parallel, direct determinant of usage (Figure 2.10). All else being equal, the easier a system is to interact with, the less effort needed to operate it, and the more effort one can allocate to other activities (Radner and Rothschild 1975), contributing to overall job performance and perceived usefulness.

It should be emphasized that perceived usefulness and perceived ease of use are people's subjective appraisal of performance and effort, respectively, and do not necessarily reflect objective reality.

Practitioners generally evaluate systems not only to predict acceptability but also to diagnose the reasons underlying lack of acceptance and to formulate interventions to improve user acceptance. In this sense, research on how usefulness and ease of use of EA techniques can be influenced by various controllable factors (e.g., design, user interface, functional characteristics, training and education, case study testing and user involvement in design, ...) is important.

2.4.1.2 Method Evaluation Model

Moody (2003) noticed that IS design research emphasized the development of new methods, while the evaluation of methods was only addressed in a limited fashion (Westrup 1993; Fitzgerald 1991; Bubenko 1986; Curtis 1986). Wynekoop and Russo (1997) conducted a review of IS design research published in the leading IS journals and concluded that there was a "lack of serious empirical research into the efficacy of methods in practice" and a "need for validation of methods in organizational contexts using real practitioners". *Regardless of the potential benefits of IS design methods published, unless they are used in practice, these benefits cannot be realized.* The issue of practitioner acceptance of methods is something which has been largely ignored in IS design research and could help improving the acceptance of EA techniques in SMEs. However, usage is an important pragmatic measure of the "success" of a method and also of the impact of research on practice (Fitzgerald 1991).

Moody (2003) proposed a theoretical model and associated measurement instrument for evaluating IS design methods, like EA methods.

The method is based on the previously mentioned TAM (Davis 1989) and Methodological Pragmatism (Rescher 1977).

2.4.1.3 Methodological Pragmatism

Methodological Pragmatism (Rescher 1977) assumes that methods have no truth value, only pragmatic value. A method does not describe any external reality, so it cannot be true or false, only effective or ineffective. Unlike theses, methods cannot be established deductively from known facts or inductively from observations. *The validity of a method can only be established by applicative success in practice.* The objective of validation should not be to demonstrate that the method is "correct", but that it is rational practice to adopt the method based on its pragmatic success. Pragmatic success is defined as "the efficiency and effectiveness with which a method achieves its objectives". All methods are designed to improve performance of a task (Figure 2.11). Task performance can be improved in two ways:

- Efficiency improvement: reducing the effort required to complete the task, i.e. reducing the inputs.
- Effectiveness improvement: improving the quality of the result, i.e. improving the outputs.

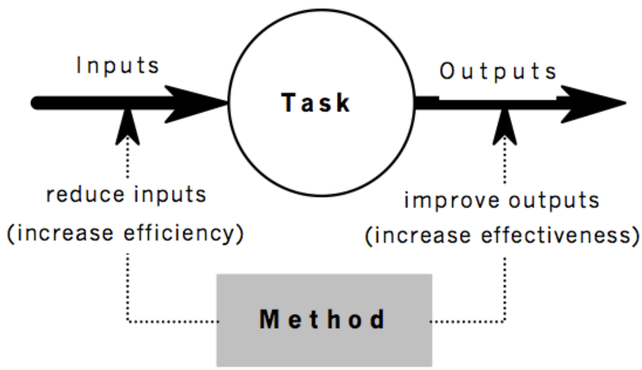

Figure 2.11: Efficiency vs. Effectiveness (from (Moody 2003))

2.4.1.4 Combining Methodological Pragmatism and TAM

Moody (2003) argued that there are clear parallels between user acceptance of information systems and practitioner adoption of methods. Both are subject to individual choice: users make decisions about what systems they will use and practitioners make decisions about what methods they will use. Both are therefore the result of reasoned action. For this reason, Moody argued that theoretical models used to explain and predict user acceptance of information technology may be adapted to explain and predict the adoption of methods.

Actual efficacy and adoption in practice are two dimensions of success. On their own, neither actual efficacy nor adoption in practice will lead to improved practices. A method that improves performance but that is not used will have no effect on practices. Similarly, a method that people use but which reduces performance of the task will have a negative effect on practices. Nowadays, as already mentioned, EA is hardly used in SMEs, although it could improve performance.

Both TAM and Methodological Pragmatism are combined in the Method Evaluation Model, a theoretical model for evaluating methods. Figure 2.12 shows the primary constructs of the model and causal relationships.

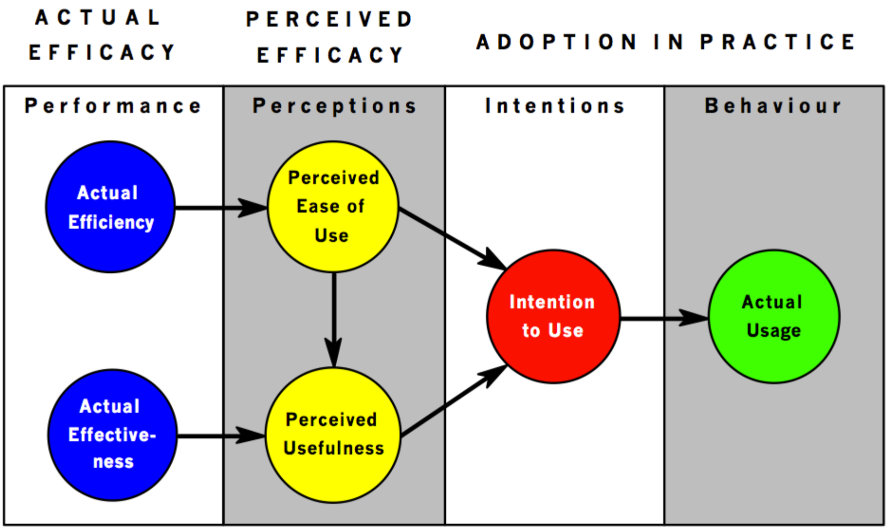

Figure 2.12: The Method Evaluation Model (from (Moody 2003))

The definitions of the constructs of the model are:

- Actual efficiency: the effort required to apply a method.
- Actual effectiveness: the degree to which a method achieves its objectives.
- Perceived ease of use: the degree to which a person *believes* that using a particular method would be free of effort.
- Perceived usefulness: the degree to which a person *believes* that a particular method will be effective in achieving its intended objectives.
- Intention to use: the extent to which a person intends to use a particular method.
- Actual usage: the extent to which a method is used in practice.

Actual efficiency and actual effectiveness are constructs from Methodological Pragmatism. Perceived ease of use, perceived usefulness and intention to use are the constructs of TAM.

The causal relationships between the constructs of the model are:

- Perceived ease of use is determined by actual efficiency: actual efficiency measures the effort required to apply the method, which should determine perceptions of effort required.

- Perceived usefulness is determined by actual effectiveness: actual effectiveness measures how well the method achieves its objectives, which should determine perceptions of its effectiveness.
- Perceived usefulness is determined by its perceived ease of use. This follows from TAM.
- Intention to use a method is jointly determined by its perceived ease of use and perceived usefulness. This follows from TAM.
- Actual usage of a method is determined by intention to use. This also follows from TAM and the Theory of Planned Behavior (Ajzen 1991), which establishes that perceptions influence intentions which in turn influence the actual behavior of the individual.

The main difference with TAM is that in the Method Evaluation Model actual efficiency and effectiveness determine intentions to use a method only via perceptions of ease of use and usefulness. This is a subtle difference, but an important one: in human behavior, subjective reality is more important than objective reality. The perceptions will also be influenced by other factors (e.g., prior knowledge, experience with particular methods, normative influences).

Moody also concluded that the relative importance of perceived ease of use in making decisions about method adoption is much higher for practitioners than it is for undergraduate students. This asks for EA techniques that are easily applicable by practitioners in SMEs. As well as trying to develop EA techniques that produce better results, it is equally important to develop EA techniques that people are willing to use. Regardless of the technical or theoretical superiority of a particular EA technique, it cannot result in improved practices unless people use it.

2.4.1.5 Adoption Models of IT in SMEs

Many studies have attempted to describe the factors influencing IT adoption in SMEs (Altaf and Schuff 2010; Chwelos et al. 2001; Kuan and Chau 2001; Igbaria et al. 1997; Iacovou et al. 1995). In order to develop an integrated model of IS adoption in SMEs, Thong (1999) specified four contextual variables as primary determinants of IS adoption. He grouped the many variables in four groups: CEO, IS, organizational characteristics, and environmental characteristics. Grandon and Pearson (2004) proposed a model for e-commerce adoption in SMEs based on a fusion of the strategic value of certain information technologies to top managers (Subramanian and Nosek 2001; Chan 2000; Barua et al. 1995) and factors that influence the adoption of IT (TAM (Davis 1989)). The results confirmed TAM in the sense that perceived usefulness and perceived ease of use turned out to be the most influential factors of e-commerce adoption as perceived by top managers of SMEs.

Although these models discuss the adoption of information technology and not methods in SMEs, they confirm the factors of TAM as being the most influential for adoption in SMEs. The Method Evaluation Model of Moody (2003), although not specifically developed for evaluation of methods in SMEs, is based on the factors of TAM and will be further used as an evaluation model for EA methods in SMEs.

2.4.2 Bringing EA to SMEs

From the TAM (Davis 1989) and the Method Evaluation Model (Moody 2003), three actions can be defined in order to enhance the adoption of EA techniques in SMEs.

First, the perceived usefulness has to be increased. Second, the perceived ease of use has to be increased. Third, the actual efficacy has to influence the perceived efficacy.

2.4.2.1 Increase the Perceived Usefulness

Usefulness can be related to the advantages of EA techniques for SMEs. However, perceived usefulness is influenced by actual effectiveness. To increase the actual effectiveness of EA techniques for SMEs, the techniques have to be implemented in practice (e.g., case studies, testing companies, ...) and feedback from the SMEs has to help developing EA techniques that bring more advantages for SMEs. The six-item scale of TAM can be used to assess the perceived usefulness.

2.4.2.2 Increase the Perceived Ease of Use

Ease of use is related to the effort that has to be spent to implement an EA technique. Complexity, defined by Rogers and Shoemaker ((1971), p. 154) as "the degree to which an innovation is perceived as relatively difficult to understand and use", parallels perceived ease of use quite closely. As SMEs have rather limited free time to work on strategic issues, limited IT knowledge, and limited resources to spend (see the previously mentioned characteristics of SMEs), a special effort has to be made to adapt EA techniques to an SME context. As Lankhorst (2013) mentioned, it is necessary to use an approach that is understood by all those involved from the different domains (see the fourth criterion for EA techniques). Perceived ease of use is influenced by the actual efficiency, so these techniques have to be implemented and tested in practice. The six-item scale of TAM can be used to assess the perceived ease of use.

2.4.2.3 From Actual to Perceived Efficacy

To get a positive influence of the actual on the perceived efficacy, EA techniques have to be implemented in SMEs. The advantage is twofold. First, feedback can be used to adapt the EA techniques and enhance the perceived ease of use and usefulness. Second, by implementing EA techniques in practice, EA can get better known in SMEs and especially the advantages can get widespread. Positive testimonials and word of mouth can generate a higher perceived efficacy.

2.5 Recommendations for EA Technique Developers

2.5.1 Research Steps

Figure 2.13 summarizes different research steps that can be taken to develop EA techniques that have a higher likelihood of acceptance in SMEs.

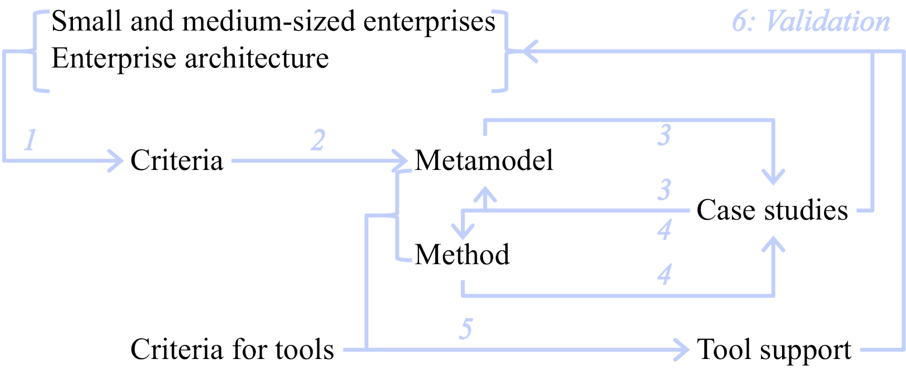

Figure 2.13: Research steps

First, both SMEs and EA have to be analyzed and relevant characteristics should be examined. From these characteristics, criteria could be extracted. This step is already done for SMEs (see the criteria for SMEs) and EA (see the criteria for EA techniques). The criteria should enable a good fit of EA with SMEs, which enhances both the actual efficiency and effectiveness.

Second, an initial metamodel can be developed, based on these criteria.

Third, during case studies in SMEs, the initial metamodel can be refined.

Fourth, the case studies will also help to develop and refine a method including step-by-step guidelines to develop an EA model of the SME. The criteria are not directly linked with the method, because it is developed from scratch during the case studies. As Moody (2003) and Rescher (1977) emphasized, the validity of a method can only be established by applicative success in practice.

Fifth, software tool support has to be developed. Tool support can help automating certain tasks, but cannot help if we do not understand the development process (Lindland et al. 1994). Tool support can have several advantages. It can facilitate the input (actual efficiency) and enhance the output (actual effectiveness). However, tool support can have disadvantages as well, especially with respect to the actual efficiency (e.g., it can be costly, there is a learning curve, users need to be able to work on a computer, ...). Perceived ease of use refers to user friendliness of the system, the ease in learning the system, and the help features provided by the system. Therefore, we can infer that a user-friendly business architecture method and tool is more likely to be adopted by small businesses. This user-friendliness could be operationalized as context-sensitive help or an intuitive user interface. We argue that tool support, if properly developed, can have substantial benefits for EA techniques. The metamodel and method, in combination with criteria for developing effective and efficient tool support, can be used to develop this tool support.

Sixth, this tool support enables both the validation in the case studies, as the validation by SMEs themselves that can use the tools. This validation step is crucial in getting from actual to perceived efficacy.

2.5.2 Design Science

Design science (Hevner et al. 2004) is a well-known methodology to develop an artifact (construct, model, method, or instantiation). The different steps of design science can be applied to the research steps for the development of EA techniques for SMEs (Figure 2.14). The development and refinement of the metamodel and method are part of the build step. The validation by the case studies is part of the evaluate step, while the tool support enables the evaluate step. The goal of design science is not the truth, but utility. Utility is found in the search for a higher perceived ease of use and usefulness of EA in SMEs. The link to existing EA approaches has to enhance the rigor of the research, while the link to and case studies in SMEs enhances the relevance of the research.

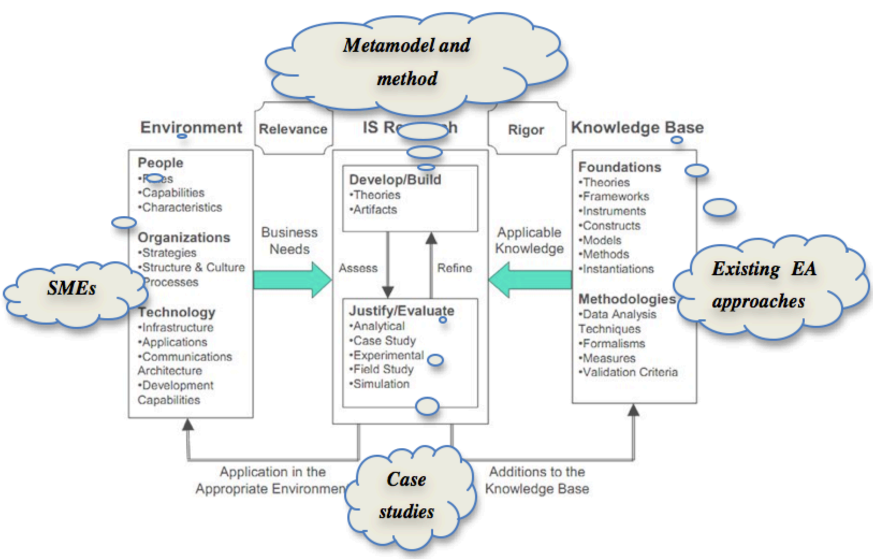

Figure 2.14: Information Systems Research Framework (from (Hevner et al. 2004))

The seven guidelines presented in (Hevner et al. 2004) can be applied to the research steps. A metamodel and method are created (guideline 1: creation of an artifact) for SMEs (guideline 2: for a specified problem domain). The approach is evaluated in case studies (guideline 3: thorough evaluation of the artifact). No specific EA approach for SMEs exists (guideline 4: innovative, novelty). The metamodel and method have to be formalized (guideline 5: the artifact must be rigorously defined, formally represented, coherent, and internally consistent). The case studies are used to refine the metamodel and develop and refine the method (guideline 6: search process). Finally, articles have to be written about the approach, both in academic journals as in journals for practitioners. Even more important, the approach has to be implemented and tested in practice (guideline 7: communication both to a technical and managerial audience).

2.5.3 A Starting Point for EA for SMEs

Bharati and Chaudhury (2006) noticed that simpler technologies and software packages have a much wider application in SMEs than more complex ones. It could be a good idea to make an initial approach according to Einstein's principle: "Everything should be made as simple as possible, but not simpler". In order to keep the approach as simple as possible, while mitigating the risk of making it too simple and loosing advantages of EA, every part of the metamodel later on has to be carefully discussed with experts (e.g., SME experts, practitioners, and academics) and tested in case studies to get a balanced result. A good starting point could be to make an EA approach, based on the core elements of existing EA techniques (see the key concepts of enterprise architecture techniques), to make the approach as simple as possible, but not simpler (Figure 2.9). A strategic dimension (why), an active actor dimension (who), an operation dimension (how), and an object dimension (what) can form the highest and most important layer, the business architecture layer, of the EA model. To get a holistic overview, these four dimensions should be interrelated. An example of this proposed business architecture layer (Bernaert and Poels 2011b) is given in Figure 2.15.

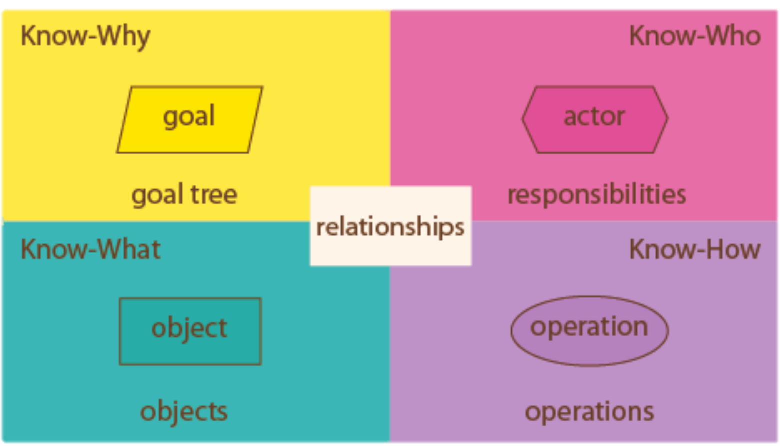

Figure 2.15: An example of a starting point for the business architecture layer (from (Bernaert and Poels 2011a))

This business architecture layer has to be supported by an application layer, which has to be supported by a technology layer.

The initial metamodel should be developed according to the criteria of both SMEs and EA techniques (see the previously mentioned criteria), and more important, it should be tested extensively in real SMEs. Regardless of the potential benefits of EA approaches published, unless they are used in practice, these benefits cannot be realized.

3

CHOOSE: Towards a Metamodel for Enterprise Architecture in Small and Medium-Sized Enterprises

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Abstract. Enterprise architecture (EA) is a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and IT infrastructure. Recent research indicates the need for EA in small and medium-sized enterprises (SMEs), important drivers of the economy, as they struggle with problems related to a lack of structure and overview of their business. However, existing EA frameworks are perceived as too complex and, to date, none of the EA approaches are sufficiently adapted to the SME context. Therefore, this chapter presents the CHOOSE metamodel for EA in SMEs that was developed and evaluated through action research in an SME and further refined and validated through case study research in five other SMEs. This metamodel is based on the essential dimensions of EA frameworks and is kept simple so that it may be applied in an SME context. The final CHOOSE metamodel includes only four essential concepts (i.e. goal, actor, operation, object), one for each most frequently used EA focus. As an example, an extract is included from the specific model that was created for the SME used in our action research. Finally, the CHOOSE metamodel is evaluated according to the dimensions essential in EA and the requirements for EA in an SME context.

Keywords: *Enterprise architecture; Small and medium-sized enterprises; CHOOSE; Metamodel*

3.1 Introduction

According to IEEE Computer Society (2000), architecture is "the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution". Architecture could thus be defined as "structure with a vision", providing an integrated view of the system designed or studied. At the level of an entire organization, it is commonly referred to as enterprise architecture (EA). This refers to a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and IT infrastructure (Lankhorst 2013). Rather than specific solutions for specific problems, EA is assumed to capture the essence of the business, IT, and its evolution, as this essence is much more stable. In this respect, EA considers an enterprise as a system in which competencies, capabilities, knowledge, and assets are purposefully combined to achieve stakeholder goals. The tangible outcome of this line of reasoning is a blueprint or holistic overview of the enterprise in the form of an integrated collection of models. Hence, architecture can help maintain the essence of the business, while still allowing for optimal flexibility and adaptability (Jonkers et al. 2006).

EA approaches are often experienced as complex, over-engineered, and difficult to implement. Because of the technical detail required for full-scale implementation, EA models tend to become very large, making them more difficult to understand and less effective to reflect on or design enterprises and their supporting systems (Balabko and Wegmann 2006). Due to their resource poverty, SMEs experience even more difficulties than larger enterprises in employing EA experts or hiring external consultants (Kroon et al. 2012). Yet, as some studies have confirmed, they may encounter several problems if they fail to implement EA (Bidan et al. 2012; Bhagwat and Sharma 2007).

Bernaert et al. (2014) did an extensive problem analysis of EA and SMEs and proposed the concept of EA as a good solution to be used for SMEs to solve problems related to a lack of structure and overview. However, EA is still unknown and hardly used in SMEs. A recent exploratory field study by De Nil et al. (2012) examined 27 SMEs and observed that nearly all of them were missing a clear overview of their business organization and none of them actually were using EA (Bernaert et al. 2014). The authors concluded that there is a pressing need to develop an EA approach specifically adapted to the SME context, consisting of a metamodel, a method, and software tool support.

The goal of the current research is to develop such an EA approach for SMEs, called CHOOSE. As some research has already focused on how to bring EA to SMEs in general (Bernaert et al. 2014; Bidan et al. 2012; Wißotzki and Sonnenberger 2012; Aarabi et al. 2011; Bernaert and Poels

2011b; Jacobs et al. 2011), the value of the current research lies in the fact that, to our knowledge, CHOOSE is the first effort to actually develop an EA approach specifically adapted to the SME context. The present chapter will elaborate on the design of the CHOOSE metamodel. The development of the other CHOOSE artifacts is on-going research, consisting of a method to guide the development of CHOOSE models through the instantiation of the metamodel and a suite of software tools to support this instantiation process.

The development of the metamodel was guided by the requirements for EA in an SME context proposed by Bernaert et al. (2014) and involves a constant trade-off between comprehensiveness and simplicity. Intended for EA, the metamodel needs to provide a holistic overview and thus incorporate the essential dimensions of existing EA approaches. At the same time, though, the metamodel is also intended for SMEs, so it is kept as simple as possible, without being too simple. In order to find the right balance, a set of EA frameworks used in business and academia was analyzed to capture the essential dimensions of EA approaches.

After the essential dimensions of EA approaches had been defined, a suitable starting point for designing the CHOOSE metamodel needed to be found. From different investigated metamodels, the metamodel of the KAOS requirements engineering methodology (Van Lamsweerde 2009) was found to be the most suitable as it is rather elaborate and provided a good match with the essential dimensions that had been determined.

Next, during multiple rounds of action research (Järvinen 2007) in one specific SME that complied with the characteristics of SMEs as proposed by Bernaert et al. (2014), the KAOS metamodel was adapted and transformed into the CHOOSE metamodel. Some of the changes to the developing metamodel were, however, triggered by parallel case study research in five other SMEs, which was initiated to design the CHOOSE method (Bernaert et al. 2015a). Any changes that the action research participants considered useful were also incorporated into the final CHOOSE metamodel.

This final metamodel comprises four viewpoints: (1) a goal viewpoint for the motivational part (i.e. why), (2) an actor viewpoint for the active performers (i.e. who), (3) an operation viewpoint for the behavioral part (i.e. how), and (4) an object viewpoint for the description of the concepts and relationships (i.e. what). In this way, the core part of the CHOOSE metamodel only consists of the bare minimum of concepts (only one main concept per viewpoint) in order to maintain the balance between both comprehensiveness for EA and simplicity for SMEs. Since in the original KAOS metamodel all the viewpoints are tightly integrated, in the resulting CHOOSE metamodel also a high traceability within and between the four viewpoints was achieved.

The CHOOSE metamodel is written in UML (Unified Modeling Language). Its elements are defined using SBVR (Semantics of Business Vocabulary and Rules) and intra- and inter-view constraints are specified as OCL (Object Constraint Language) constraints. These SBVR definitions are based on definitions of well-known modeling languages and thus contribute to the unambiguous definition of the metamodel concepts. The OCL constraints, in their turn, help ensure the completeness and consistency of the models that instantiate the metamodel.

The instantiation of the proposed metamodel is demonstrated by means of the EA model that was developed during the action research programme in the SME. This also provided the basis for the evaluation of the metamodel, a process that was guided by the EA essential dimensions and the requirements for EA in SMEs.

Section 3.2 of this chapter elaborates on the research problem, the intended contribution of this research, and the requirements for EA in an SME context. In section 3.3, the solution approach, the scope of the research presented in this chapter, and the research methodology are presented. The results are shown from section 3.4 onwards: the definition of essential EA dimensions based on an analysis of EA frameworks (section 3.4); the choice of KAOS as a starting point for the metamodel design (section 3.5); the adaption of the initial metamodel and the development of the CHOOSE metamodel during the action research and case studies (section 3.6); the formal definition of the resulting CHOOSE metamodel (section 3.7); and, finally, its evaluation (section 3.8). The final section, section 3.9, presents conclusions and outlines the current and future research required to complete the development of CHOOSE.

3.2 Problem Description and Solution Requirements

This section describes the research problem and the requirements for its solution, based on a review of related and previous research.

3.2.1 Problem Description

A good EA gives a static overview of the enterprise and offers a means for supporting change. A good architectural practice helps a company innovate and change, by providing both stability and flexibility (Jonkers et al. 2006). Jonkers et al. (2006) further mention that it is important to realize that most stakeholders of a system are probably not interested in its architecture, but only in the impact of this architecture on their concerns. In addition, although they often have radically different backgrounds, an architect should be able to explain the architecture to all of the stakeholders just as clearly. This highlights one of the most important roles of EA: it serves as an instrument in the communication among diverse groups and interests and produces a common ground for discussion and decision-making.

EA has become one of the top priorities of IT executives and is considered an important instrument for aligning the required changes in corporate strategy and business processes with an increasingly complex IT landscape (Luftman and Ben-Zvi 2011). Some of the most recognized benefits of EA are that IT can be used more efficiently and flexibly, business and IT can be better aligned (Radeke 2011; Tamm et al. 2011; Daneva and van Eck 2007; Lindström et al. 2006), and a better fit between business operations and strategy can be achieved (Hoogervorst 2004; Veasey 2001). Braun and Winter (2005) underscore that in order for business-IT and strategy to be aligned, EA must be adaptable and constantly held up-to-date.

SMEs constitute over 90 % of operating businesses in many countries, in the U.S. even 99.7 % (Small Business Administration 2011) and in Europe 99.8 % (European Commission 2011). There is therefore a great need for more rigorous research that is relevant for this important sector of the economy (Devos 2011).

Right now, existing EA frameworks are primarily used in large enterprises (Gartner 2012). Wißotzki and Sonnenberger (2012), among others, recognize the importance of EA and EA management (EAM) in particular, but also notice that EAM is still mostly unexplored and rarely used, especially in the context of SMEs (see also (Bernaert et al. 2014; Devos 2011). Yet, such specific research is crucial, as research findings based on large businesses cannot be generalized to small businesses due to the inherent differences between SMEs and large businesses (Aarabi et al. 2011).

Lybaert (1998) discovered that SME owners or managers with a greater strategic awareness use more information and that SMEs that use more information are generally more successful. Hannon and Atherton (1998) further revealed that for SMEs success is correlated with higher levels of strategic awareness and better planning of owners-managers. In addition, there is evidence to believe that companies that make strategic rather than just financial business plans perform significantly better financially than those that do not (O'Regan and Ghobadian 2004; Smith 1998). Jacobs et al. (2011) argue that from the perspective of change and complexity, EA could assist SME management during the growth of a small enterprise. For example, according to Aarabi et al. (2011), ERP (Enterprise Resource Planning) systems cannot be successfully implemented and utilized in SMEs if EA is disregarded. In fact, it is EA’s integration of strategic goals, business processes, and technology planning methods that provides the standards, roadmap, and context for ERP implementation (Zach 2012). As Bidan et al. (2012) conclude, process standardization in SMEs is more important than the deployment of technology (e.g., ERP systems) to improve organizational performance. In short, SMEs need to get a structured view of their company, even before they start implementing an ERP solution.

Hence, while EA might offer SMEs a solution to typical problems related to a lack of overview, strategic awareness, IT planning, and business-IT alignment, EA approaches that cater for the specificities of small businesses are still missing. This lack of research on an EA approach that can readily be used for SMEs is exactly the problem that is addressed in the present research.

3.2.2 Requirements for EA for SMEs

To guide the development and evaluation of an EA approach for SMEs, requirements for an appropriate solution are needed. These requirements were specified in previous research (Bernaert et al. 2014) and will be summarized here. First, the requirements for EA in general are presented, followed by those for the adoption and successful use of IT in SMEs. To end, the combination of these two sets of requirements into a single set for EA in an SME context, as per (Bernaert et al. 2014), is also described.

3.2.2.1 Requirements for EA

The essential requirements for EA (Bernaert et al. 2014; Lankhorst 2013; Zachman 1987) are the following:

1) Control: EA should be usable as an instrument in controlling the complexity of the enterprise and its processes and systems.
2) Holistic Overview: EA should provide a holistic overview of the enterprise and be able to capture its essence: the stable elements that do not vary across specific solutions found for the problems currently at hand.
3) Objectives: EA should facilitate the translation from corporate strategy into daily operations.
4) Suitability: EA should be suitable for its target audience. It needs to be understood by all those involved, even if they come from different domains.
5) Enterprise-wide: EA should enable optimization of the company as a whole instead of doing local optimization within individual domains.

The fourth requirement refers to the target audience. In our case, the target audience is SMEs and, more specifically, their owners or managers. Therefore, requirement 4 is refined using the requirements for the adoption and successful use of IT in SMEs. This topic has been dealt with extensively in several studies, listed by Bernaert et al. (2014). The authors argue that since Moody (2003) showed that IT adoption models are also useful for evaluating the adoption of IT-related methods (e.g., information systems design methods), and that EA, with its origins in IT research (Zachman 1987), can be seen as such a method, IT adoption models for SMEs can provide useful insight into the determining factors for successfully using EA in SMEs.

3.2.2.2 Requirements for the Adoption and Successful Use of IT in SMEs

The requirements for the adoption and successful use of IT in SMEs (Bernaert et al. 2014) are as follows:

4.1) The approach should enable SMEs to work in a time-efficient manner on strategic issues.
4.2) A person with limited IT skills should be able to apply it.

4.3) It should be possible to apply the approach with little assistance of external experts.
4.4) The approach should enable making descriptions of the processes in the company.
4.5) The CEO must be involved.
4.6) The expected revenues of the approach must exceed the expected costs and risks.

By combining these requirements with the EA requirements of the previous section, Bernaert et al. (2014) obtained a set of requirements for the adoption and successful use of EA in SMEs.

According to requirement 4 and thus 4.1-4.6, the EA model should be understandable and adaptable by non-EA experts in SMEs. The previously mentioned role of EA as a communication instrument can only be established by tailoring an EA approach to the specificities of SMEs. Bernaert et al. (2014) therefore argue for a different EA approach for SMEs, based on simplicity. We are fully aware that focusing on simplicity rather than on completeness is not common in an academic context. However, also Balabko and Wegmann (2006) emphasized that current EA approaches are often experienced as complex, over-engineered, and difficult to implement.

3.3 Solution Approach and Research Methodology

In this section, we will present CHOOSE as the solution to the problem described in the previous section. We will limit the scope of the research presented in this chapter to the primary artifact of CHOOSE (i.e. its metamodel) and we will describe the research methodology that was followed to develop and evaluate this metamodel.

3.3.1 CHOOSE: Balancing Comprehensiveness and Simplicity

Our solution consists of developing a new EA approach guided by the requirements for EA in an SME context (cf. section 3.2.2). The approach was called CHOOSE, so that these requirements would always be kept in mind. CHOOSE is an acronym for "maintain Control, by means of a Holistic Overview, that is based on Objectives and kept Simple, of your Enterprise".

It is clear that the development of the CHOOSE metamodel will involve an on-going assessment of comprehensiveness and simplicity (see the methodological pragmatism (Rescher 1977)), because it should include the necessary information to get a holistic overview of the enterprise, while still being as simple as possible. As Albert Einstein once said, "A scientific theory should be as simple as possible, but no simpler".

The meaning of simplicity and complexity of a metamodel can be found in related work by Erickson and Siau (2007), in which a simplified core of the UML metamodel is proposed, based on key constructs. They argue that any increase of this core comes at the expense of increased complexity. Their work is mainly based on the work of Rossi and Brinkkemper (1996), who argued that "the relative complexity of methods and techniques based on metamodels is significant because it can be expected to affect the learnability and ease of use of a method". In other words, the number of metamodel objects, relationships, and properties to be learned adds to the complexity.

There is of course a trade-off between a metamodel's learnability and its expressive power. When organizations select metamodels, they should be aware that more powerful metamodels may be harder to learn, yet may also be more effective for experienced users. As previously mentioned, though, related research on EA in SMEs shows that SMEs hardly use EA, even hardly know about its existence, and can therefore be seen as novice users.

3.3.2 Research Process and Scope

This work extends the earlier research by Bernaert et al. (2014). Their research investigates why EA has not yet been adopted by SMEs, despite its possible benefits. In this respect, Bernaert et al. (2014) also present a research process (Figure 3.1) for developing an EA approach adapted to the SME context.

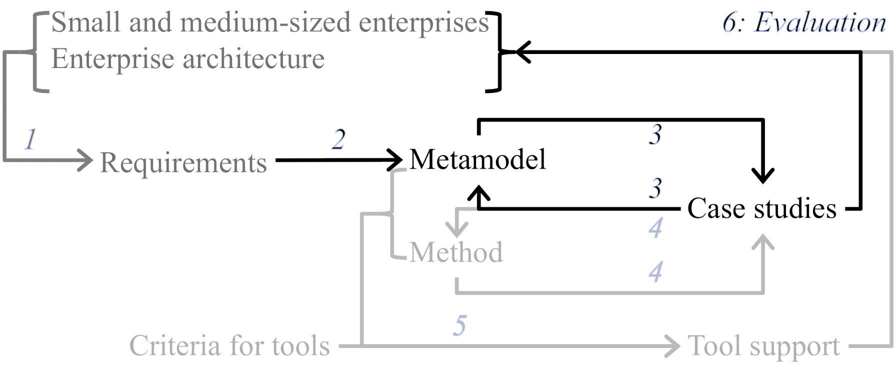

Figure 3.1: Research process for developing an EA approach for SMEs (from (Bernaert et al. 2014))

The dark grey lines in Figure 3.1 express the work that has been done by (Bernaert et al. 2014). In step 1, both the literature on EA and IT use in SMEs were analyzed and relevant characteristics were examined. From these characteristics, requirements were extracted for EA in an SME context, which have already been summarized in this chapter in section 3.2.2.

The black lines in Figure 3.1 highlight the part of the research process that is reported in this chapter. The light grey lines in Figure 3.1 refer to the (on-going) research required for developing the CHOOSE method and supporting software tools, which lies beyond the scope of this chapter.

Step 2 was desk research based on a literature study and analysis, which involved choosing a suitable starting point to design the CHOOSE metamodel. While constantly keeping in mind the balance between comprehensiveness and simplicity, we analyzed a large number of existing EA frameworks in order to extract the essential dimensions of EA frameworks. In the end, an initial metamodel (i.e. the KAOS metamodel) was selected that matched these dimensions.

Step 3 was field research conducted primarily by means of action research in an SME and complemented with case study research in five other SMEs. Through the action research programme, the metamodel was gradually further developed, with the initial metamodel as a starting point. The outcome of the action research was also used to evaluate the research results with respect to the EA essentials and the requirements for EA in an SME context (step 6).

After the start of the action research, five case studies involving the use of CHOOSE were initiated in SMEs with different characteristics (e.g., size, sector). These case studies were primarily used to develop the CHOOSE method (step 4). As the development of this method required us to implement CHOOSE, the initial version of the metamodel that was available at that time in the action research programme was also tested in these other SMEs. Hence changes to the initial metamodel were also tested in other SMEs. Conversely, the experiences in the case study companies were used as additional input to the action research. Therefore, when necessary, these other case studies are briefly referred to in section 3.6, where the development of the CHOOSE metamodel is described.

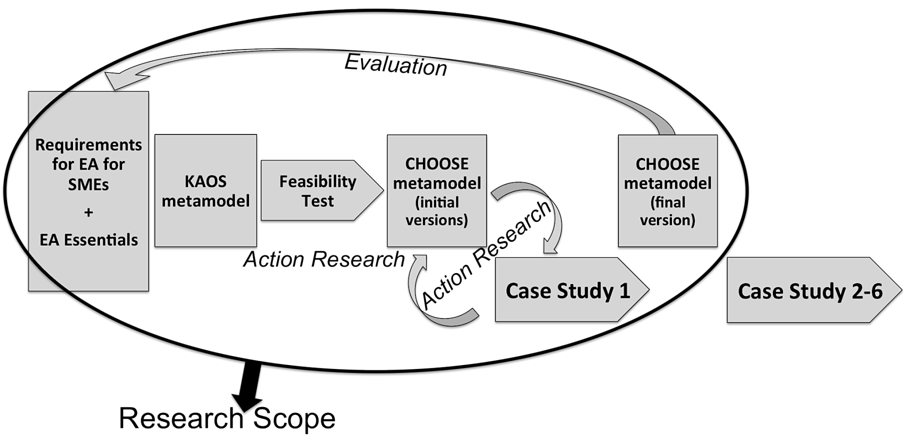

Figure 3.2: Research process for developing the CHOOSE metamodel

3.3.3 Action Research

The main research methodology employed in step 3 of Figure 3.1 was action research (Susman and Evered 1978). Action research employs the researcher as an active participant rather than a passive observer. It is a cyclical process of actively participating in an enterprise change situation while at the same time doing research. The basic steps are *planning* (i.e. problem identification), *acting* (i.e. changing and learning processes), and *evaluating* (i.e. measuring results) (French and Bell 1973). According to Järvinen (2007), action research is an instance of the design science methodology (Hevner et al. 2004) that is suitable when little theoretical background or experience is available, which is the case for the implementation of EA in SMEs.

Baskerville and Myers (2004) provide three guidelines for good action research, which we applied as follows:

1) Demonstrate a contribution or potential contribution to practice (i.e. the action): EA for SMEs could provide SMEs with solutions to problems related to a lack of structure and overview (Bernaert et al. 2014).
2) Demonstrate a clear contribution to research (i.e. the theory): This research develops the CHOOSE metamodel for EA in an SME context, an artifact that can be further refined and tested in other research.
3) Identify the criteria by which to judge the research and demonstrate how these criteria are met: The criteria for our research were presented as requirements for EA in an SME context in section 3.2.2 and are part of the evaluation in section 3.8.

The action research was performed in multiple rounds in an SME that sells car tires and performs small maintenance jobs on cars (i.e. case study 1 in Figure 3.2). It has six permanent employees and works with temporary employees during the busy winter season. This SME was chosen because it complied with the common characteristics of SMEs (Bernaert et al. 2014): management has little time to look at strategic matters, no EA experts are employed, no funds to hire external consultants are available, the extent of employees' responsibility for certain tasks is often discussed, the CEO is the central figure, and the CEO takes the decision of whether or not to adopt a new approach.

In the first action research cycle, of which the results were published in (Bernaert and Poels 2011b), the KAOS metamodel was used in its original form as a feasibility test (Figure 3.2) to see if it could be used to model the EA of an SME. It turned out that KAOS in fact did have the ability to document and analyze the EA of an SME, although it was originally developed for modeling software-intensive systems within their organizational or physical environment (Van Lamsweerde 2009). Nevertheless, the test also showed that the metamodel needed to be adjusted in order to change its scope from a system on the software level (KAOS) to a system on the enterprise level (CHOOSE). This called for more action research cycles.

Four further cycles of action research were performed (see action research cycles in Figure 3.2). In each round, the CEO of the SME was involved in completing the SME's EA model according to the CHOOSE metamodel version available at that moment. To ensure more objectivity in evaluating the results, in each round two researchers were involved to obtain investigator triangulation (Denzin 2006). Each round was voice recorded to obtain raw data and both researchers made additional notes. The voice recordings, notes, and models were stored in a case study database. As most of the data involved strategic issues, a limitation of this research is that the case study database contains confidential data and cannot be made public.

To analyze the data obtained in each action research cycle, the process presented in (Susman and Evered 1978) was followed:

- Diagnosing: The model, voice recordings and the notes of both researchers were analyzed, on the basis of which a list was established of encountered problems that called for adaptations to the metamodel.
- Action planning: For each problem, a set of possible adaptations to the metamodel was considered by the researchers, favoring adaptations that were likely to be more generally accepted by CEOs of SMEs.
- Action taking: The SME's EA model was changed according to the proposed adaptations to the metamodel.
- Evaluating: The model changes were evaluated to see if the problems were solved and if new problems would surface.
- Specifying learning: Positively evaluated adaptations were included in the next version of the CHOOSE metamodel.

As expected, after each round fewer changes had to be made and after three of the four additional rounds the metamodel had become stable. In the meantime, some other adaptations triggered by the case study research in the other five SMEs (i.e. case studies 2-6 in Figure 3.2) were tested and evaluated in the SME used in the action research. If these adaptations were positively evaluated, they too became part of the final version of the CHOOSE metamodel.

This final metamodel provided input for the development of prototype software tools (step 5 in Figure 3.1) (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013). One such tool was installed in the SME in the last round and enabled it to manage its EA model after the end of the action research programme. As such, this tool can supply longer-term feedback on the CHOOSE metamodel.

3.4 Essential Dimensions of Enterprise Architecture

In this section, existing EA frameworks are first reviewed, so that the most important ones may be pinpointed. Next, the identified frameworks are analyzed in order to determine the essential EA dimensions. These dimensions are then used in the next section to help select a suitable starting point to design the CHOOSE metamodel.

3.4.1 Enterprise Architecture Frameworks

Since the publication of the Zachman framework in 1987 (Zachman 1987), a multitude of EA frameworks have been proposed. In order to identify the essential elements of an EA metamodel in its most simple form, balancing comprehensiveness and simplicity (see section 3.3.1) and meeting the EA requirements for SMEs (see section 3.2.2), this section aims to identify the most common elements in the most important EA frameworks proposed so far. These essential dimensions of EA define the degree of freedom that can be exerted in adapting the CHOOSE metamodel during the action research cycles, as they set clear and minimal boundaries for the key elements that the metamodel should include.

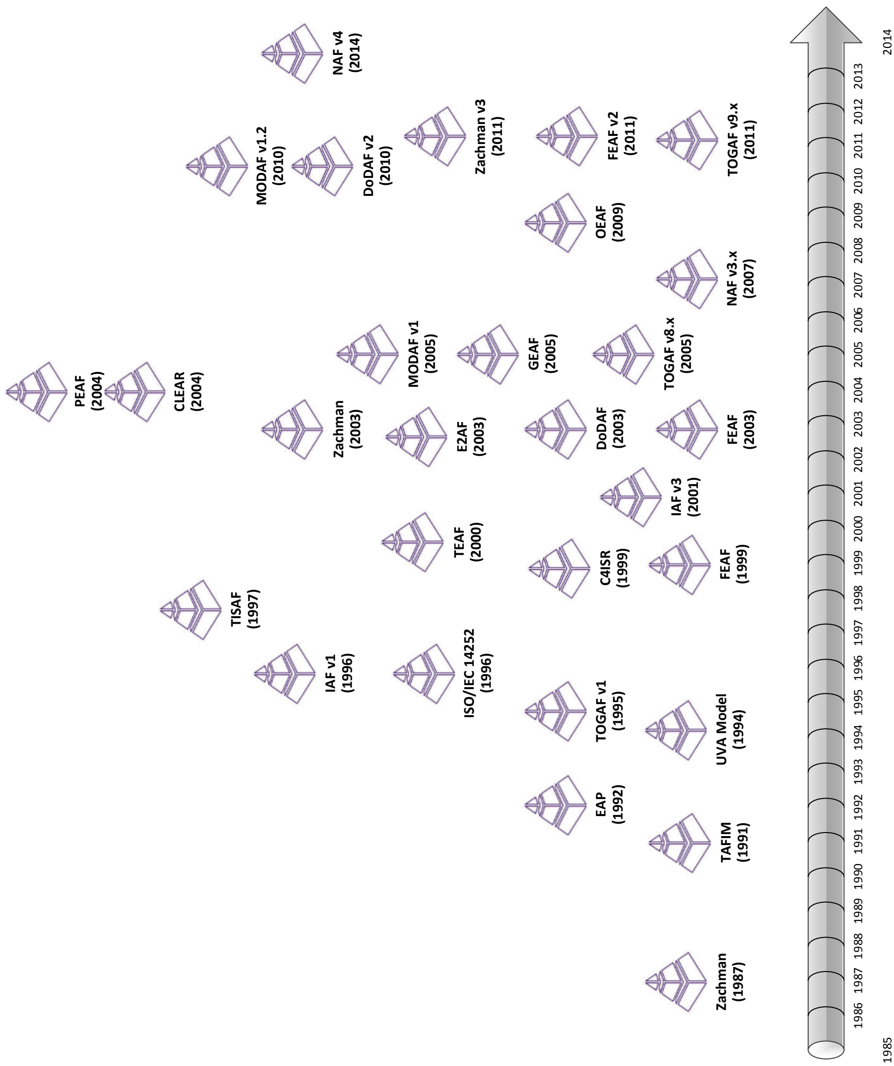

Figure 3.3: Historical overview of EA frameworks (updated by Georgadis (2015) from (Schekkerman 2006))

To identify the most important frameworks, we studied several reviews and historical overviews of EA frameworks, such as the one provided by Georgiadis (2015) (Figure 3.3). The overview by Schekkerman (2006) is less recent, but interesting for its explanation of the influences EA frameworks have had on each other. Based on these influence relationships, Zachman (Zachman International 2011), TOGAF (The Open Group 2009), DoDAF (DoD 2010), and E2AF (IFEAD 2006) appear to be important EA frameworks. Zachman gave rise to another EA framework, TEAF, which was created for the US Department of the Treasury. Yet, since it is subsumed in the Federal Enterprise Architecture (FEA), just like FEAF, it is better to include FEA instead of TEAF.

Zachman, TOGAF, DoDAF, FEAF, and TEAF are all analyzed in the study of Urbaczewski and Mrdalj (2006). Sessions (2007), on the other hand, compares the first two, Zachman and TOGAF, with FEA and Gartner's GEAM. Yet another study by Leist and Zellner (2006) juxtaposes Zachman, TOGAF, DoDAF, FEAF, TEAF, ARIS, and MDA (model-driven architecture). The last one, MDA, is more a general systems development approach, so it will not be included in our further analysis here.

In short, the most widely discussed EA frameworks that should also be included in the present analysis are Zachman (Zachman International 2011), TOGAF (The Open Group 2009), DoDAF (DoD 2010), E2AF (IFEAD 2006), FEA (The White House Office of Management and Budget (OMB) 2013, 2012), GEAM (Gartner) (Bittler and Kreizmann 2005; James et al. 2005), and ARIS (Scheer 2000) (Table 3.1).

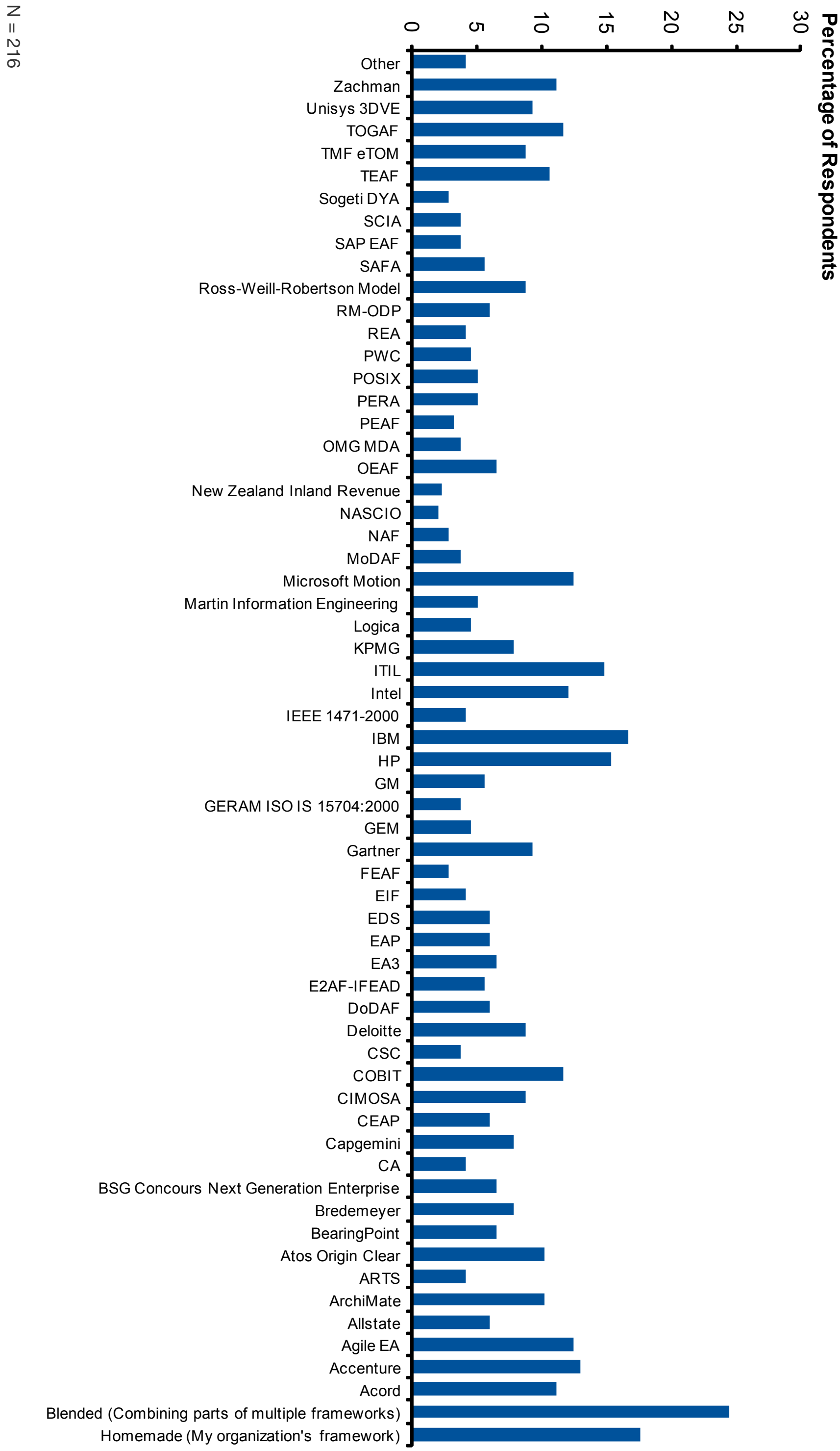

Figure 3.4: EA frameworks currently being used (from (Gartner 2012))

This selection of relevant EA frameworks is confirmed by the survey of IFEAD (2005) and, more recently, by the survey of Gartner (2012) on the use of EA frameworks in companies (Figure 3.4). However, a lot of companies also use a homemade EA framework or hire a consulting firm (e.g., IBM, Deloitte) to help them craft a best-of-breed framework. ArchiMate (Lankhorst 2013) was also included in Table 3.1, because it was recently adopted as a standard by The Open Group (2012) to be used in combination with TOGAF. Capgemini’s IAF (van 't Wout et al. 2010) was also added because it was built based on experience in more than 3000 EA projects and it evolves faster than any standard ever can. As such, it lies at the basis of large parts of TOGAF 9’s content framework. The Business Motivation Model (BMM) (OMG 2010) is also relevant for our study because of its emphasis on the motivational dimension. Yet it does not give a holistic EA overview and is not actually an EA framework, so it has been placed between brackets in Table 3.1. At the same time, though, BMM is often included in business architecture analyses (Glissman and Sanz 2009), so it should definitely be taken into account in our analysis. Finally, Sogeti’s DYA (Wagter et al. 2005) offers a holistic view and should therefore also be included in Table 3.1.

To make sure that recently developed EA frameworks were not ignored, we also included several EA frameworks developed in academia, namely CARP (derived from DoDAF) (Business Transformation Agency 2009), Enterprise Modeling (Bubenko 1993) and its successors Enterprise Knowledge Development (EKD) (Stirna and Persson 2007) and 4EM (Sandkuhl et al. 2014), REA extended with goal modeling (Andersson et al. 2009) (Figure 3.4), SEAM (Wegmann et al. 2007b), and LEAP (Clark et al. 2011).

3.4.2 Essential Dimensions of EA

The essential dimensions of EA were determined in three consecutive steps.

Firstly, according to Schekkerman’s (2006) and Georgiadis’ (2015) overview of EA influence history, Zachman (1987) seems to be at the very origin of many EA frameworks. The collection of EA frameworks identified in the previous section will therefore be analyzed by means of the six focuses (columns) of the Zachman framework (*what*, *how*, *where*, *who*, *when*, *why*). These focuses make it possible to classify architectural descriptions according to content or subject focus (e.g., objects or data for *what*, processes for *how*, networks or locations for *where*, etc.), so that architecture models according to a particular focus represent a single aspect of the enterprise, abstracting from relationships with the other aspects.

Secondly, Winter and Fischer (2007) identified five essential architectural layers in EA frameworks (i.e. business, process, integration, software, infrastructure). These architectural layers allow a further classification of (parts of) architectural descriptions, so that architecture models are expressed using concepts that represent the enterprise elements that are relevant to a certain perspective, in a way that is comprehensible for the stakeholders in that perspective. The process architecture layer can then be further merged with the business architecture layer and, in its turn, the integration architecture layer can be combined with the software architecture layer. This results in three essential EA layers: business, software, and infrastructure. These layers were used to analyze the EA frameworks in Table 3.1 (i.e. *business (B)*, *software (IS)*, *infrastructure (IT)*, or a *blend* of the three).

Thirdly, during the analysis of the selected EA frameworks, no additional focuses or architectural layers were identified. However, what also became apparent during the analysis was that most EA frameworks make it possible to translate strategy into operations and often stress the importance of a long and thorough analysis of the strategy space, free from all implementation constraints. Lankhorst (2013), for instance, refers to the strategic alignment model of Henderson and Venkatraman (1993), according to which EA can help in executing the business or IT strategy and enable the alignment between (business or IT) strategy and (organizational or IT) infrastructure and processes. In fact, many EA frameworks provide guidance for the translation from corporate strategy into daily operations. For example, Zachman (2011) defines six views (rows) from "scope" all the way to the "full enterprise", adding more implementation constraints towards the "full enterprise" view. Another example is IAF (van 't Wout et al. 2010), which is primarily built upon the principle of analyzing the strategy space for as long as possible without taking into account the constraints of operations beforehand, by using contextual, conceptual, logical, and physical abstraction levels that are closely related to the different views of Zachman.

Since this aspect can be found in many EA studies, we too have decided to incorporate this, so the last column of our analysis shows whether the EA frameworks provide a means to analyze the (business or IT) strategy space while still disregarding the constraints of (organizational or IT) operations (i.e. *strategy–operations*).

Table 3.1 gives an overview of the analyzed EA frameworks. For each Zachman focus, one or more concepts that represent enterprise elements according to that focus are provided as examples, if they are defined in the metamodel of the EA framework. In the *strategy-operations* column, a minus/plus-minus/plus indicates that a translation from (business or IT) strategy into (organizational or IT) operations is not/limited/clearly supported.

Table 3.1: Analysis of EA frameworks

	WHAT	HOW	WHERE	WHO	WHEN	WHY	BUSINESS - IS - IT	STRATEGY - OPERATIONS
Zachman	What	How	Where	Who	When	Why	B/IS/IT	+
TOGAF	Data entity, ...	Process, ...	Infrastructure extension	Organization unit, actor, role, ...	Event, ...	Motivation extension	B/IS/IT	+
ArchiMate	Information	Behaviour	Network, ...	Structure	Event, ...	Motivation	B/IS/IT	+
DoDAF	Resource	Activity	Location	Performer	-	Capability	Blend	+
CARP	Resource	Activity	-	Performer	-	Capability	B	+
IAF	Object	Activity	Interaction	Actor, role, ...	Event	Why, goal, ...	B/IS/IT	+
E2AF	Business objects, resources, ...	Business activities, ...	With who?	Organization structure, actors, ...	When?	Why?	B/IS/IT	+
FEA: FEAF	Objects, ...	Business process, ...	Business locations, ...	-	-	-	IS/IT	-
FEA: TEAF	Information, ...	Business process, ...	Information exchange, ...	Organization chart, ...	Event, ...	Mission, vision, ...	B/IS/IT	+
GEAM	-	-	-	-	-	Requirements vision	B/IS/IT	+
ARIS	Input, output, ...	Function	-	Organizational unit, ...	Event	Goal	Blend	+-
(BMM)	-	(Business process)	-	(Organization unit)	-	End	B	+
DYA	Product, data, ...	Process	Network	Organization, ...	-	Business objectives	B/IS/IT	+
Enterprise modelling / EKD / 4EM	Concepts model	Business process model	-	Actors and resources model	-	Goals model	B/IS	+
REA	Resource	Event	-	Agent	-	Goals	B	-
SEAM	-	-	-	-	-	Strategies	B/IS	+
LEAP	Object	Operation	-	Object	Condition	OCL constraint	B/IS/IT	-

Most of the frameworks use (at least) four focuses from Zachman's framework: *what*, *how*, *who*, *why*. The *where*-focus is usually only implicitly present in, for instance, relationships between elements and in networks.

Often, an explicit metamodel concept for expressing enterprise elements according to this focus is missing. The *when*-focus, if used, is mostly related to conditions or events that trigger processes. In this respect, it is closely related to and often included in the *how*-focus (e.g., event-driven process chains). Yet, Winter and Fischer (2007) argue that in EA, "business processes should not be decomposed further than to the subprocess level. Detailed process descriptions including specifications of activities and work steps are out of EA scope and should be maintained by using specialized business process modeling tools". This holistic overview function of EA is confirmed by other authors, such as (Lankhorst 2013; Jonkers et al. 2006).

The importance of these four focuses is confirmed by a large number of application cases performed with EKD. Stirna and Persson (2007) point out that, while EKD specifies six sub-models, it focuses predominantly on the goals model, business process model, concepts model, and actors and resources model. According to these authors, these sub-models correspond to the *why*, *how*, *what* and *who* questions, which are the four essential Zachman focuses that we identified. EKD sub-models thus represent a single aspect of the enterprise using concepts related to a particular focus.

Most of the time, all three layers (i.e. *business (B)*, *software (IS)*, *infrastructure (IT)*), or a *blend* of them are used. Most EA frameworks also emphasize the importance of analyzing the strategy space without worrying about the constraints of operations beforehand (*strategy–operations*).

Hence, these three things are defined as the essential EA dimensions to be supported by the CHOOSE metamodel: (1) the presence of the four focuses (*why*, *who*, *how*, *what*), (2) at least a *blend* of three architectural layers (*business*, *IS*, *IT*), and (3) analyzing the strategy space without considering any future constraints of operations (*strategy–operations*). This means that the CHOOSE metamodel needs to define concepts for each of the four essential focuses, that the metamodel concepts may represent elements related to business, IS and IT, and that CHOOSE models can be constructed for representing and analyzing enterprise strategy without being constrained by the current operations, so that strategy (needs) and operations (means) are not mixed.

3.5 Initial Metamodel

We will first explain why the metamodel of the KAOS approach was chosen as a starting point for designing the CHOOSE metamodel. Next, the KAOS metamodel itself will briefly be presented. A more detailed description is provided in Appendix A.1.

3.5.1 KAOS as a Starting Point

In addition to the EA approaches listed in Table 3.1, we also investigated goal-oriented requirements engineering (GORE) approaches. The main reason for choosing KAOS as a starting point is that from the investigated EA and GORE approaches, only KAOS (Van Lamsweerde 2009) and EKD

(Stirna and Persson 2007) are explicitly built around the four essential EA focuses. Furthermore, KAOS was preferred to EKD as its metamodel is formally defined, which helps provide precise definitions for the concepts in the CHOOSE metamodel. The KAOS metamodel also explicitly distinguishes between concepts related to strategy and concepts related to operations. On the other hand, it should be pointed out that KAOS is not an original EA approach, but rather a requirements engineering approach intended to model systems. Therefore, its selection as the initial metamodel for CHOOSE was not trivial and had to be based on well-reasoned considerations, as explained below.

Engelsman et al. (2011) wrote an interesting paper on the use of GORE in EA in order to deal with the problem that current EA frameworks offer little support for modeling the underlying motivation of EAs in terms of stakeholder concerns and the high-level goals addressing these concerns. Their work lay at the basis of the ArchiMate 2.0 standard for EA modeling that extended ArchiMate 1.0 with a motivational extension (The Open Group 2012). The need for (a simple version of) goal refinement in EA approaches was confirmed after tests in case studies (Engelsman and Wieringa 2012). Therefore, GORE approaches were also considered as candidates for the selection of the initial metamodel, apart from the EA approaches listed in Table 3.1.

Well-known GORE techniques are i* (Yu 1993) and KAOS (Dardenne et al. 1991; van Lamsweerde et al. 1991). KAOS is a requirements engineering approach for software-intensive systems within an organizational or physical environment (Van Lamsweerde 2009). It is important to stress that KAOS is primarily intended to model organizational or physical systems based on goals and requirements, rather than used to model software. However, since enterprises are regarded as systems within EA (Jonkers et al. 2006), they can also be modeled as systems with KAOS. Compared to i*, which is more focused on the early requirements engineering phase and the modeling of dependencies between actors (Engelsman et al. 2011), KAOS has an important advantage since it makes it possible to make a broader overview of a system within its environment.

The ultimate choice for KAOS was, however, based on its great fit with the essential EA dimensions that we identified after analyzing important EA frameworks (see section 3.4). First of all, its metamodel is based on four viewpoints that provide a one-to-one mapping with the four essential EA focuses. Second, KAOS models systems that can be composed of business (or real-world), software, data and technology components, so a blend of the three architectural layers can be used. Third, since KAOS is a GORE approach, it provides a means to analyze the strategy space without anticipating any constraints of operations. In GORE, abstract higher-level goals are gradually refined to more concrete lower-level goals, which are used to specify requirements for systems (Anton 1996; Anton et al. 1994; Dardenne et al. 1993). These goals, which are part of the why-focus, are then linked to operations, which are part of the how-focus, in order to maintain traceability (Mostow 1985). Engelsman et al. (2011) state that a company is a good example of a system and goals can be a good basis for modeling the motivational dimension of a company. Other research concludes that business goals form an integral part of enterprise models (Boman et al. 1997; Loucopoulos and Kavakli 1995).

A final motivation for choosing KAOS is that its metamodel is well elaborated after more than twenty years of research, and is hence a good starting point to reuse existing knowledge.

3.5.2 KAOS Metamodel

The KAOS metamodel consists of four main viewpoints that define different sub-models (Figure 3.5): goal, agent, operation, and object. These viewpoints are mapped onto the four essential EA focuses of *why*, *who*, *how* and *what*:

- Goal viewpoint (why-focus), where goals are refined and justified until a goal hierarchy has been put together for tackling a particular problem.
- Agent viewpoint (who-focus), in which agents are assigned to the goals they are responsible for.
- Operation viewpoint (how-focus), which defines various behaviors that the agents need to fulfill their requirements.
- Object viewpoint (what-focus), which is used to define and document the objects (i.e. entities, agents, and associations).

There is an additional viewpoint (not shown in Figure 3.5), which completes the static representation of system functionalities by capturing the required system dynamics. This behavior viewpoint defines sub-models that can be represented using UML sequence diagrams and state diagrams. The concepts used in these sub-models are most closely related to the *when* Zachman focus, but this is not among the essential focuses of EA frameworks that we identified. Hence, it is clear that the behavior viewpoint is not essential for EA modeling and can therefore be left out of the initial metamodel.

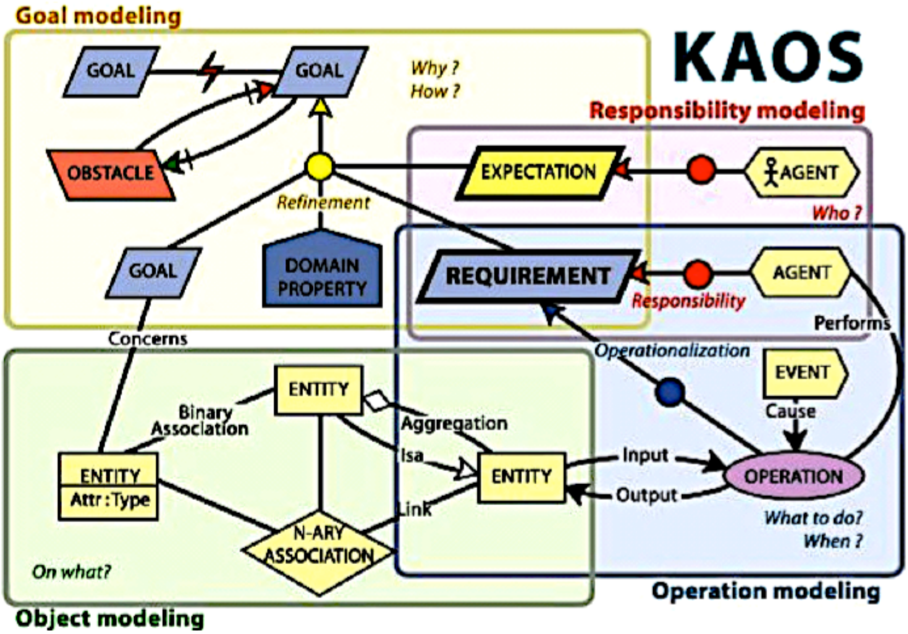

Figure 3.5: A simplified overview of the KAOS metamodel (from (Respect-IT 2007))

In the remainder of the chapter, concepts from the goal, agent, operation, and object viewpoints will further be coloured in yellow, red, purple, and green, respectively. Definitions can be found in Appendix A.1 and will be provided in the remainder of the chapter when relevant to the discussion regarding the changes made during the action research and case studies (see next section).

3.6 From KAOS to CHOOSE

The most important change to transform the KAOS metamodel into the CHOOSE metamodel entailed deleting the elements that were not further used after the feasibility test of the full KAOS metamodel in the SME (Bernaert and Poels 2011b) and were not asked for in the following rounds. As Moody (2003) mentioned, adoption is related to both effectiveness (i.e. benefits) and efficiency (i.e. costs). In order to develop CHOOSE, we first focused on efficiency and started with the essential part of an EA approach. During the action research in the SME, we then found out which parts had to be added for which the increase in effectiveness (i.e. increase in benefits) was larger than the decrease in efficiency (i.e. increase in costs).

Firstly, it is important to note that only two meta-attributes are mandatory for any meta-concept of all viewpoints in KAOS: *Name* and *Def*. These meta-attributes are also the attributes of the four central CHOOSE concepts; all other KAOS meta-attributes were omitted. *Def* was changed into a less formal *Description* attribute. This attribute has to be comprehensive and precise, yet also needs to provide a clear, though informally stated, description in natural language.

Secondly, other parts were omitted, changed, or added in each viewpoint and will be discussed for each viewpoint in the next sections. As mentioned before, after the action research was set up in the SME, five more case studies in SMEs with different characteristics were performed. Therefore, sometimes a particular change was triggered by a problem experienced with the use of CHOOSE in a case study company. If a similar problem was noticed in the action research SME, the solution chosen for the case study company was also evaluated in the action research SME, and after a positive evaluation this solution was then also incorporated into the metamodel.

In Appendix A.1, a visual overview is given of the transformation of the KAOS metamodel into the CHOOSE metamodel (Figure A.6 to Figure A.8). It is important to note that the following discussion is based on the complete KAOS metamodel (Figure A.6 in Appendix A.1) and not on the simplified overview presented in the previous section (Figure 3.5). In the following sections, changes to the different viewpoints will be discussed.

3.6.1 Goal Viewpoint

The *Goal* concept was retained together with the concept of *Refinement*. The attribute of *Refinement* became *Id*, in order to enable the SME to distinguish between alternative *Refinements*. The distinction between *BehaviouralGoals* and *SoftGoals* was omitted, because the SME was not interested in qualitative (Mylopoulos et al. 1992) nor quantitative (Letier and van Lamsweerde 2004) analyses, because of time constraints.

The same holds for the *Obstacle* analysis. This part was left out because it was never used as such. In the SME, *Obstacles* were implicitly addressed by naming the *Goals* according to the problem they aim to resolve (e.g., "decrease out of stock situations") instead of using *Obstacles* (e.g., "out of stock situation") and then *Resolving* them by means of a *Goal*. However, the SME wanted to model conflicting *Goals* of different stakeholders of the company in order to resolve these conflicts. The *Conflict* relationship between *Goals* was thus retained and explicitly represented by a relationship in the CHOOSE metamodel.

DomDescript was never used since it corresponds in KAOS to physical laws that cannot be broken. If it would be needed in CHOOSE, this aspect could be replaced by formulating business rules in the context of an enterprise as part of an EA model. For example, an SME can express that a specific bank account (*Object*) can only be *Controlled* by maximum three *Human Actors*. As no business rules have been expressed so far in the SME, this concept of business rules is not yet explicitly represented in the CHOOSE metamodel. Nevertheless, the tool support we are developing for CHOOSE (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013) does make it possible to check such rules, by means of queries of the model level.

Finally, there is no longer an explicit distinction between *Expectations* and *Requirements* in CHOOSE. Since *Actors* can be different types, these types of *Goals* can simply be queried from the CHOOSE model to determine which *Goals* are from a specific type of *Actor*.

3.6.2 Agent Viewpoint

The *Agent* concept was renamed into *Actor*, so that it would be more consistent with the terminology used in most EA frameworks (Table 3.1). The distinction between *SoftwareToBeAgent* and *EnvironmentAgent* was turned into a distinction between *Human Actor*, *Role*, *Software Actor*, and *Device* (hardware and equipment), which were only implicitly present in the KAOS metamodel via the optional *Category* attribute of an *Agent*. This change was not initiated by the SME, but rather by the need to adapt KAOS so that it would support the EA essential dimensions better (see section 3.4.2) and be able to model a blend of the three architectural layers (business, IS, IT). The SME used the distinction between these types of *Actors* sometimes but not all the time, in order to speed up the modeling task. As a consequence, the specialization became optional in CHOOSE.

The SME experienced problems linking *Operations* to functions, for which a solution had to be found. Sometimes, functions appeared to switch between *Human Actors*, depending on the availability of the actors themselves, as well as their available time. The use of *Roles* and *Human Actors* that *Perform Roles* is briefly mentioned in KAOS, but not explicitly present in its metamodel. Still, as this is widely supported by EA frameworks (Table 3.1), it was explicitly added to the CHOOSE metamodel so that this issue could be addressed.

The reflexive *Supervision* relationship was added between *Human Actors* because the SME immediately became aware of the need to make organizational charts. A many-to-many *Supervision* relationship was chosen to also enable matrix organizational structures in which a *supervisee* can have more than one *supervisor*.

Another reflexive relationship between *Actors*, *Aggregation*, was initially not included in the metamodel. However, one of the SMEs in which we performed case study research (to design the CHOOSE method, see section 3.3) had 37 employees and the metamodel did not allow us to group *Actors* into departments or other categories, because such units are neither *Human Actors* nor *Roles*. In order to be able to group *Actors* according to different levels of granularity (e.g., business unit or department), which is also common in EA frameworks (Table 3.1), the reflexive *Aggregation* relationship was thus added again. However, the SME did not express the need to make a further specialization of *Actor* in department or business unit. Therefore, the specialization of *Actor* in its subtypes is not covering (incomplete), since an *Actor* can be something other than a *Human Actor*, a

Role, a *Software Actor*, or a *Device*. The problem of not being able to group *Actors* was initially not brought to the attention in the action research SME, because this is an SME with only six employees. When the SME discovered in the second additional action research cycle that it could model its organizational chart more precisely, it fully supported this change in the metamodel.

At first, only one type of relationship was retained between *Goals* and *Actors* (i.e. *Assignment*). However, this soon became insufficient, because the relationship was used to assign *Actors* to *Goals* (as executing *Actor*) for lower-level *Goals*, but was also incorrectly used to express that an *Actor* "wanted" a *Goal* to be fulfilled for higher-level *Goals*. Therefore, the *Wish* relationship between *Actors* and *Goals*, only implicitly present in the KAOS metamodel as an attribute of *Agent*, was made explicit in the CHOOSE metamodel as a relationship. This was usually on a higher *Goal* level than the *Assignment* relationship between both.

The *Assignment* relationship, however, has a different meaning than the relationship in KAOS. In KAOS, an *Assignment* relationship makes it possible to *OR-Assign* different *Agents* to the same *Goal*, while only one *Agent* can be made *Responsible* of that *Goal*. In CHOOSE, *Actors* have an *Assignment* relationship with a *Goal* if they have been instructed to achieve that *Goal* (i.e. they are IOR-assigned). This enabled the SME to assign multiple *Actors* to the same *Goal*, which was more in line with the SME's business reality. Whether or not the *Actors* were responsible for that *Goal* at a specific time, there were more ad-hoc decisions and there was no need for this to be expressed in the metamodel. The SME also *Assigned* some *Actors* to non-*LeafGoals* so that the model would reflect reality more clearly. Yet, this is not possible in the original KAOS metamodel. This is a subtle, yet important difference between KAOS and CHOOSE: in KAOS, *Goals* have to be *Refined* until they can be under the *Responsibility* of just one *Agent*. These *LeafGoals* can then be *Operationalized* by one or more *Operations*. The *Operations* also have to enable *Performance* by just one *Agent*. In contrast, in CHOOSE, *Goals* at any level can be assigned to *Actors* and can be *Operationalized* by *Operations* that can be *Performed* by more than one *Actor*. This clearly reflects the real-life organizational levels that can exist in a company. Nevertheless, some consistency problems still occurred in the SME due to this adaptation, for which additional OCL constraints (Appendix A.2 Table A.1: constraints 5-6, 21-22) were added.

At the start, only one relationship was retained between *Actor* and *Object* to express that an *Object* belonged to an *Actor*. However, this relationship could be more correctly modeled with an *Association* between an *Actor* and *Entity* in the object viewpoint if *Actor* was seen as a subtype of *Object*. The relationship between *Actor* and *Object* was therefore omitted and *Actor* was kept as a subtype of *Object* and could be used in the object viewpoint by the SME. Thus, the CHOOSE metamodel did not contain any extra relationship between *Actor* and *Object* anymore. One of the case study SMEs did a lot of administrative work and some discussions arose based on read and write rights of documents. This problem did not occur in the action research SME at first. When the EA model of the action research SME became more complete, it did become an issue as the action research SME also wanted to express the confidentiality of financial data. For example, it had to be decided who could see a particular bank account and who could make payments. In order to solve this problem, some options were considered and most often, a distinction between creating (if the object is newly created), transforming (if it is changed), and using (if it is only used and not modified) was found to be of importance. The SME did not make a distinction between creating and transforming. Therefore, the *Monitoring* and *Control* relationships from KAOS were added again, but instead of linking them to *Associations* and *Attributes,* we provided a direct link from *Actors* to *Objects* (Appendix A.1 Figure A.6). This was a logical step, because the SME did not specify any additional *Attributes* for *Objects* and because *Associations* are still subtypes of *Objects*. As a result, if an *Association* has to be explicitly *Monitored* or *Controlled*, the *Association* can be objectified, and *Actors* in CHOOSE can thus *Monitor* and/or *Control* an *Object*.

Finally, *Dependencies* between *Actors* can be queried from the CHOOSE model, and were therefore omitted from the metamodel. The assumption behind this is that if *Actors* are *Assigned* to the same *Goal*, or if they have to *Perform* the same *Operation*, they are dependent on each other.

3.6.3 Operation Viewpoint

The operation viewpoint differs significantly between KAOS and CHOOSE. As mentioned before, an *Operation* in KAOS can only have a *Performance* relationship with exactly one *Agent*. However, when more *Operations* were added to the SME's EA model during the action research, there was no clear overview anymore. A solution to this problem was found by examining how ARIS (Scheer 2000) and BPMN (OMG 2011a) structure processes. A reflexive *Includes* relationship was added to enable the SME to make *Operations* part of other(s) in order to make it possible to create a structured *Operation* overview (sometimes called a map or landscape). Some constraints (Appendix A.2 Table A.1: constraints 9, 11, 22, 25) were adapted or added to maintain consistency.

It has already been pointed out that process modeling should not be included in EA. The SME, for its part, did not feel the need to make any process descriptions either. Still, some SMEs are likely to be confronted with this need for process modeling if standardization becomes more important (Ross et al. 2006). To make sure that they have some kind of EA overview of *Processes* at their disposal, a *Process* overview is included, while detailed process modeling is left out of the CHOOSE metamodel. However, process modeling descriptions can easily be linked to this *Process* overview of CHOOSE (e.g., with attachments in the software tool), which has as an advantage that the choice of process modeling language (e.g., BPMN, EPC, UML activity) can be made based on the SME's preferences, without this affecting the CHOOSE metamodel.

The name *Operation* was retained, since there is a clear distinction in a business context between a *Process* (Weske 2012) and a *Project* (Kerzner 2013), which was confirmed by the action research SME. A *Process* will typically be performed multiple times, while a *Project* is performed only once and has time, budget, and other constraints. In CHOOSE, an *Operation* can therefore either be a *Process* or a *Project*. The SME had some *Projects* that could be quite disruptive for their business and wanted to treat these *Projects* differently than the *Processes* (e.g., some milestones were formulated for these *Projects)*. Therefore, the SME sometimes, but not always, wanted to distinguish between a *Process* and *Project*. That is why the specialization is optional: if not further specified, the SME is not interested in making the difference between a *Process* and *Project*.

The *Performance* relationship helped the SME to make a load analysis of all *Operations* linked to an *Actor*. However, this load analysis needed some corrections, because for example sometimes the *Actor* would only be informed about the *Operation* once in a while, which was less time-consuming than being held responsible for it. For this problem, different solutions exist (e.g., RACI, RASCI, CAIRO). In order to be able to use a RACI (Responsible, Accountable, Consulted, and Informed) labeling of the *Performance* relationships, an association class including the attribute *Type* was added to the *Performance* relationship. This RACI chart is also used, for example, by the IT governance reference framework COBIT to define responsibilities (ISACA 2012). Working with a generic *Type* attribute instead of a specific set of labels makes the modeling effort much more flexible, so that the SME may choose another responsibility assignment matrix. The load analysis during the action research would then be more accurate, based on the different *Types* of *Performance* relationships between *Actors* and *Operations*.

As the SME linked *Operations* with *Goals* - not only *LeafGoals* - at different levels, the *Operationalization* link needed to be adapted. A constraint (Appendix A.2 Table A.1: constraint 9) was added to maintain consistency. However, it is best to delay the *Operationalization* of a *Goal* as long as possible, to make sure that the constraints of operations are still disregarded during the analysis of the strategy space, which is an essential element in EA frameworks (Table 3.1). This aspect could be further investigated with regard to the future development of the CHOOSE method, but is beyond the scope of the present chapter.

The *Input* and *Output* links between *Operations* and *Objects* were retained for the same reasons as the *Monitor* and *Control* links between *Actors* and *Objects*: to give the SME the possibility to express which *Objects* are the *Input* (i.e. using) of an *Operation* and which ones are *Output* (i.e. creating or transforming). These relationships were also directly linked to *Objects* instead of *Associations* and *Attributes* (Appendix A.1 Figure A.6). An *Object* that is the *Input* of an *Operation* was often a resource in the SME, while an *Object* that is *Output* was often a product of the SME. However, as there are multiple exceptions, this was not included in the metamodel. For example, for more administrative *Operations* documents were sometimes needed as *Input*, in which case the *Output* would be an invoice, for example.

3.6.4 Object Viewpoint

The object viewpoint was less used than the other three viewpoints. The SME only needed to model *Objects* and the *Associations* between them. Only if more specificity was required, was an *Object* further broken down into *Entity*, *Actor* or *Association*. As a consequence, this specialization could be optional. There was no need to include extra *Attributes*, *DomDescripts* or *DomInits* either, because the *Description* attribute of an *Object* was sufficiently specific and the CHOOSE metamodel is not focused on precise system specification like KAOS. The *Event* concept, referred to in this object viewpoint but part of the behavioral viewpoint in KAOS, was also omitted. This can again be accommodated by process modeling languages and state diagrams.

In the SME of the action research, only *Associations* that *Link* two *Objects* were used. To enhance semantic clarity, *Associations* between more than two *Objects* were disregarded. The SME did not use any specific *Attributes* for *Objects*, nor did it define *ApplicationSpecific Associations*. Instead, the two attributes of an *Association* - *Name* and *Description* because an *Association* is a subtype of an *Object* - were sufficient to clearly describe the different *Associations*.

Aggregation and *Specialization* were first hardly used. However, when the CEO of the SME tried to specify a bill of materials (for example, by asking himself which car parts could be replaced by the SME), the *Aggregation* relationship offered a good solution (Hegge and Wortmann 1991). The same happened when the CEO tried to get a product overview (for example, by asking himself how the SME sorts the warehouse according to tire type), the *Specialization* relationship was a good solution (Eriksson and Penker 2000). A good method to explain these options can also be recommended. Preferably, this explanation does not use the terms *Aggregation* and *Specialization*, which were unknown to the CEO in this particular case. The choice to specify an *Association* as either an *Aggregation* or *Specialization* is an *Optional*, disjoint (*Or*) choice (OMG 2011c). This means that an *Association* does not have to be further specified in CHOOSE if the SME does not need it, but if it is, it can only be one of the subtypes.

The *Concern* relationship between *Goal* and *Object* was retained, although the SME in fact did not use it frequently. Further research in more SMEs could give more insight into the use of this relationship, for example in order to detect consistency conflicts (Appendix A.2 Table A.1: constraint 12).

An *Object* can be *Input* and *Output* of the same *Operation*, as its *State* can be changed by an *Operation* (for example, the customer file that was updated in the SME). However, there was no need to explicitly model these *States*. This is in line with the choice to also exclude process modeling from the CHOOSE metamodel, because this can also be achieved by process modeling languages and state diagrams.

3.7 CHOOSE Metamodel

3.7.1 Complete CHOOSE Metamodel

The CHOOSE metamodel was robust after the third action research cycle and no further changes needed to be made during the fourth cycle. According to the Object Management Group (OMG) (2013, 2012b) standards, the metamodel presented in this research is a computation independent model (CIM) at M2-level. Since it is described as a unified modeling language (UML) class diagram (OMG 2011b, c), this model can also serve as a platform independent model (PIM) for software tool support development (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013). The models made with this metamodel, and thus instantiating it, will be at M1-level and will be EA models for the specific SME being modeled.

Figure 3.6 shows this final CHOOSE metamodel, including all optional parts. *Actor* is represented twice for clarity's sake, but refers to the same concept.

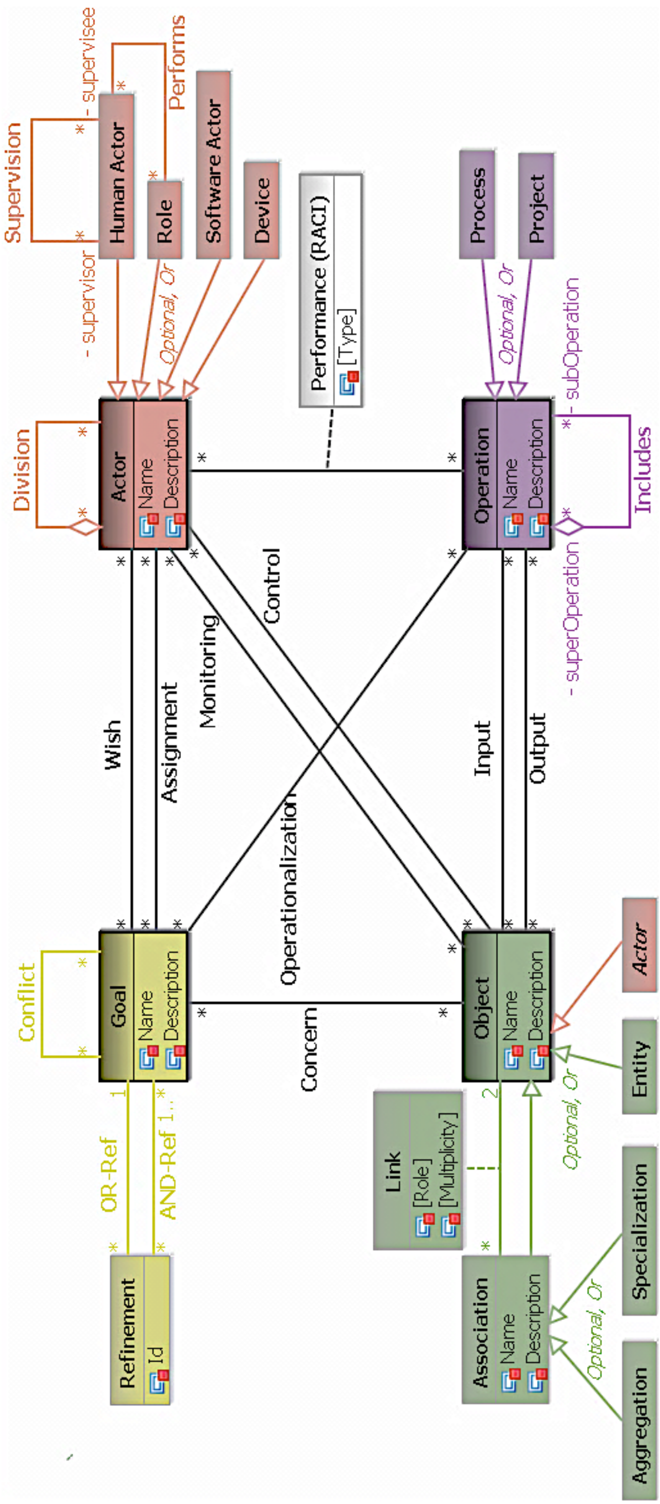

Figure 3.6: CHOOSE metamodel

3.7.1.1 CHOOSE Goal Viewpoint

Goal is the central concept in the goal viewpoint and has the attributes *Name* and *Description*. A *Goal* can have a *Conflict* relationship with zero or more other *Goals*.

An *OR-Ref* links one higher-level *Goal* with a *Refinement*. If different *Refinements* are linked via *OR-Ref* links to the same higher-level *Goal*, this means the *Goal* is *OR-Refined* several times. If only one *Refinement* is linked via an *OR-Ref* link to a higher-level *Goal*, this means the *Goal* can only be refined in one possible way. Each *Refinement* is then linked via *AND-Ref* links with one or more lower-level *Goals*. This implies each alternative *Refinement* of a higher-level *Goal* is linked via *AND-Ref* links with one or more lower-level *Goals*, which all have to be fulfilled in order to meet the higher-level *Goal* with which this *Refinement* is linked via an *OR-Ref* link. A special case is when a higher-level *Goal* is *OR-Refined* by just one *Refinement* and this *Refinement* is *AND-Refined* by just one lower-level *Goal*. In this case, the higher-level *Goal* is simply refined by the lower-level *Goal*. If a *Refinement* thus only has one upper *Goal* (*OR-Ref*) and one lower *Goal* (*AND-Ref*), it can be seen as a single refinement of a higher-level *Goal* in a lower-level *Goal*. A *Goal* does not have to have a link with a higher *Refinement* (reached through an *AND-Ref* link) if it is one of the highest-level *Goals* in the *Goal* hierarchy, and it does not have to have a lower *Refinement* (reached through an *OR-Ref* link) if it is one of the lowest-level *Goals* in the hierarchy (i.e. a leaf *Goal*).

A *Goal* can have a *Wish* or *Assignment* relationship with zero or more *Actors*, can be *Operationalized* by zero or more *Operations*, and can have a *Concern* relationship with zero or more *Objects*.

3.7.1.2 CHOOSE Actor Viewpoint

Actor is the central concept in the actor viewpoint and has the attributes *Name* and *Description*. An *Actor* can be an aggregation of zero or more other *Actors* and can be part of zero or more *Actors* via a *Division* relationship. However, if an *Actor* is a *Human Actor*, it cannot be an aggregation of other *Actors* (Appendix A.2 Table A.1: constraint 14) and other relevant constraints to limit the *Aggregation* of different *Actor* types are added (Appendix A.2 Table A.1: constraints 15-19). An *Actor* can, but does not have to be (i.e. it is *Optional*) *Specialized* in either (disjoint *Or*) a *Human Actor*, a *Role*, a *Software Actor*, or a *Device*. A *Human Actor* can be *Supervised* by zero or more *supervisors*, or can *Supervise* zero or more *supervisees*. A *Human Actor* can *Perform* zero or more *Roles*, while a *Role* can be *Performed* by zero or more *Human Actors*.

Actors can have a *Wish* (only unspecialized *Actors* or *Human Actors*, see Appendix A.2 Table A.1: constraint 4) or *Assignment* relationship with zero or more *Goals*, they can have a *Performance* relationship (some kind of RACI or other *Type*) with zero or more *Operations*, and they can *Monitor* or *Control* zero or more *Objects*.

3.7.1.3 CHOOSE Operation Viewpoint

Operation is the central concept in the operation viewpoint and has the attributes *Name* and *Description*. An *Operation* can be *Included* in zero or more other *superOperations* and can *Include* zero or more *subOperations*. An *Operation* can, but does not have to be (i.e. it is *Optional*) *Specialized* in either (disjoint *Or*) a *Process* or a *Project*.

An *Operation* can *Operationalize* zero or more *Goals*, can have a *Performance* relationship (some kind of RACI or other *Type*) with zero or more *Actors*, and can have zero or more *Objects* as *Input* or *Output*.

3.7.1.4 CHOOSE Object Viewpoint

Object is the central concept in the object viewpoint and has the attributes *Name* and *Description*. An *Object* can, but does not have to be (i.e. it is *Optional*) *Specialized* in either (disjoint *Or*) an *Entity*, *Actor*, or *Association*. An *Association Links* two *Objects*, while an *Object* can have zero or more *Associations* with one other *Object*. An *Association* inherits the attributes *Name* and *Description*, which are also visualized for clarity's sake, and a *Link* has the optional attributes *Role* and *Multiplicity*. An *Association* can, but does not have to be (i.e. it is *Optional*) *Specialized* in either (disjoint *Or*) an *Aggregation* or a *Specialization*.

An *Object* can have a *Concern* relationship with zero or more *Goals*, can be *Monitored* or *Controlled* by zero or more *Actors*, and can be *Input* or *Output* for zero or more *Operations*.

3.7.2 Core Part of the CHOOSE Metamodel

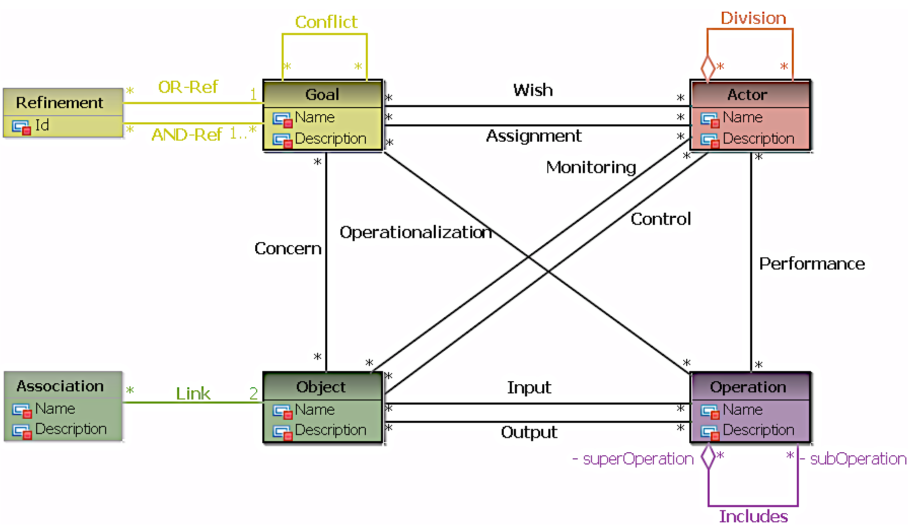

Figure 3.7: Core part of the CHOOSE metamodel

Figure 3.7 shows the core part of the CHOOSE metamodel, which only includes the minimum set of concepts and relationships of the CHOOSE metamodel required to model an SME's EA. The optional specializations and attributes are left out of this core representation of the CHOOSE metamodel, since they were only useful in some scenarios for the action research SME and do not belong to the essential EA dimensions.

These minimal parts of the CHOOSE metamodel can be used by SMEs to quickly and easily create an EA model. If needed, however, an *Actor* could then for example later on be specialized as a *Human Actor* in order to use the *Supervision* relationship of the complete CHOOSE metamodel. For instance, if the SME treats a *Process* differently than a *Project*, it could use the extensions of the complete metamodel and specialize the *Operations* into *Processes* and *Projects*. This core part of the CHOOSE metamodel represents the bare minimum, while still conforming to the EA essentials from section 3.4.2.

3.7.3 CHOOSE Definitions Using SBVR

In order to decrease misunderstandings, formal definitions are provided to contribute to the unambiguous definition of the CHOOSE concepts. Not all concept definitions in the CHOOSE metamodel could be retained from KAOS, since KAOS is used for system specification, while CHOOSE is used to make EA models of SMEs. Hence, the context in which the concepts are used is different.

When the KAOS definitions had to be adapted, the first choice was to relate the definitions, if possible, to ArchiMate definitions for two reasons. First, ArchiMate has been adopted by The Open Group (2012) as a standard and second, in future research, CHOOSE will be mapped onto ArchiMate to make bidirectional translation possible (Roose et al. 2013). For the organizational chart, definitions are linked to OMG's (2009) organization structure metamodel (OSM), since this metamodel is a widely used standard. The *Project* definition is adapted from the project management body of knowledge (Project Management Institute 2013) and the *Process* definition from OMG's (2011a) BPMN and ArchiMate (The Open Group 2012). Finally, the concepts derived from KAOS that cannot be related to a relevant EA definition are taken from the original KAOS definition (Van Lamsweerde 2009).

In Table 3.2, the definitions of the entities and relationships of CHOOSE are explained by means of SBVR (OMG 2008). Only the business vocabulary part of SBVR is used, as the rules are expressed in OCL (section 3.7.4).

Table 3.2: CHOOSE entities and relationships defined with SBVR

CONCEPT	**DEFINITION**	**SOURCE**
Object Type		
Goal	An end state that an actor wishes to achieve and that is to be brought about or sustained through appropriate operations.	Goal (The Open Group 2012; OMG 2010)

Refinement	Groups lower-level goals that all have to be fulfilled in order to fulfil a higher-level goal. Different refinements for one higher-level goal express different alternatives.	Refinement (Van Lamsweerde 2009)
Actor	An organizational entity that is capable of performing operations.	Business actor (The Open Group 2012)
Human Actor	A human being who is capable of performing operations.	Human actor (The Open Group 2012)
Role	The responsibility for the performance of specific operations, to which a human actor can be assigned who performs the role.	Business role (The Open Group 2012)
Software Actor	A software system or part of a software system that encapsulates its behaviour and data to perform operations.	Business actor + Application component (The Open Group 2012)
Device	A hardware resource or physical equipment that is capable of performing operations.	Business actor + Device (The Open Group 2012)
Operation	Internal behaviour that needs objects as input and produces objects as output, in order to operationalize goals. It can be a process or project.	Adapted from Operation (Van Lamsweerde 2009)
Process	A behaviour element that groups behaviour based on an ordering of activities with the objective of carrying out work. It is intended to produce a defined set of products or business services.	Process (OMG 2011a) + Business process (The Open Group 2012)
Project	A temporary endeavour undertaken to create a unique product, service or result.	Project (Project Management Institute 2013)
Object	A passive element that has relevance from a business, information, or technological perspective. It corresponds to a real world counterpart that may or may not be physical.	Business object (The Open Group 2012) + Object (Snoeck et al. 1999)
Entity	An autonomous and passive object.	Entity (Van Lamsweerde 2009)
Fact Type		
OR-Ref	Refines a higher-level goal in alternative refinements.	OR-refinement (Van Lamsweerde 2009)
AND-Ref	Expresses that an alternative refinement of a higher-level goal can be satisfied by satisfying all its subgoals.	AND-refinement (Van Lamsweerde 2009)
Conflict	Interconnects goals to capture potential conflicts among them.	Conflict (Van Lamsweerde 2009)

Wish	Captures the fact that an actor would like a goal to be achieved.	Wish (Van Lamsweerde 2009)
Assignment	An actor is assigned to a goal if it is required to restrict its behaviour so as to achieve the goal.	Responsible (Van Lamsweerde 2009)
Operationalization	Refers to the process of mapping goals (ends) to operations (means) realizing them.	Operationalization (Van Lamsweerde 2009) + Realization (The Open Group 2012)
Concern	Connects goals to the objects to which they refer.	Concern (Van Lamsweerde 2009)
Division	Indicates that an Actor groups a number of other Actors.	Aggregation (The Open Group 2012)
Supervision	A supervisee reports to a supervisor.	Supervises (OMG 2009)
Performs	Links roles with human actors that fulfil them.	Assignment (The Open Group 2012)
Performance (RACI)	Links operations with active elements (actors) that perform them or more specifically that are responsible, accountable, consulted, or informed.	Assignment (The Open Group 2012) + RACI (ISACA 2012)
Monitoring	An actor monitors an object if it can use the object, without changing it.	Monitoring (Van Lamsweerde 2009)
Control	An actor controls an object if it can create or transform the object.	Control (Van Lamsweerde 2009)
Includes	Groups suboperations in the superoperations of which they are part.	Aggregation (The Open Group 2012)
Input	Designates an object to which the operation applies.	Input (Van Lamsweerde 2009)
Output	Designates an object on which the operation acts.	Output (Van Lamsweerde 2009)
Association	Models a relationship between objects that is not covered by another, more specific relationship.	Association (The Open Group 2012)
Aggregation	Indicates that an object groups a number of other objects.	Aggregation (The Open Group 2012)
Specialization	Indicates that an object is a specialization of another object.	Specialization (The Open Group 2012)

It is important to note that *Aggregation* and *Specialization* of *Objects* cannot directly be used for further model-driven development of systems, since additional information needs to be added by IS experts, like for example whether the *Specialization* between *Objects* is total or not. CHOOSE is not intended to be directly used for implementation (e.g., to build an enterprise database for the SME), but rather a means to provide an EA overview for the SME's CEO or managers. As such, it could be a starting point for further detailed elaboration and analysis.

3.7.4 CHOOSE Constraints Using OCL

Finally, the metamodel is completed by adding constraints (see Appendix A.2 Table A.1 for a full list of the constraints). These constraints are meta-constraints as they constrain metamodel components. They are to be determined at metamodel definition time, checked at model-building time when enough model elements are available in each view, and rechecked at model evolution time when the linked items are changed. Most rule-based checks can be fully automated through queries on a model database structured according to the metamodel, for instance in further software tool development efforts (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013). The main advantage of having constraints is that constraint violations drive models towards structural consistency. Further, since missing items are often revealed, these constraints address structural completeness as well (Paige et al. 2007). Next to these universal consistency rules, a model may also be further constrained by business-specific rules at M1-level.

Within the constraints, a distinction can be made between hard or soft ones, on the one hand, and intra-view or inter-view ones, on the other hand. Hard constraints (1, 4, 13-20, 25-26) refer to those that must never be violated, while soft constraints (2-3, 5-12, 21-24) can be seen as recommendations for the SME in order to arrive at a more balanced and complete enterprise model. The latter make it possible for the user to figure out what remains to be done at any step of the model-building method. The distinction between intra-view and inter-view constraints involves the extent to which the whole model is checked or not. Intra-view constraints (1-2, 13-20, 25-26) are related to only one of the four viewpoints of CHOOSE and are marked by the corresponding colour. They check the structural consistency, completeness, and correctness within just one of the views. Inter-view constraints (3-12, 21-24), in contrast, are related to at least two of the four viewpoints and are also marked by the corresponding colours. These constraints are not limited to just one viewpoint, but check the structural consistency, completeness, and correctness of the whole model. As mentioned before, this improves the cohesion of the four viewpoints and enhances the integration and traceability of the different domains of a company.

Some constraints (2-3, 5, 7-8, 10-12, 21, 23-24, 26) are based on earlier KAOS constraints (Van Lamsweerde 2009), but often required some alterations because of the changed metamodel, as mentioned earlier (e.g., *Actors* can be linked to more *Goals*, *Operations* can be performed by more *Actors* and can also be linked to non-leaf *Goals*). Some new constraints (1, 4, 6, 9, 13-20, 22, 25) had to be developed since the KAOS metamodel was adapted to form the basis of the CHOOSE metamodel and inconsistent or incomplete models were discovered during the action research.

The constraints are expressed using the object constraint language (OCL), a standard of OMG (2012a) that can easily be used with the other OMG standards UML and SBVR (Warmer and Kleppe 2003). In order for the constraints to be tested and validated on instantiations of the metamodel, a UML-based specification environment tool (USE) was used, which was developed to test OCL constraints on UML models (Gogolla et al. 2007). Of course, this was not presented to the SMEs, since this software tool is rather meant to support the CHOOSE metamodel development effort and is not adapted to the characteristics of SMEs and EA. In Table A.1 of Appendix A.2 the metamodel including a full list of all constraints is presented as the text file serving as input for the USE tool. An example of resolving a constraint violation is given in Figure 3.10 of section 3.8.1.

Although this set of constraints proved to be sufficient for developing the EA model of the action research SME, it can definitely be extended. A possible future area of research could involve other relevant constraints and queries, for example to assist in conflict management (van Lamsweerde et al. 2002) or reasoning about alternative options (Heyse et al. 2012; Mylopoulos et al. 1992).

3.7.5 Model Viewpoints

It became clear during the action research that even though the CHOOSE metamodel contains few elements, the CHOOSE models became quite large, even in small SMEs (Figure 3.8).

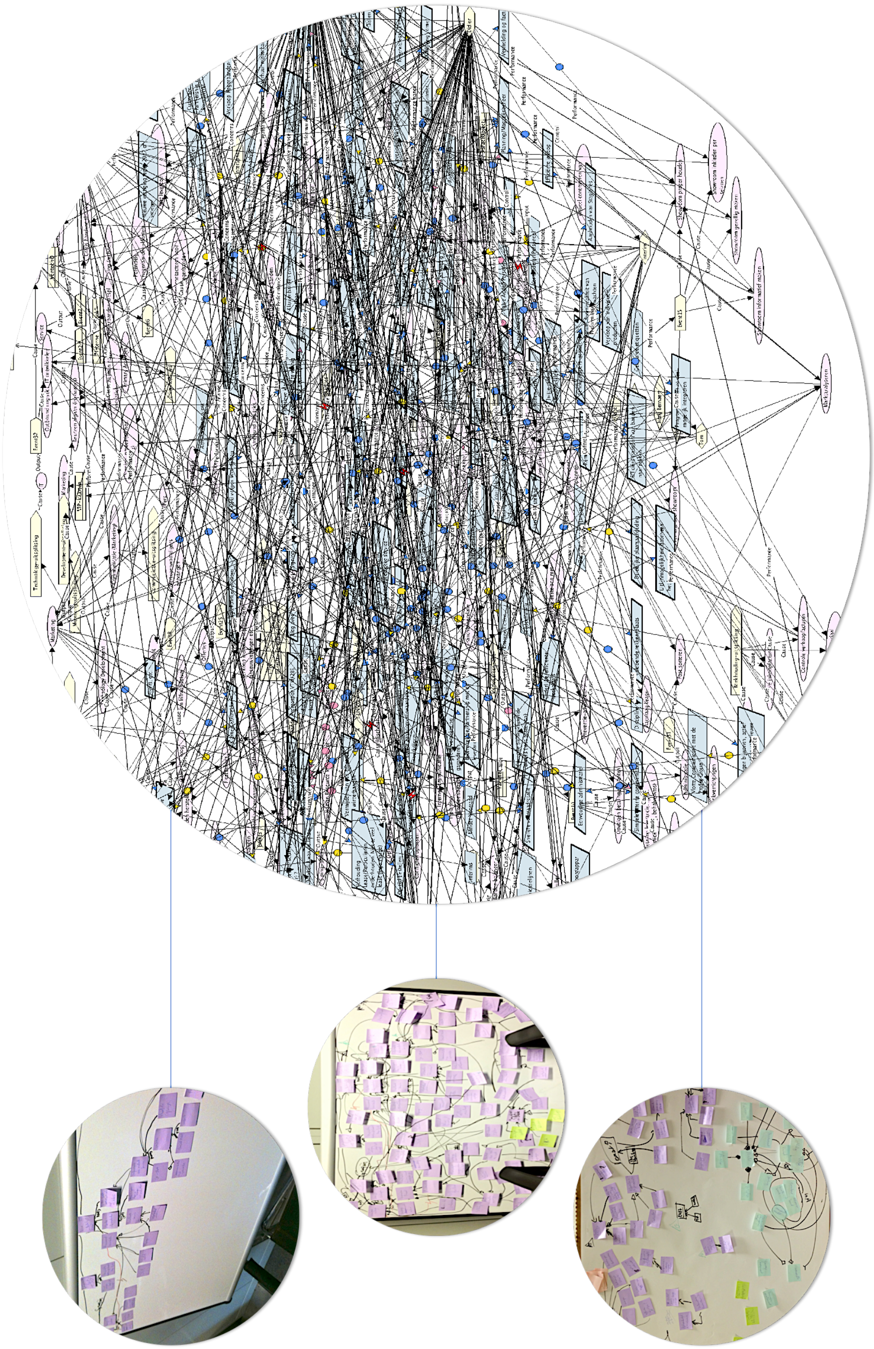

Figure 3.8: The CHOOSE model of the action research SME (using post-its and afterwards inserting it in the Objectiver tool for KAOS) became quite large

Therefore, queries can be used on the model database to extract other model views and visualize these for dedicated analyses, in order to be able to keep an overview of the EA model. For instance, if an *Object* is *Output* of an

Operation under the *Performance* of an *Actor* and *Input* for an *Operation* under the performance of another *Actor*, an implicit relationship exists between the *Actors* since they are dependent on each other. This provides a useful, direct view of mutual interfaces among *Actors*. Another example is load analysis, to see what *Operations* each *Actor* is *Performing*, or a RACI chart, if the *Performance Types* are according to RACI. Problematic situations can be spotted where a *Human Actor* appears overloaded.

A sufficient set of viewpoints will be further developed with the help of additional case studies.

3.8 CHOOSE Metamodel Evaluation

The evolving CHOOSE metamodel was evaluated through the different rounds of the action research programme. The results of this evaluation will be summarized in this section, and it will be determined whether the final metamodel supports the essential EA dimensions (section 3.4.2) and meets the requirements for EA for SMEs (section 3.2.2).

3.8.1 Action Research Evaluation and Example

The action research effort demonstrated that CHOOSE enables the development and management of an EA model for SMEs. It made the CEO think about his SME, how things work, why things are done, who is involved in and responsible for what, what the conflicting goals of different stakeholders are, and how balanced decisions should be made between these conflicting goals. In this respect, one specific advantage was that the CEO of the action research SME became able to assess which operations could be executed by software instead of by the employees that executed them up to that moment. For example, because of some insights from the CHOOSE model, the CEO decided to purchase an extra module for the ERP system. This module allowed him to automatically link payments with the correct customer, an operation that he used to have to do himself and that was very time-consuming.

In general, it is safe to say that the CHOOSE model enabled a better control of the SME, with improved communication and interaction, by offering a holistic overview, in which elements are part of a bigger picture. The approach was primarily used in a top-down manner (i.e. from *Goals* to *Operations*), thus increasing the CEO's control of the SME. At the same time, though, CHOOSE also increased communication and interaction among employees and other stakeholders, as it was also used to discuss parts of the model with them. Although the terminology may not be clear to all users right now, this will definitely be remedied by the software tools we are developing (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013). A final advantage could be that employees may become more motivated if they know how their role is situated within the bigger picture of the whole SME. This was not yet visible in the SME, but longer-term evaluation will undoubtedly provide more insight into this type of benefits.

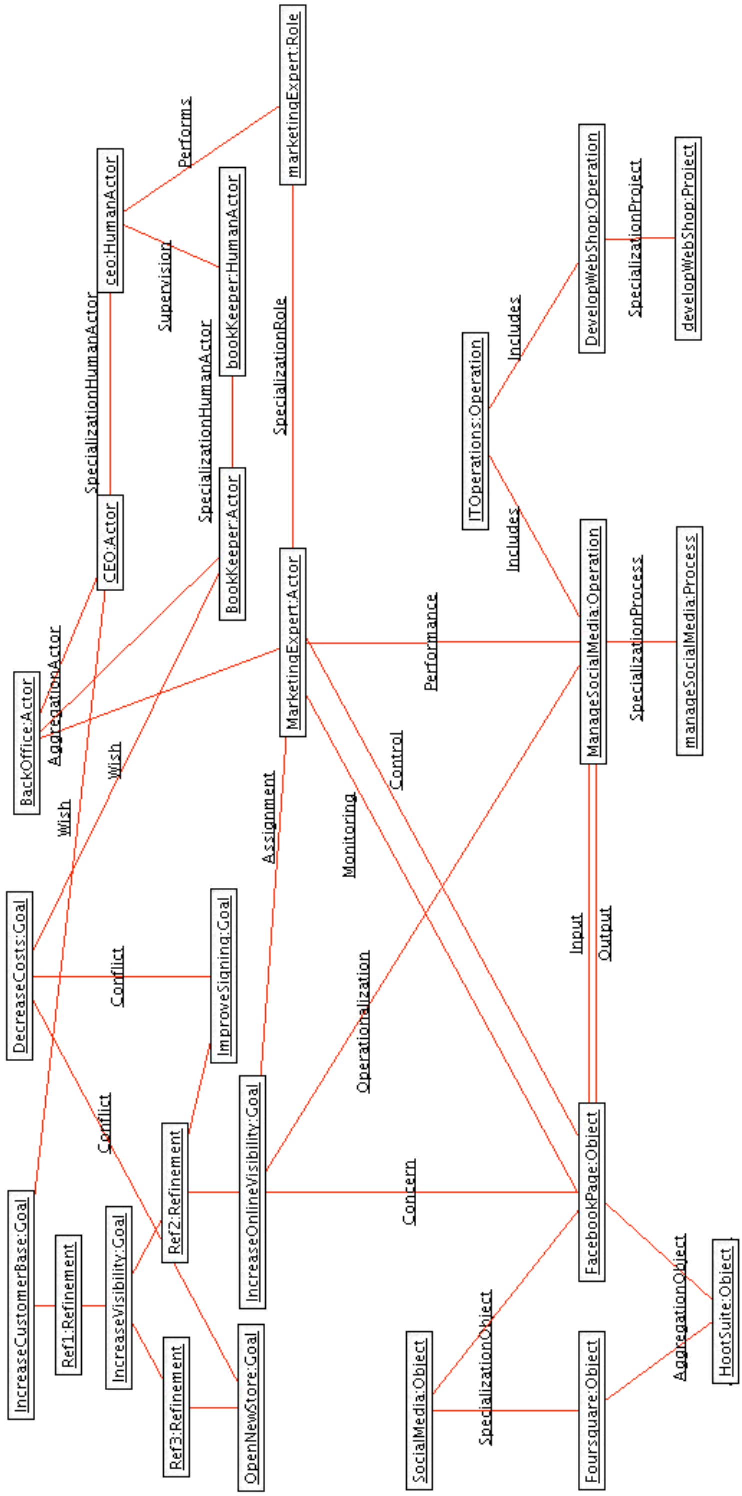

Figure 3.9: Extract from the CHOOSE model from the action research SME

In order to illustrate most of CHOOSE's concepts and relationships, Figure 3.9 shows an extract from the SME's CHOOSE model, modeled in the USE tool. In this example from the action research SME, the CEO wished to increase the customer base by increasing visibility in one of two possible ways. First, he could open a new store, but this conflicts with decreasing the costs, an objective of the bookkeeper. Second, he could improve the signage of the building and enhance online visibility. This second alternative was chosen. Since signage can be a pricy affair and thus conflicts with decreasing the cost, first online visibility was enhanced. In this particular SME, the CEO also performs the role of a marketing expert and is part of the SME's back office together with the bookkeeper, who is supervised by the CEO. As marketing expert, the CEO is assigned to the goal of increasing the online visibility. This is operationalized by managing the social media. More specifically, the SME's Facebook page will be managed and the marketing expert can see (i.e. *Monitor*) and even change (i.e. *Control*) this page. Managing social media is part of the IT operations in this SME, like for example also the project of the web shop development. The company also has a Foursquare page as a kind of social media, however, nothing is currently being done with this page. Both Facebook and Foursquare are part of the SME's Hootsuite account, in which different social media platforms can be managed.

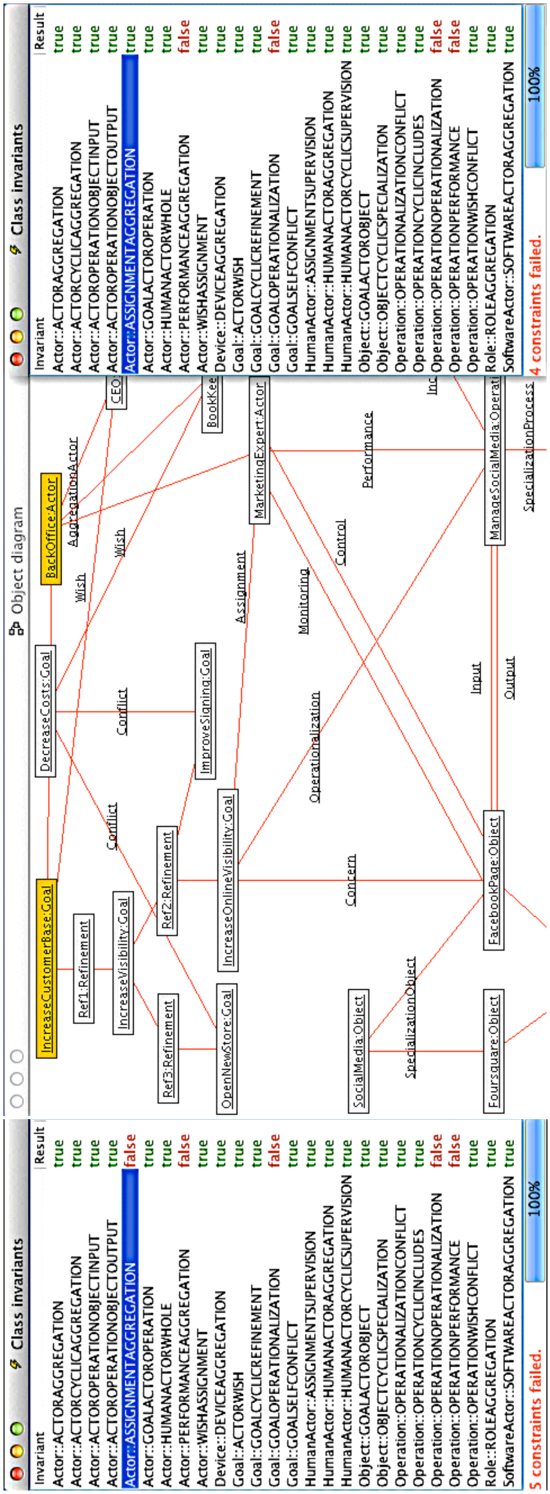

Figure 3.10: OCL constraints failed (left) and one constraint resolved (right)

Five OCL constraints are violated in this model extract (left part of Figure 3.10), which could guide the SME to make the CHOOSE model more consistent and complete. For example, *ASSIGNMENTAGGREGATION* (constraint 5) failed because the *Actor* BackOffice has no *Assignment* relation with any of the higher-level *Goals* of IncreaseOnlineVisibility, which is *Assigned* to MarketingExpert, one of the *subActors* of BackOffice. This could be resolved by *Assigning* BackOffice to IncreaseCustomerBase (right part of Figure 3.10).

3.8.2 Support of Essential EA Dimensions

The CHOOSE metamodel conforms to the essential dimensions of EA frameworks as identified after analysis of important EA frameworks in section 3.4:

- The CHOOSE metamodel covers and integrates the four essential EA focuses: *why* through the goal viewpoint, *who* through the actor viewpoint, *how* through the operation viewpoint, and *what* through the object viewpoint. Relationships are defined to relate concepts from different viewpoints.
- The CHOOSE metamodel *blends* the three EA layers (*business*, *IS*, *IT*) by providing *Actors* for each layer (*Human Actor* / *Role*, *Software Actor*, *Device*) and enabling the other three viewpoints to be related to it. *Goals*, *Operations*, and *Objects* could also originate from the three different EA layers, as seen in the EA model of the SME during the action research. Yet, for this SME, no explicit specialization was needed.
- The CHOOSE metamodel provides a means to analyze the strategy space without worrying about any constraints of operations beforehand, as it separates *Goals* from *Operations* via *Operationalization* links.

3.8.3 Meeting the Requirements for EA for SMEs

The CHOOSE metamodel conforms to the EA requirements listed in section 3.2.2.1:

1) By providing a means to analyze the SME by using a metamodel, control was increased for the CEO. Constraints in OCL that are generally applicable are presented. SME-specific queries can be made on the EA model.
2) By conforming to the essential parts of EA frameworks, a holistic overview can be provided, but the SME is not obliged to make a global model. If necessary, the models can be made for one project at a time (Ross et al. 2006). The when and where-focus can be considered to be part of the operation viewpoint, which could be elaborated by business process modeling languages. The SME did not need separate Operation attributes for these two focuses, since the Description attribute was sufficient to describe details.

3) Since the CHOOSE metamodel is based on goal refinements, the requirement regarding objectives is fulfilled.
4) This requirement (fit for the target audience) was split up into SME-specific requirements (see further).
5) Since CHOOSE is based on the essential dimensions from EA frameworks used for modeling enterprises, it provides an enterprise overview.

As the fourth requirement of EA is related to SMEs as a target audience (and, more specifically, to the CEOs or managers of SMEs), the requirements for adoption and successful use of IT in SMEs can be discussed (section 3.2.2.2):

4.1) To allow the CEO to work more efficiently, the CHOOSE metamodel is kept to the bare minimum (e.g., a comparison can be made between the number of metamodel elements and relationships in CHOOSE and ArchiMate). Nevertheless, a metamodel by itself did not appear to offer the CEO enough flexibility to work whenever and wherever he had the time for it. Further software tool support (i.e. research step 5 in Figure 3.1) should be developed to make this possible (Ernst et al. 2006). In the fourth round of the action research programme, a prototype CHOOSE software tool was installed in this SME.

4.2) To make the approach accessible to people with few IT or modeling skills, the metamodel is kept as simple as possible (including some optional parts that do not have to be used), with just four viewpoints that each contain only one central concept. The CEO was able to work with CHOOSE and is now also using the software tool. Still, a longer-term evaluation and further case studies are needed to improve the CHOOSE approach and software tool support.

4.3) Throughout the different rounds of the action research programme, the researchers guided the CEO in the development of the EA model. After the fourth round, the CEO started working with the software tool himself. The ultimate goal is to further develop the CHOOSE approach so that any need for external help is reduced to a minimum.

4.4) A process overview can be built with the operation viewpoint. Processes (or projects) can be elaborated by using a business process management approach (or project management approach) and linking this to the corresponding process (or project) in the CHOOSE model. In the SME of the action research, no processes were elaborated. As this could be the case in other SMEs, further research is still needed on how to easily link process models to the process overview (e.g., by providing attachment options in the software tool support).

4.5) The CEO was involved in developing the CHOOSE model, as he possessed the required knowledge to make an overview of the SME. The CHOOSE model is an instantiation of the CHOOSE metamodel that is developed and further refined throughout the action research cycles, based on the problems the CEO and the researchers encountered.

4.6) In terms of complexity, the number of metamodel concepts and relationships of CHOOSE is considerably lower than in other EA frameworks and kept to the bare minimum. The main benefits in the SME from the action research were threefold. First, because the EA was built from scratch, this offered considerable insight into the structure and inner workings of the SME. It was clear that the CEO became very enthusiastic after he had explicated his goals for the SME, because he experienced this entire process as a steep learning curve. Second, when managing the EA, the CHOOSE metamodel helped store decisions of meetings in one place (i.e. in the EA model). Third, CHOOSE provided the SME a platform for analysis and guided change, especially because of the built-in traceability by integrating four viewpoints into one metamodel. Among other things, it became possible to predefine analyses and enabled easy querying. In the SME, it was the OCL constraints that gave the most guidance. However, additional benefits are now becoming apparent while the SME is actually using the software tool. Some functions have already been programmed (e.g., Excel output, different viewpoints, querying) and others will mainly be developed in line with the feedback from the case study research that is conducted in other SMEs.

3.9 Conclusion

This chapter presents the design of the CHOOSE metamodel as the first effort to develop an EA approach specifically tailored to SMEs. The CHOOSE metamodel is designed according to the requirements for EA in an SME context (Bernaert et al. 2014). This is achieved by means of an action research programme in one specific SME, complemented by case study research in five more SMEs. The resulting metamodel is expressed as a UML class diagram, and extended with concept and relationship definitions in SBVR and intra- and inter-view constraints in OCL.

As the action research SME implemented certain changes according to the insights gained from the EA model, it was clear that the CHOOSE metamodel was indeed very valuable. In fact, CHOOSE is still used in the SME, with the help of a software tool to support it.

Nevertheless, further work is still required. A first limitation is that the scope of the research was limited to a single company, which is typical of action research. However, five more case studies were concurrently performed in different kinds of SMEs, as research indicates that SMEs differ significantly in size, sector, and other factors (Bernaert et al. 2014). The input, management, and output of CHOOSE models are hence tested in multiple SME settings. These case studies serve as input for the development and refinement of a method with step-by-step guidelines, for a further evaluation of the metamodel presented in this chapter, and for the evaluation of the benefits of EA for SMEs. For example, the explicit representation of business rules in the CHOOSE metamodel has to be further examined if the need arises in further case studies. Possibilities of how this representation could be achieved can be found in (Businska et al. 2012).

Another area for future research involves software tool support for different platforms. This would enable an easier interface for SMEs to input, adjust, and analyze their EA model. Prototypes for PCs (Ingelbeen et al. 2013), smartphones, and tablets (Bernaert et al. 2013; Dumeez et al. 2013) have already been developed and are currently being tested in different case studies. At present, we are also working on different possibilities to make as-is and to-be models and analyses, and are testing which best meet the needs of the SMEs. Moreover, the cognitive effectiveness of alternative notations for CHOOSE models (Boone et al. 2014) is being researched so as to provide a more efficient and effective visualization, since this also influences usability (Henderson-Sellers et al. 2012; Moody 2009a). Finally, an integration with ArchiMate is being developed. This would allow users to switch from CHOOSE to ArchiMate if a more elaborate EA approach is needed to increase effectiveness for experienced EA users (Rossi and Brinkkemper 1996) (e.g., if a more detailed representation of the IT architecture would be needed), or to switch from ArchiMate to CHOOSE (Roose et al. 2013).

4

Enterprise Architecture for Small and Medium-Sized Enterprises: Action Research to Develop, Refine, and Evaluate the CHOOSE Method

Submitted as Bernaert, M., Callaert, M., Poels, G., Snoeck, M., De Backer, M. (2015). Enterprise Architecture for Small and Medium-Sized Enterprises: Action Research to Develop, Refine, and Evaluate the CHOOSE Method. Revised after submission to Enterprise Information Systems.

Abstract. Enterprise architecture (EA) is a holistic approach to achieve business-IT and strategy-process alignment in a company. Recent research efforts indicate the need for EA in small and medium-sized enterprises (SMEs) due to problems related to a lack of structure and overview. Bernaert et al. (2015c) therefore developed the CHOOSE approach, an EA approach specifically adapted to the SME context. This chapter develops, refines and evaluates the method of this CHOOSE approach by means of action research. First, a CHOOSE method including step-by-step guidelines is developed from scratch and further refined. Four SMEs, a department of a large enterprise, and one complete large enterprise were used as multiple case studies in the action research programme. Second, as a side effect of implementing CHOOSE in the different companies, the earlier developed metamodel is refined and made more robust. As a final step of this research, both artifacts were independently evaluated by the CEOs of the SMEs and additionally by an SME expert with good knowledge of EA.

Keywords*: enterprise architecture; small and medium-sized enterprises; CHOOSE; action research; method; metamodel*

4.1 Introduction

According to Lankhorst (2013), enterprise architecture (EA) is a coherent whole of principles, methods, and models to provide a holistic overview of the enterprise. As EA captures the essentials of the enterprise, it enables the optimization of the company as a whole and thus, achieves business-IT and strategy-process alignment in the company. Bernaert et al. (2014) concluded that small and medium-sized enterprises (SMEs) face a number of problems due to a lack of structure and overview in the company. In addition, based on their exploratory research, it is also clear that there still exists a gap between current EA approaches and EA needs of SMEs.

Based on these two observations, Bernaert et al. (2014) offered the starting point to develop an EA approach for the SME context. This approach is called CHOOSE, an acronym for "keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise". The proposed CHOOSE approach includes only four essential dimensions (Goal, Actor, Operation, Object), one for each essential EA focus (Why?, Who?, How?, (With) What?). The CHOOSE approach consists of four EA artifacts (Jonkers et al. 2009): a metamodel and visualization, a method (including step-by-step guidelines and heuristics), and software tool support. In (Bernaert et al. 2015c) field research in an SME (a car tire center) was used to ground and apply the CHOOSE metamodel. The experiences with the car tire center made clear that a practical method is needed to support SMEs in applying the CHOOSE metamodel for EA modeling and that software tools could give additional support during this process. Additionally, more case studies were needed to evaluate and refine the metamodel and to make it more robust so as to increase its potential of wide applicability.

This chapter presents the development, refinement, and evaluation of CHOOSE through an action research programme. The focus in this chapter is on the construction of the method, and to a lesser extent on the impact of the action research on the earlier developed metamodel (Bernaert et al. 2015c). The development of software tool support (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013) and a visualization (Boone et al. 2014) is presented elsewhere.

In this action research programme, four SMEs with distinctive characteristics were selected. In addition, also an independent department of a large enterprise and one large enterprise were selected to test if the CHOOSE approach would produce different results in larger enterprises. As final step of the research, the CHOOSE method and metamodel were evaluated by the CEOs of the case study companies and by an SME expert with good knowledge of EA.

Section 4.2 describes the background of the action research by presenting the criteria for applying EA in an SME context and the derived design and evaluation criteria for the CHOOSE approach. It also presents the previous research for designing CHOOSE. In section 4.3, the research plan and methodology for the action research are presented. Section 4.4 gives an overview of the case study companies. Sections 4.5 and 4.6 present the study results, meaning the development process of the method and the refinement process of the metamodel. The chapter continues with an evaluation of both artifacts in section 4.7 and ends with conclusions in section 4.8.

4.2 Background

4.2.1 Enterprise Architecture

Lankhorst (2013) defines EA as "a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure". Based on an extensive study of the EA literature, Bernaert et al. (2014) derived five criteria for an EA approach:

1) Control: EA should be usable as an instrument in controlling the complexity of the enterprise and its processes and systems.
2) Holistic Overview: EA should provide a holistic overview of the enterprise and be able to capture the essentials of the enterprise, which are the elements that are stable and do not vary across specific solutions found for the problems currently at hand.
3) Objectives: EA should facilitate the translation from corporate strategy to daily operations.
4) Suitability: EA should be suitable for its target audience. It needs to be an approach that is understood by all those involved, even when coming from different domains.
5) Enterprise-wide: EA should enable optimization of the company as a whole instead of doing local optimization within individual domains.

The fourth criterion can be split up in criteria for the SME context, which will be discussed in the next section.

4.2.2 Small and medium-sized enterprises

The European Commission (2003) defines SMEs as companies that employ less than 250 employees and of which the annual turnover is less than 50 million euros or of which the total assets are less than 43 million euros. SMEs constitute over 99.8 percent of operating businesses in Europe. SMEs are not a homogeneous group. They can be classified according to size, industry sector, and other factors (e.g., family business or not) (De Nil et al. 2012).

Six criteria for the successful adoption and use of information systems in an SME context were distilled based on relevant literature of characteristics influencing IT adoption in SMEs (Bernaert et al. 2014), allowing to refine the fourth criterion of suitability of an EA approach for SMEs:

4.1) The approach should enable SMEs to work in a time efficient manner on strategic issues.
4.2) A person with limited IT skills should be able to apply the approach.
4.3) It should be possible to apply the approach with little assistance of external experts.
4.4) The approach should enable making descriptions of the processes in the company.
4.5) The CEO must be involved in the approach.
4.6) The expected revenues of the approach must exceed the expected costs and risks.

4.2.3 EA for SMEs (CHOOSE approach)

The derived criteria were integrated to form an evaluation model to which the proposed CHOOSE approach should adhere (section 4.7.1.3).

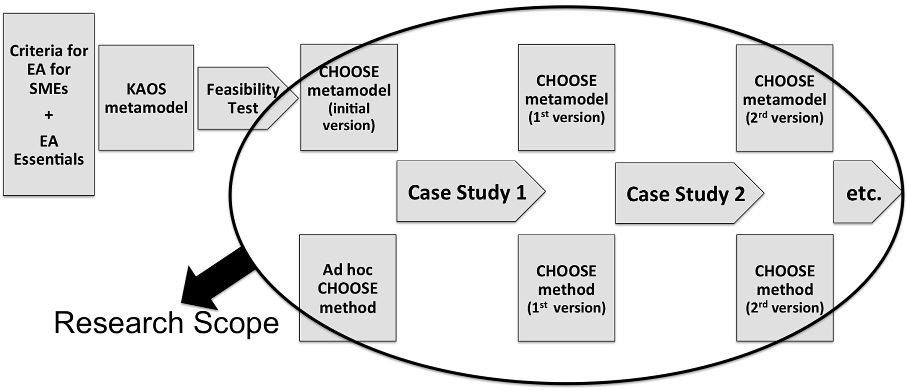

Figure 4.1: The research scope

The left part of Figure 4.1 shows that in previous research (Bernaert et al. 2015c), the KAOS metamodel (Van Lamsweerde 2009) was chosen as starting point for the development of an initial proposal for a CHOOSE metamodel, based on the criteria for EA for SMEs (sections 4.2.1 and 4.2.2) and on the essential dimensions and layers of EA metamodels. A feasibility test led to the development of an initial version of the CHOOSE metamodel (Bernaert and Poels 2011b). Figure 4.2 shows the initially developed CHOOSE metamodel from (Bernaert and Poels 2011b). It is based on four dimensions: a *Goal* dimension, an *Actor* dimension, an *Operation* dimension, and an *Object* dimension. This metamodel is used in this research as a starting point for the action research which was conducted in six case study companies, of which the first case study is the same and the mainly one used in the prior research in (Bernaert et al. 2015c). The initial CHOOSE metamodel enabled us to start making EA models of the SMEs, and thus served as a means to create the CHOOSE method as the focus of this research.

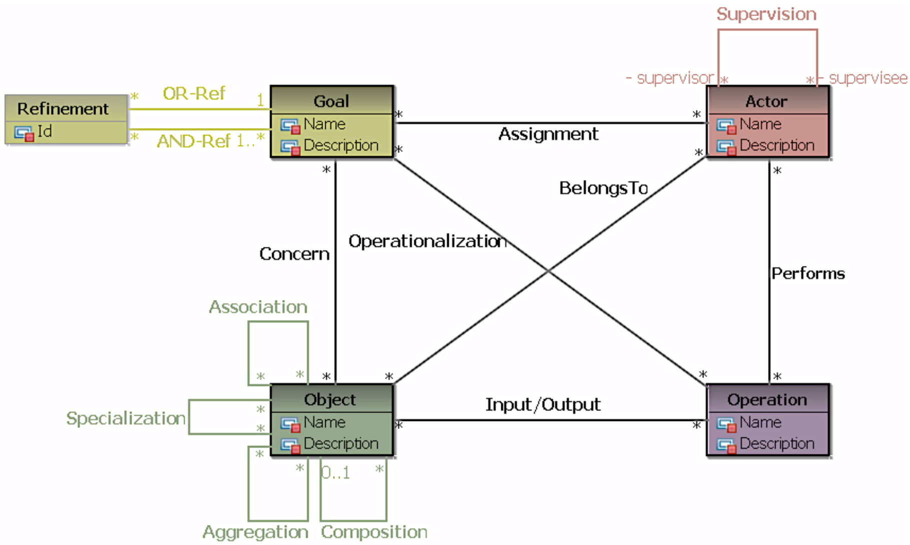

Figure 4.2: Initial CHOOSE metamodel from (Bernaert and Poels 2011b)

4.3 Methodology

Action research can be seen as an instance of the more general design science research methodology (Järvinen 2007). As we conducted our action research programme via case studies, our research methodology is guided by principles from design science, action research, and case study research. We first present how these different principles are addressed and next we present our concrete research plan.

4.3.1 Design Science

Design science (Hevner et al. 2004) is a well-known methodology to develop an artifact, such as the metamodel and method in this research.

The seven guidelines presented in (Hevner et al. 2004) were applied to this research. A method and metamodel are designed (guideline 1: design as an artifact) for EA in SMEs (guideline 2: problem relevance). Because design is inherently an iterative and incremental activity, the evaluation phase provides essential feedback to the construction phase. Hevner et al. (2004) proposed case study research as an observational design evaluation method. Multiple case studies are therefore used in this research (guideline 3: design evaluation). The design of the CHOOSE approach contributed new knowledge on how to apply EA in the SME context (Bernaert et al. 2014) (guideline 4: research contributions). The method and metamodel development is based on criteria resulting from previous EA and 'IT in SME' research (Bernaert et al. 2014) (guideline 5: research rigor). The iterative cycles of action research are used to develop and refine the method and to refine the metamodel (guideline 6: search process). Simon (1996) describes the nature of the design process as a Generate/Test Cycle. This corresponds with the cycles for development and evaluation of the CHOOSE method and metamodel. Finally, the approach is implemented and tested in several SMEs and communicated in this chapter (guideline 7: communication of research).

As Järvinen (2007) concluded that action research and design science are similar research approaches, the action research methodology is the main guideline of our research.

4.3.2 Action Research

The six characteristics of action research, presented by Susman and Evered (1978), also apply to our research:

1) Future-oriented: The research is oriented at creating a robust and refined method and metamodel.
2) Collaborative/participatory: The researcher and CEO of each case study company worked together to apply the CHOOSE metamodel in order to make an EA model of the SME, i.e. implementing the CHOOSE method.
3) Implies system development: The research is structured around the cyclical process of action research (diagnosing the problem, action planning, action taking, evaluating the consequences of the action, and specifying learning) (Susman and Evered 1978) in order to develop a new 'system' in the form of new EA artifacts.
4) Generates theory grounded in action: The research contributes to the development of a theory for design and action (Gregor 2006) (i.e., CHOOSE as a design theory for EA models for SMEs) by taking actions guided by theory (sections 4.5 and 4.6) and evaluating the consequences (section 4.7). Theory may be supported or revised on the basis of the evaluation.
5) Agnostic: During the research, the prescriptions for action and theories to refine the CHOOSE method and metamodel are also the product of previously taken action and are subject to re-examination and reformulation upon entering a new research situation (sections 4.5 and 4.6).
6) Situational: We know that many of the modeled constructs and relationships are a function of the situation since relevant actors currently define it.

Those six properties provide a corrective to the deficiencies of positivist science (Susman and Evered 1978). Susman and Evered (1978) further defined action research as a cyclical process with five phases. All these phases are necessary for a comprehensive definition of action research (Baskerville 1997):

- Diagnosing: Corresponds to the identification of the primary problems that are the underlying causes of the organization's desire for change: as a first step, every case study starts with diagnosing the characteristics of the particular enterprise and its particular challenges.

- Action planning: Specifies organizational actions that should relieve or improve these primary problems: during the CHOOSE implementation process at a particular case study company, different actions (e.g., introduce new model constructs) are proposed to improve the CHOOSE method and/or metamodel to deal with these challenges.
- Action taking: Then implements the planned action: after careful analysis, the planned actions are also incorporated in the CHOOSE method and/or metamodel (e.g., new metamodel constructs).
- Evaluating: Includes determining whether the theoretical effects of the action were realized, and whether these effects relieved the problems: after implementing the actions, the CHOOSE method and models (as instantiations of the metamodel) are evaluated by the CEOs and an expert.
- Specifying learning: The action research cycle can continue, whether the action proved successful or not, to develop further knowledge about the organization and the validity of relevant theoretical frameworks: if the actions are evaluated, the evaluation results (section 4.7.2) will influence the adoption of the actions in the CHOOSE method and/or metamodel.

The refinement process (sections 4.5 and 4.6) is structured around the first three phases (diagnosing, action planning, action taking). In addition, the evaluation of both artifacts (section 4.7) is organized around the two other phases (evaluating, specifying learning).

4.3.3 Case Study Research

Scientific research can be approached from different epistemological positions. It can thereby be based on three philosophical perspectives: a positivist, interpretive, and critical perspective (Yin 2009). The latter is about a world constrained by social, cultural, and political predominance and will not be discussed further. For our research, the interpretive perspective of case study research is taken. In contrast to the positivist perspective, the interpretive researchers start out with the assumption that access to reality is only through social constructions such as language, consciousness, and shared meanings. In contrast to the positivist research, interpretive research is not value-free. The researcher subjectively observes the reality (Yin 2009).

Despite the fact that an interpretive perspective is chosen, it is desirable to deal with the four design tests of the positivist perspective (Yin 2009) to support this interpretive perspective. The main design tests of this case study research are external validity and reliability. Construct and internal validity are less relevant.

- Construct validity: The research does not employ testable constructs, so construct validity is not an issue.
- Internal validity: This is mainly a concern for explanatory case studies (Yin 2009). Since the case studies are used for designing artifacts rather than explaining phenomena, this is not a concern.
- External validity: This deals with the problem of knowing whether the findings of the study are generalizable beyond the immediate case study (Yin 2009). In order to increase the external validity of this research, replication logic is used in multiple case studies. In our research, both literal and theoretical replication are used as a means for analytic generalization (Yin 2009): each of the four case studies in SMEs should produce similar results and confirm the suitability of the method and metamodel (literal replication), while the two other case studies in non-SMEs should produce different results (theoretical replication). An important step of the replication procedure is the development of a rich, theoretical framework (Yin 2009). In our research, this is the CHOOSE method and metamodel. A limitation of the case study evaluation is the fact that the results are not statistically generalizable (Yin 2009).
- Reliability: The goal is to minimize the errors and biases and maximize the falsifiability of a study. During this research, a case study protocol was followed and a case study database has been developed. The case study protocol prescribed that interviews would be used where the researcher asks questions and that every interview would be voice recorded. The case study database is constructed based on Yin's (2009) guidelines and includes voice recordings, notes, and the developed CHOOSE models of the case study companies. Due to confidentiality issues, these data cannot be made public in this chapter, however, an anonymous version of the case study database is shown in Figure 4.3.

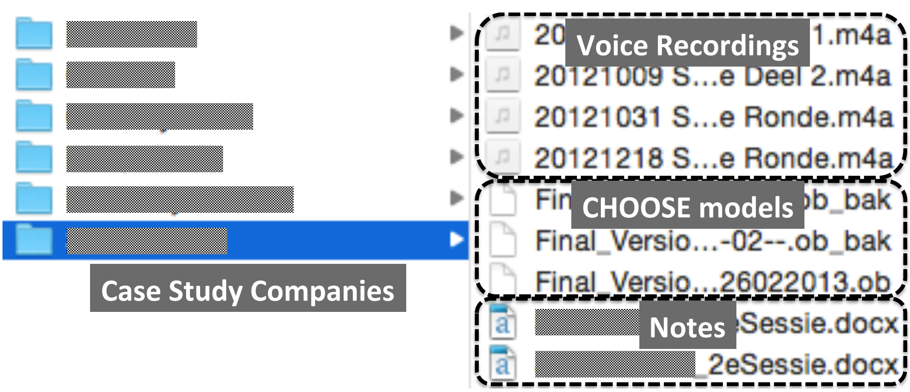

Figure 4.3: Case study database structure

4.3.4 Case Study Research as Action Research

Figure 4.4 summarizes our research plan. Multiple case studies were used in an action research programme (Baskerville 1997) to develop a CHOOSE method, which was in the beginning only an ad hoc way of working, and to refine the initial CHOOSE metamodel.

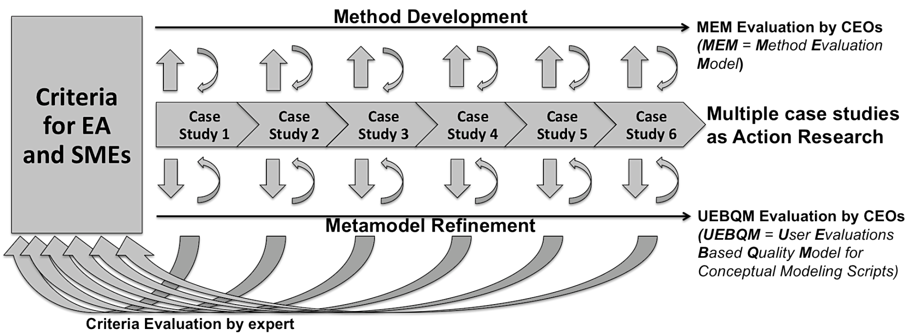

Figure 4.4: Research overview

In each of the six case studies, the method in its current state was used to develop an instance of the metamodel (also in its current state). If a shortcoming or issue in a particular case study was encountered, the cyclical process of action research (Susman and Evered 1978) was initiated to refine the CHOOSE method and metamodel. Afterwards both artifacts were evaluated by the case study companies' CEO and by an SME expert with good knowledge of EA.

In section 4.7, the evaluation is described. The method is evaluated by means of MEM (Moody 2003), the models by means of UEBQM (Maes and Poels 2007) and according to the criteria for EA and SMEs (Bernaert et al. 2014). The MEM and UEBQM evaluation frameworks will be presented in section 4.7.

In order to be able to analytically generalize the findings (Yin 2009) and thus produce a more robust method and metamodel, each of the case studies was chosen based on its unique characteristics. The case study portfolio is diversified based on size, industry sector, and family business or not (De Nil et al. 2012). When introducing the case studies in section 4.4, other distinguishing characteristics will be highlighted. Case studies 1 to 4 are performed in SMEs according to the definition of the European Commission (2003). Case studies 5 and 6 are not SMEs according to the definition (European Commission 2003) to check if using the CHOOSE method and metamodel in larger enterprises than a normal SME would produce different results (theoretical replication). Therefore important to notify is that the proposed adaptations (e.g., model constructs) of these two case studies were first tested in at least one SME (from case studies 1 to 4) before actually adapting the metamodel, since CHOOSE is intended for SMEs.

Section 4.5 presents the development of the CHOOSE method and section 4.6 describes the incremental refinement of the CHOOSE metamodel, both in chronological order (from case study 1 to 6). The case studies were started chronologically, but are mostly performed in parallel since each next case study was started shortly after the previous one, which explains the overlap during the different action research cycles. After we introduce each case study, we present the refinement process in three steps (Mohr 1982): problem/shortcoming identification, opening the solution space, closing the solution space.

4.4 Presentation of the Case Study Companies

4.4.1 Case study 1

The first case study is an SME with six permanent employees and additional temporary employees during the winter (busy) season. The company sells car tires and performs small maintenance jobs on cars. It has two differentiating elements: a difficult franchising relation and being governed by more than one person. It is the same SME as more extensively described during the initial development of the metamodel in (Bernaert et al. 2015c; Bernaert and Poels 2011b).

4.4.2 Case study 2

Case study 2 was done in a company that employs 11 full-time equivalents (FTE) and is active in the construction sector. It has three distinguishing features: strong growth (+27% increase in employees the previous year), organizational changes, and is governed by three partners.

4.4.3 Case study 3

Case study 3 was performed in a sanitary wholesaler that employs 37 FTE. It has four distinguishing characteristics: tough industry (consolidation), fragmented enterprise (representatives), part of a larger group (more than 100 employees), and larger size of the enterprise.

4.4.4 Case study 4

Case study 4 is a family-owned business in the no-added-sugar chocolate industry and employs 40 FTE. It has two distinguishing characteristics: focus on internationalization and the recent introduction of a new product group.

4.4.5 Case study 5

Case study 5 is an administration department of a university, which employs 3 FTE. Since a university can be considered as a large enterprise, we investigated the use of the CHOOSE approach in one department of a large enterprise. The department has three distinguishing features: various responsibilities/tasks per employee, lack of efficient process description, and part of a larger enterprise.

4.4.6 Case study 6

The last case study is not an SME, but a large global enterprise with more than 500 employees. The enterprise is active in the chemical industry. A limitation of the sixth case study is that we interviewed the Chief Financial Officer (CFO), instead of the Chief Executive Officer (CEO) of the company. This enterprise has two distinctive characteristics: entrepreneurial mind-set (despite its large size) and the continuous search and development of new growth markets.

4.5 CHOOSE method

The first CHOOSE artifact is a method and will be discussed in this section. It took on average 41 hours per case study to build a complete CHOOSE model (Table 4.1), except for the first case study in which only an ad hoc method was used. On average, 8 hours were used for interviewing the CEO and 33 hours were back office hours (without attendance of the CEO) during which the interviews were processed and the models were developed. In accordance with literature (van 't Wout et al. 2010; Van Lamsweerde 2009; Ross et al. 2006), there is no one-size-fits-all method (including step-by-step guidelines and heuristics) to implement the CHOOSE approach. The CHOOSE method has a roadmap (section 4.5.1) and an interview-method (section 4.5.2) and can be terminated upon reaching the stop-criteria (section 4.5.3). First of all, each initial design decision (adjustment or addition) concerning the roadmap and interview-method and stop-criteria was based on literature research. Secondly, these decisions were confirmed or slightly adapted based on our experience and informal evaluation by the SMEs' CEOs. Finally, the roadmap, interview-method, and stop-criteria are formally evaluated by the CEOs of the case studies (section 4.7.2.1). Since the experience and informal evaluation confirmed or only slightly adapted these decisions to arrive at the final method (sections 4.5.1.4, 4.5.2.4, 4.5.3.3), the decision process based on literature research is mainly described below. This literature research was performed every time when method-related problems were detected during the case studies. The method was mainly developed and refined during the first three case studies and stayed robust in further case studies. Therefore, only the first three case studies are described.

Since the metamodel also evolved during the case studies, references to both the initial metamodel (Figure 4.2) and the final metamodel (Figure 4.7) are used.

Table 4.1: Average time to implement the CHOOSE approach per case study

Activity	Time
Interviewing	3 rounds x 2,5 hours/round = 7,5 hours 7,5 hours + 0,5 hours (validation step) = **8 hours**
Analysis of the interview and writing the transcript	3 rounds x 4 hours/round = **12 hours**
Developing the CHOOSE models	3 rounds x 7 hours/round = **21 hours**
Total	**41 hours**

4.5.1 Roadmap

4.5.1.1 Case study 1

Since the *Goal* dimension is the main dimension of the CHOOSE approach (Bernaert and Poels 2011b), the CHOOSE method starts by eliciting the *Goals* of the company. The first challenge is to find a framework that allows us to holistically elicit the *Goals* of the case study company. Three potential frameworks were examined: the Balanced Scorecard (Kaplan and Norton 1992), the European Foundation for Quality Management (EFQM) Excellence Model (European Foundation for Quality Management 1999), and the Economic Value-Added (EVA) model (Adimando et al. 1994). Shulver et al. (2007) concluded that the Balanced Scorecard is a strategic management tool, while there are some doubts about the effectiveness of the EFQM Excellence Model as a strategic management tool. According to Lawrie (2006), the Balanced Scorecard is a strategic management tool, while EVA focuses on the development of financial goals for the organization. Since the Balanced Scorecard has been specifically developed to broaden the strategic view of a company on more than only financial aspects to give managers a fast but comprehensive view of the business and is widely known and used (Schelp and Stutz 2007), we decided to use the Balanced Scorecard in order to elicit the highest-level *Goals* as holistically as possible. The Balanced Scorecard (Figure 4.5) consists of four dimensions: financial, learning & growth, customer, and internal business processes.

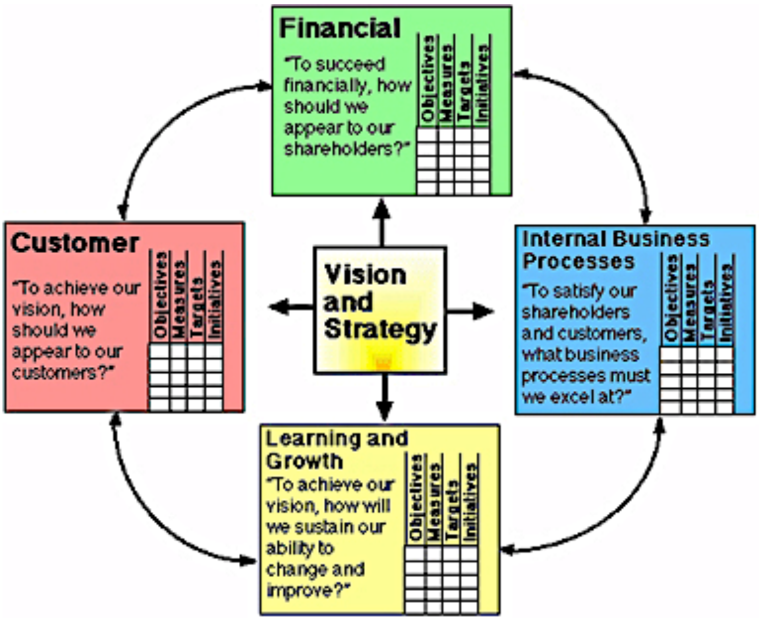

Figure 4.5: Balanced Scorecard (Kaplan and Norton 1992)

The highest-level *Goals* were described for the SME for each of the four dimensions of the Balanced Scorecard and were then broken down into lower-level *Goals* through How?-questions. Related higher-level *Goals* were found by asking Why?-questions (Bernaert et al. 2015c). We started from the elicited *Goals* in order to discover the *Actors*, *Operations*, and *Objects*. As final step of the CHOOSE method, there was a validation of the developed model by showing the complete CHOOSE model (in a visual representation) to the CEO in order to obtain feedback.

4.5.1.2 Case study 2

Since the elicitation of the *Operations*, *Objects*, and *Actors* was a time-costly process during the first case study, we started to look for a more efficient way to elicit the *Operations* and *Actors*. First of all, in order to holistically and efficiently elicit *Operations*, we explored three potential frameworks: Ishikawa (1982) diagram with material, machines, methods, technology, people, and processes; the McKinsey 7S model (Waterman et al. 1980); or Porter's Value Chain (Porter and Millar 1985). According to Pearson and Times (1999), a good strategy should cover every aspect of an enterprise (holistic overview). They conclude that Porter's Value Chain is very suitable to holistically describe the different activities of an enterprise and from there on derive a strategic impact. Since Porter's Value Chain (Figure 4.6) is also simple and more straightforward, the third alternative was used. It distinguishes between primary and support activities. The primary activities are composed of five elements: inbound logistics, operations, outbound logistics, marketing & sales, and service. In addition, four supporting activities are defined: firm infrastructure, human resource management, technology, and procurement.

Figure 4.6: Porter’s Value Chain (Porter and Millar 1985)

The *Operations* for the SME were grouped according to the different activity groups of Porter’s Value Chain and if necessary extra activity groups were defined. Each *Operation* was then further refined in *subOperations*. Secondly, in order to elicit the *Actors*, the organization chart of the SME was asked for.

4.5.1.3 Case study 3

In order to further increase the elicitation efficiency and test the method decisions, we incorporated a rigorous structure in the method’s roadmap. While no additional frameworks or techniques were added during the third case study, a clear six-step procedure was developed, as described below.

4.5.1.4 Final Roadmap

As already described, the CHOOSE method is structured around two well-known frameworks: the Balanced Scorecard (Kaplan and Norton 1992) and Porter’s Value Chain (Porter and Millar 1985).

The first is mainly used in order to elicit the *Goals* of the SME. The second is mainly used to elicit the *Operations* of the SME. Both are helpful in making the overview of *Goals* and *Operations* in a more exhaustive way. The roadmap has six consecutive steps:

1) (*Goal* dimension): The CEO of the enterprise is asked to define the highest-level *Goal* in each of the four Balanced Scorecard dimensions.
2) (*Goal* dimension): From the four highest-level *Goals*, the *Goals* are broken down into lower-level *Goals*. More *Goals* are found through the 'Why/How?'-questions (Bernaert et al. 2015c; Bernaert and Poels 2011b).

3) (*Actor* dimension): The *Human Actors*, *Roles*, *Software Actors*, and *Devices* are added through interviewing and consulting other secondary sources (e.g., organization charts).
4) (*Operation* dimension): The different activity groups of Porter's Value Chain (Porter and Millar 1985) are used to elicit the *Operations* (*Processes* and *Projects*). The *Operations* are linked with the other two dimensions (*Goals* and *Actors*).
5) (*Object* dimension): The *Objects* and corresponding relationships with *Goals* (*Concern*), *Actors* (*Monitoring*/*Control*), and/or *Operations* (*Input*/*Output*) are added to the model based on the interviews and visual inspection.
6) (Validation): The last step of the roadmap is a validation round of the model by the CEO.

4.5.2 Interview-method

4.5.2.1 Case study 1

During the first case study, it took three full days of interviewing the CEO in order to elicit the relevant elements. During the first day, we mainly elicited the *Goals* and *Operations* of the SME. Intermittently (between two interviewing days), an EA model was developed with the obtained information. During the second interviewing day, we mainly tried to incorporate the *Actors*, *Operations*, and *Objects* in the model. The EA model was validated during the third interviewing day. SMEs however have higher resource poverty (e.g., time) than their larger counterparts (Welsh and White 1981). This triggered the process to continuously improve this CHOOSE method.

4.5.2.2 Case study 2

From the second case study on, the CHOOSE model was created through three interviewing sessions of 2,5 hours with the CEO and intermittently developing the CHOOSE model with the obtained information. Case study 2 resulted in two adjustments of the interview-method. Firstly, van Lamsweerde (2009) suggests using three interaction techniques to efficiently acquire knowledge from stakeholders: interviews, visual observation, and group sessions. Related to the interview technique, there are three alternatives: unstructured questioning, structured questioning, or a combination of both. The third alternative is suggested by van Lamsweerde (2009) as it combines the merits of both. A structured interview supports more focused discussion, while an unstructured interview allows for the exploration of issues that might otherwise be overlooked. Thus, before every interview session, a specific interview guide (part of the case study database) was created. This resulted in a reduction of a full interviewing day to only 2,5 hours. Secondly, since the *Goal* and *Operation* dimension contain the highest number of elements and need a lot of refinement, there are two alternatives to cope with this: spend a whole interviewing session per dimension to insert and update the concepts and relationships, or splitting the insert- and update-phase of each of these two dimensions over separate interviewing sessions. The second alternative was selected as it enables the CHOOSE architect to model and read the obtained information intermittently between two interviewing sessions and afterwards, fill the gaps by asking structured questions during the next interviewing session.

4.5.2.3 Case study 3

The third case study enabled the interview-method to be structured in three consecutive interviews of 2,5 hours, as described below.

4.5.2.4 Final Interview-Method

In addition to the roadmap, the interviews are divided in three consecutive rounds:

1) During the first interview, step 1 and 2 of the roadmap are executed in order to create a holistic *Goal* tree of the enterprise. The second part of the interview focuses on the *Actor* tree by executing step 3.
2) The second interview is divided in three parts. First of all, a questionnaire, created after the analysis and implementation of the *Goal* and *Actor* tree of the first interview, is used to fill the gaps (e.g., missing elements or relationships) of the *Goal* and *Actor* tree. Secondly, the activity groups of Porter's Value Chain are used to define the *Operations* of the enterprise in each activity group (step 4). Thirdly, the *Objects* of the enterprise are added based on their relationships with the other three dimensions (step 5).
3) The third interview consists of two parts. Firstly, after analysis and implementation of the *Operations* tree and *Objects*, the interviewer tries to find missing constructs and relations or resolve ambiguities. Secondly, the interviewee (CEO of the SME) visually validates the final CHOOSE-model (step 6).

4.5.3 Stop-criteria

4.5.3.1 Case study 1

Since the CHOOSE approach consists of four dimensions, it is our aim to develop a stop-criterion for each dimension. In order to develop the stop-criteria of the CHOOSE method for the first case study, inspiration was found in KAOS (Van Lamsweerde 2009). First of all, van Lamsweerde (2009) defined the following *Goal-Refinement* stop criterion: "The process of asking How?-questions along a refinement path in the goal model terminates when we reach a fine-grained goal that can be operationalized." The heuristics for building *Agent*, *Operation*, and *Object* models are based on the already obtained *Goal* diagram. So secondly, following the logic of van Lamsweerde (2009), we identified the *Actors* based on their relationships (*Wish* and *Assignment*) with the *Goals*. Thirdly, van Lamsweerde (2009) defines *Operationalization* as the process of mapping leaf *Goals* to *Operations* ensuring them. Thus, each leaf *Goal* must be *Operationalized* by an *Operation*. Fourthly, the *Object* model has to be built systematically from the *Goal* model through the heuristics of van Lamsweerde (2009).

4.5.3.2 Case study 2

As already stated, the four stop-criteria of the first case study are derived of van Lamsweerde's (2009) heuristics. During our experience at the first and second case study, we did three adjustments to the initial stop-criteria. The bottom-line of the adjustments are based on the (previously) sole dependence of the three dimensions upon the *Goal* dimension.

First of all, based on our first case study experience, not all the *Actors* were included in the model. There were three proposed alternatives to cope with this issue: check if all the *Actors* of the organization chart are included and if every *Actor* is linked (*Wish* or *Assignment*) to a *Goal*; check if every *Actor* is linked to at least one *Operation* and *Goal*; or check if all *Actors* of the organization chart are included and check if every *Actor* is at least linked to one *Operation*. We opted for the third alternative for the following two reasons. First of all, all employees of the SME were in the organization chart. Further, the *Goals* are elicited through interviews with only the CEO-level of the SME, for which the model only contains the CEO's *Goal-Actor Wish* relationships and the *Goal-Actor Assignment* relationships the CEO is aware of. For the other *Actors*, only the *Assignment* with *Goals* can thus be checked objectively by asking the CEO.

Secondly, the *Operation* model was incomplete, because not all the *Operations* were linked to an *Actor*. The solution space only had one alternative: do a formal check if every *Actor* is *Performing* at least one *Operation* and preferably check if all *Operations* an *Actor Performs* are in the model. The formal check ensures the exhaustiveness of the *Operation* model.

Lastly, concerning the *Object* dimension, van Lamsweerde's (2009) heuristic resulted in an incomplete *Object* model. By investigating the issue, we discovered that the cause of the problem was the lack of relationship checks with the *Operations*. The issue was solved by checking if all the necessary *Objects* (*Input* or *Output*) of the *Operations* are included in the *Object* model.

4.5.3.3 Final stop-criteria

In analogy with the four dimensions of the CHOOSE metamodel, the stop-criteria are also fourfold. The CHOOSE architect has to do a quadruple check in order to terminate the input-phase:

1) *Goal* dimension: The *Goal*-check is twofold.
    a. Do the downward *Goal Refinement* paths of each *Goal AND-Refinement* and of one alternative of each *Goal OR-Refinement* only stop if at least one of its fine-grained *Goals* is *Operationalized*?

   b. Is every lowest-level (*AND-Refinement*) *Goal Operationalized* by an *Operation*? If this is not possible, there are two possibilities: it is a to-be *Goal* (another alternative of a *Goal OR-Refinement*) or there is a misfit between strategy and *Operations* (Henderson and Venkatraman 1993).
2) *Actor* dimension: The *Actor*-check is also twofold:
   a. Are all employees (*Human Actors* and *Roles*) of the organization chart, all other relevant stakeholders, and all relevant *Software Actors* and *Devices* included in the *Actor* dimension?
   b. Is every *Actor* linked to at least one *Operation*?
3) *Operation* dimension: First of all, take into consideration that relationships can sometimes be transferred to a related element (Bernaert et al. 2015c): a *superOperation* groups the relations (with e.g., *Goals*) of its *subOperations* and a lower-level *Goal* inherits the relations of its related higher-level *Goals* (with e.g., *Operations*). If for example a *superOperation* does not *Operationalize* any *Goal*, however one of its *subOperations* does, then this *superOperation* actually also *Operationalizes* this *Goal* through one of its *subOperations*. The *Operation*-check is then threefold:
   a. Are all *Performed Operations* for every *Actor* included?
   b. Does each *Operation* contribute to a *Goal*?
   c. Is every *Operation* linked to an *Actor*?
4) *Object* dimension: In analogy with the three other dimensions, the *Object*-check is also threefold:
   a. Are all products and resources (either physical or not) of the SME represented in the *Object* model?
   b. Are all the necessary *Objects* (*Input*/*Output*) of the *Operations* (*Operation* dimension) included in the *Object* dimension?
   c. Are all the necessary *Objects* of the *Goals* included in the *Object* dimension?

In addition, Bernaert et al. (2015c) proposed constraints in order to check the consistency of the model, for example to avoid that an *Actor* is *Responsible* for an *Operation* that *Operationalizes* a *Goal* that *Conflicts* with another Goal that is *Wished* by this *Actor*. The *Actor* would then normally not be the most motivated one to *Perform* that *Operation*.

A short remark is that in the SMEs where the model was updated frequently and used throughout the company on a regular basis, the model became more complete and consistent.

4.6 CHOOSE metamodel

After we introduce each case study, we present the refinement process in three steps (Mohr 1982): problem/shortcoming identification, opening the solution space, closing the solution space. To close the solution space and choose a solution for the refined metamodel, the principles of Paige et al. (2000) were referred to: simplicity, uniqueness, consistency, seamlessness, reversibility, scalability, supportability, reliability, and space economy.

4.6.1 Case study 1

During the implementation of the CHOOSE approach in the first case study, we encountered the following seven problems regarding the initial metamodel (Figure 4.2).

The first problem was that the CEO did not understand the three relationships in the *Object* dimension (*Aggregation*, *Composition*, *Specialization*). The solution space consisted of two alternatives: changing the name of these relationships or limiting the number of relationships. Since there is only a subtle semantic difference between *Composition* and *Aggregation*, it was decided to choose the second alternative. This choice was mainly based on the simplicity principle. Thus, the metamodel only offers the choice to specify an *Association* of *Objects* as either an *Aggregation* or *Specialization*.

Secondly, this SME with more than one person defining the company's goals needed a *Conflict* relationship. We explored two alternatives: obstacle analysis with a separate *Obstacle* construct (from the KAOS metamodel) (Bernaert et al. 2015c) or a *Conflict* relationship between the conflicting *Goal* constructs. The second alternative was chosen based on simplicity and uniqueness reasons.

Since the SME is governed by more than one person, there was a third need to know which stakeholder wishes which *Goal*. There are two potential solutions: add a new *Wish* relationship and rename the current *Goal-Actor* relationship as an *Assignment* relationship or only rename the current *Goal-Actor* relationship as a *Wish* relationship. It occurred to be useful in the first case study to incorporate both the *Assignment* and *Wish* relationship in the metamodel. This decision is mainly based on the exhaustiveness principle.

Fourthly, the SME's stakeholders were very interested to model an as-is and to-be model of the enterprise. During the investigation of this need, we explored three potential solutions: two separate models (an as-is and to-be model), using a particular symbol (e.g., '??') in the *Goal Name* to indicate a to-be *Goal*, or using the *Goal AND-Refinement* for as-is *Goals* and the *Goal OR-Refinement* for to-be *Goals* like in KAOS (Van Lamsweerde 2009). Based on simplicity, uniqueness, and consistency reasons, it was decided to model as-is *Goals* in *AND-Refinements* and to-be *Goals* as other alternatives in *OR-Refinements*.

Fifthly, it was not clear to the CEO in which case to model an object as an *Object* (passive object) or *Actor* (active object). There are two alternatives to solve this indistinctness: to incorporate a relationship between the *Object* and *Actor* (e.g., an *Object* relates to an *Actor*) or to *Specialize* an

Object as an *Entity* (passive) or *Actor* (active). Based on the simplicity and uniqueness principles, the second alternative was selected.

In addition to the five adjustments, we observed two other shortcomings that emerged in this case study, but they either did not weigh heavily enough to immediately search for a solution or they could possibly be related to this one company and were not generalizable with certainty. Therefore, these shortcomings were not yet solved, but were taken into account during the next case studies. First, there has to be a clear distinction for the CEO between a lowest-level *Goal* (wished) and *Operation* (performed). A second observation is that the CEO sometimes assigns a particular *Operation* to a person and sometimes to a role.

The two main benefits of the CHOOSE approach for the CEO are the holistic overview and the strategic thinking process during the interview rounds. After performing the case study, the CEO decided to buy an extra module for the ERP system to automatically check payments of invoices, because using CHOOSE triggered him to think about changing the actor that performed this operation.

4.6.2 Case study 2

This case study confirmed the five adjustments of the first case study and led to one metamodel adjustment.

Since three partners govern the SME, the previously added *Conflict* and *Wish/Assignment* relationships were very useful. Related to the *Object* dimension, the two adjustments (*Object Specialized* in *Entity/Actor* and the limited set of *Object* relationships) were advantageous to model the *Objects* of this case study company. Due to its strong growth, company 2 encountered major organizational changes. The ability to model as-is and to-be *Goals* respectively using an *AND-* and *OR-Refinement* resulted in an integrated overview of the SME's current (as-is) and future (to-be) *Goals*.

As already stated, the second case study resulted in one metamodel adjustment. Due to the strong growth, the company had some vacancies. The partners think in terms of roles instead of persons. Related to this observation, there are two alternatives in the solution space: the ability to explicitly specialize the *Actor* construct in *Human Actor* and *Role* constructs or use the generic *Actor* construct for both human actors and their roles. The first option was chosen since the ability to assign a *Human Actor* to a particular *Role* increased the exhaustiveness and consistency of the metamodel and was also asked for in the first case study.

According to the CEOs, the main benefits of the CHOOSE approach are the ability to model as-is and to-be *Goals* and the strategic thinking process during the interviews. In addition, the holistic overview and potential for change impact analysis are also two benefits of the CHOOSE approach according to the CEOs.

Based on the insights gained during the case study, this SME could identify a strategic goal to remove the growth barrier of the companies and the three partners finally decided to purchase a new office building.

4.6.3 Case study 3

This case study confirmed four metamodel adjustments and proposed two metamodel adjustments.

Since the SME is part of a larger group and has many stakeholders, the *Wish/Assignment* and *Conflict* relationships proved their utility. In contrast to the two previous case studies, case study 3 doubled the number of employees and thus strongly confirmed the need to *Specialize* the *Actor* construct in *Human Actor* and *Role* constructs. Fourthly, case study 3's *Objects* are hierarchically structured. Thus, this confirmed the need to *Specialize* higher-level *Objects* in lower-level *Objects* to, for example, build a product overview.

In addition, during our experience at the third case study firm, two shortcomings were discovered. First of all, the CEO and stakeholders structure their business in business units. Therefore, there is a need to group the employees. The solution space had three alternatives: the use of an *Actor* attribute that groups the *Actors*, a separate *Group* construct to assign the *Actors* to, or a reflexive *Aggregation* relation with the *Actor* construct. The third alternative was selected based on simplicity and consistency reasons. After implementation of this change in the first two case studies, it also helped making better organizational structures of the employees in these SMEs. Secondly, according to the CEO, there is a significant difference between processes (short-term, repetitive, etc.) and projects (long-term, non-repetitive, etc.), as also noticed in the first case study. In order to deal with it, we explored three alternatives: *Specialize* the *Operation* construct in a *Process* and *Project* construct, add a Boolean attribute (Yes/No) to the *Operation* construct, or use a particular symbol in the *Operation Name*. Based on exhaustiveness, uniqueness, and consistency reasons, we opted for the alternative to *Specialize (Optional, Or)* the *Operation* construct in *Process* and *Project* constructs.

The main benefit of the CHOOSE approach to the CEO is the holistic strategic overview.

4.6.4 Case study 4

The fourth case study mainly confirmed three adjustments and discovered three desirable adjustments to the metamodel.

Since the fourth case study organization is also quite big (40 FTE), the ability to *Specialize* the *Actor* construct in *Human Actor* and *Role* is very useful. Secondly, due to its international and dynamic environment with new product launches, the utilization rate of the *Project* construct is high. Further, the *Aggregation* relation of the *Actor* construct is very useful to assign an *Actor* to a particular business unit.

In addition, the experience during the fourth case study advised three metamodel adjustments. Firstly, the CEO expressed the need to specify the *Actor-Operation* relation. After a careful investigation of potential solutions, the solution space consisted of three alternatives: ad-hoc customized relations; a relation based on the responsibility assignment matrix (RAM or acronym RACI) (ISACA 2012): Responsible, Accountable, Consulted, Informed; or a RACI standard relation with the ability to add customized relations. The third alternative is taken based on the consistency and simplicity principles, however, also taking flexibility into account in choosing different responsibility assignment *Types* if other standards than *RACI* are used by the SMEs. Secondly, since the fourth case study had a lot of different *Operations*, there was a need to structure the *Operations* hierarchically. The first case study also confirmed this need, because of the otherwise unstructured operation overview. The solution space consisted of two alternatives: adding a many-to-many *Includes* relation or use the *Operation Description* to structure the *Operations*. We opted for the first alternative based on the exhaustiveness and consistency principles. Thirdly, there is a need to model an *Object* as an *Input* or *Output* of the *Operation*. We explored two alternatives: add a separate *Input* and *Output* relation between the *Object* and *Operation* or describe the relation type in the relation *Description*. The first alternative is taken based on exhaustiveness and consistency reasons.

According to the CEO, the principal benefit of the CHOOSE approach is the holistic overview with the ability to assign *Operations* to *Actors* with the *RACI* relation.

4.6.5 Case study 5

The fifth case study mainly confirmed five metamodel adjustments and explored the need to do one metamodel adjustment.

Related to the EA version of this operational department, the need to *Specialize* an *Object* into an *Entity* or *Actor* and to model a *RACI Performance* relation between the *Actors* and *Operations* was evident. In addition, the *Project* construct and *Conflict* relation (between *Goals*) had a high utilization rate. Finally, as documents were often used to read or adjust, an *Object* was often modeled as an *Input* or *Output* of an *Operation*.

Since the fifth case study allowed us to model a more detailed EA version of the small department, one metamodel adjustment is mainly useful at a more day-to-day operational level. Since the small department of case study 5 is quite operational and part of a larger enterprise, there are accessibility and security rights of *Actors* to *Objects*. In exploring this metamodel shortcoming, there are two alternatives in the solution space: add a *Monitoring* and *Control* relation between the *Actor* and *Object* construct like in KAOS (Van Lamsweerde 2009) or describe the kind of relation in a relation *Description*. Based on exhaustiveness and consistency reasons, we opted for the first alternative. *Monitor* means that an *Actor* has read rights, while *Control* means that an *Actor* has create and write rights. This seemed very useful in addition to the *Input* and *Output* relationship of *Objects* and *Operations* to describe the necessary rights. After testing this non-SME initiated need for a metamodel adjustment in the previous four SMEs, it also proved to provide the necessary benefits in real SMEs, especially for confidential financial and new product data. Therefore, the adjustment was incorporated in the CHOOSE metamodel.

The main benefit of the CHOOSE approach to the employees of the fifth case study is the strategic thinking process during the interviews and the possibility to make the process flow more efficient. For example, the department began to search for an e-mail management system and for a better job distribution between the employees after the first round of the case study.

4.6.6 Case study 6

The sixth case study allowed us to confirm four metamodel adjustments, but did not lead to additional adjustments, which we would otherwise critically investigate since CHOOSE is intended for SMEs. Given the fact that the sixth case study is a large enterprise (more than 500 employees), the *Includes* (between *Operations*) and *Aggregation* relation (between *Actors*) seemed to be very useful. In addition, the use of *Roles* and *RACI Performance* relationships had a very high utilization rate.

According to the CFO, the main benefit of the CHOOSE approach is the strategic thinking process. Despite the fact that the CFO is convinced of the holistic overview ability in an SME context, he raised his doubts about the feasibility to holistically model a large enterprise with the CHOOSE approach. The created CHOOSE model for example particularly modeled the parts of the company from the CFO's viewpoint.

4.6.7 Final CHOOSE metamodel

Bernaert et al. (2015c) proposed two additional metamodel adjustments that did not originate primarily from the case studies. These adjustments were primarily added to adhere to the earlier discovered essentials of EA frameworks (Bernaert et al. 2015c). First of all, as already stated in case study 1, there has to be a clear distinction between the lowest-level *Goal* and *Operation*. In order to deal with this issue, there is a separation of strategic domain (*Goal*) and operational solutions incorporating implementation constraints (*Operation*) through *Goal* modeling and *Operationalization* (Bernaert et al. 2015c; Van Lamsweerde 2009). Simply said: "You first have to dream before limiting your dreams". 'Dreaming' takes place when the company's *Goals* are expressed, while 'limiting the dreams' is done when *Operations* are being expressed to fulfill (*Operationalize*) these dreams (*Goals*). 'Dreaming' takes place in CHOOSE's *Goal* dimension, while 'doing' takes place in CHOOSE's *Operation* dimension. Of course, an ideal situation takes place when a 'dream' is fulfilled; this is when an *Operation* is similar (without any implementation constraints) to the *Goal* it is fulfilling (*Operationalizing*). Secondly, the blend of the three architectural layers (business, IS, IT) is the reason to *Specialize* the Actor construct in *Human Actor* (business), *Role* (business), *Software Actor* (IS), and *Device* (IT). All four types were already used in the case studies, however, often without explicitly specializing these *Actors*. Figure 4.7 is the final result of the metamodel development and refinement process (Bernaert et al. 2015c).

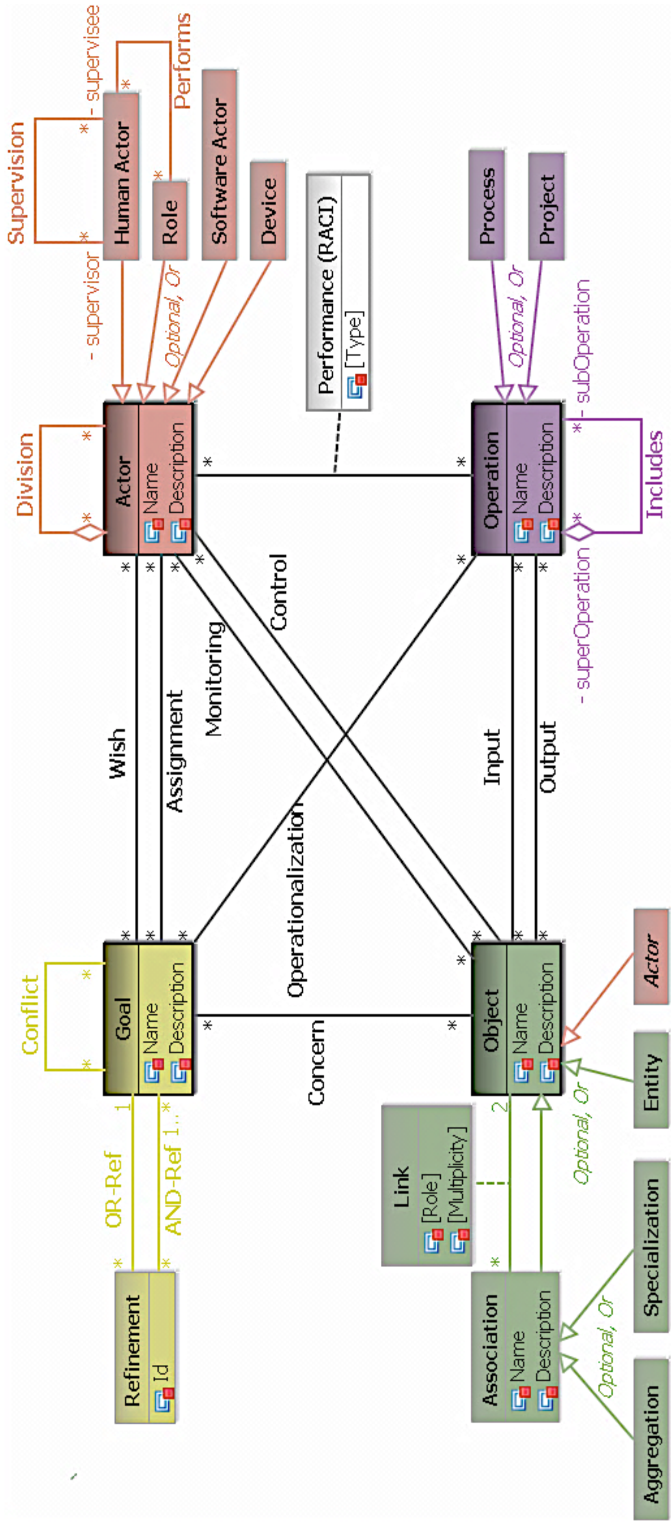

Figure 4.7: The final CHOOSE metamodel (from (Bernaert et al. 2015c))

4.7 Evaluation

4.7.1 Evaluation models

The CHOOSE method and metamodel are evaluated in three steps. First of all, the CHOOSE method is evaluated by Moody's (2003) Method Evaluation Model. Secondly, the quality model of Maes and Poels (2007) is used to evaluate the developed instances of the CHOOSE metamodel (CHOOSE models). Thirdly, the CHOOSE models are evaluated with respect to the initial criteria for EA in an SME context (sections 4.2.1 and 4.2.2).

The two first steps are evaluated by the CEOs of the case study companies. In contrast, an SME expert with good knowledge of EA performed the third evaluation.

4.7.1.1 Method Evaluation Model

The Method Evaluation Model (MEM) (Moody 2003) is a theoretical model for validating IS design methods. It is based on the Technology Acceptance Model (TAM) (Davis 1989) and Methodological Pragmatism (Rescher 1977). Both theories will be shortly described before presenting the MEM.

The Technology Acceptance Model (TAM) is a well-known model regarding the adoption of IS technology (Davis 1989). It consists of four important constructs:

1) Perceived Usefulness: "The degree to which a person believes that using a particular system would enhance his or her job performance."
2) Perceived Ease of Use: "The degree to which a person believes that using a particular system would be free of effort."
3) Intention to Use: "The extent to which a person intends to use a particular system."
4) Actual System Use: "The extent to which a system is used in practice."

Both Perceived Usefulness and Perceived Ease of Use influence the Intention to Use. Davis (1989) measures both variables (Perceived Usefulness and Perceived Ease of Use) using six-item scales (Table 4.2). In addition, it should be emphasized that Perceived Usefulness and Perceived Ease of Use are people's subjective appraisal of performance and effort, respectively.

Table 4.2: Perceived Usefulness and Perceived Ease of Use (Davis 1989)

Perceived Usefulness	Perceived Ease of Use
1. Work more quickly	1. Easy to learn
2. Improve job performance	2. Controllable
3. Increase productivity	3. Clear and understandable
4. Enhance effectiveness	4. Flexible to interact with
5. Makes job easier	5. Easy to become skillful
6. Useful	6. Easy to use

Methodological Pragmatism (Rescher 1977) assumes that methods have no truth-value, only pragmatic value. Pragmatic success is defined as "the efficiency and effectiveness with which a method achieves its objectives". "The validity of a method can only be established by applicative success in practice." (Rescher 1977) This is the reason why we implemented the CHOOSE approach in six consecutive case studies. "The objective of validation should not be to demonstrate that the method is 'correct' but that it is rational practice to adopt the method based on its pragmatic success." (Rescher 1977)

The Method Evaluation Model (MEM) (Figure 4.8) is a theoretical model for evaluating IS methods that combines both TAM and Methodological Pragmatism (Moody 2003).

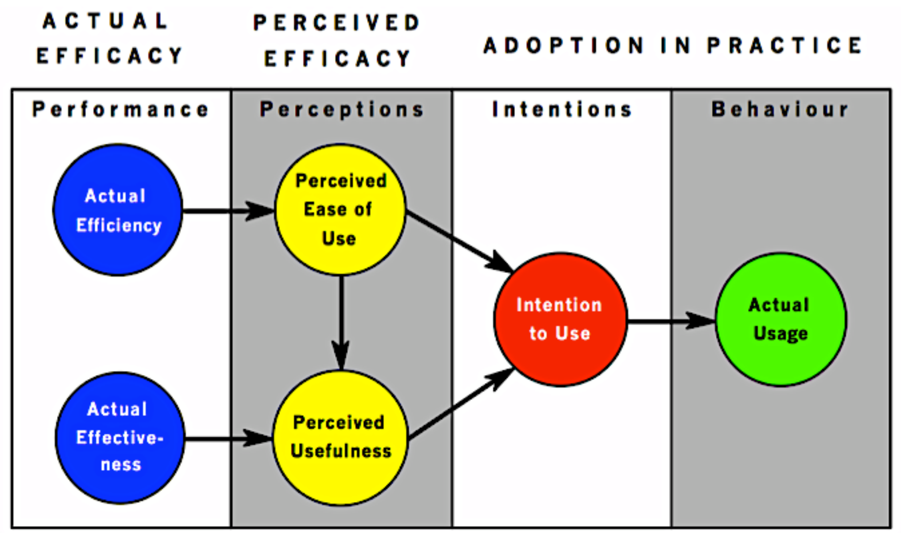

Figure 4.8: Method Evaluation Model (Moody 2003)

The constructs of the model are:

- Actual Efficiency: "The effort required to apply a method." (Methodological Pragmatism) (Rescher 1977)
- Actual Effectiveness: "The degree to which a method achieves its objectives." (Methodological Pragmatism) (Rescher 1977)
- Perceived Ease of Use (TAM) (Davis 1989)
- Perceived Usefulness (TAM) (Davis 1989)
- Intention to Use (TAM) (Davis 1989)
- Actual Usage (TAM) (Davis 1989)

The relationships are shown in Figure 4.8, where the arrows show the causal relationships between the constructs of the model:

- Actual Efficiency has an effect on Perceived Ease of Use: Actual Efficiency measures the effort required to apply the method, which affects perceptions of effort required.

- Actual Effectiveness has an effect on Perceived Usefulness: Actual Effectiveness measures how well the method achieves its objectives, which impacts perceptions of its effectiveness.
- Perceived Usefulness is determined by its Perceived Ease of Use. This follows from TAM.
- Intention to Use a method is jointly determined by its Perceived Ease of Use and Perceived Usefulness. This follows from TAM.
- Actual Usage of a method is determined by Intention to Use. This also follows from TAM and the Theory of Planned Behaviour (Ajzen 1991), which establishes that perceptions influence intentions which in turn influence the actual behavior of the individual.

The main difference with TAM is that in the Method Evaluation Model Actual Efficiency and Effectiveness influence the Intentions to Use a method only via Perceptions of Ease of Use and Usefulness. This is a subtle difference, but an important one: in human behavior, subjective reality is more important than objective reality. The perceptions will also be influenced by other factors (e.g., prior knowledge, experience with particular methods, normative influences) not included in the evaluation model.

Moody (2003) and Rescher (1977) emphasized that the validity of a method can only be established by applicative success in practice. Therefore, the CHOOSE method was developed and refined during action research in different SMEs in an attempt to increase its validity (in terms of pragmatic value). During the evaluation phase of the action research cycle, the CEO of the SME in which the case study for the cycle was conducted, evaluated the CHOOSE method by a questionnaire based on Moody's (2003) reformulations of the TAM six-item scales for Perceived Usefulness and Perceived Ease of Use (Table 4.3) on a 7-point Likert scale from 'strongly disagree' to 'strongly agree'. Measures for Actual Efficiency and Actual Effectiveness must be developed for each class of methods, based on their objectives and the task being evaluated. There is no way to prescribe these apart from general guidelines about measures of time, cost and cognitive effort (efficiency), and quantity and quality of results (effectiveness). Therefore, Moody (2003) rather proposes measures for Perceived Usefulness and Perceived Ease of Use, which we used in our evaluation.

Table 4.3: Questionnaire for Perceived Usefulness and Perceived Ease of Use

Perceived Usefulness	PU_1	The CHOOSE method enabled me to more quickly create the CHOOSE model.
	PU_2	With the aid of the CHOOSE method, I was able to create a better and more consistent model.
	PU_3	The structured CHOOSE method contributes to an increased productivity.
	PU_4	The applied CHOOSE method increases the effectiveness of the enterprise architecture process and contributes to the final result.
	PU_5	The offering of the method facilitates the enterprise architecture process.
	PU_6	I consider the applied method as a useful aid in creating the enterprise architecture model.
Perceived Ease of Use	PEU_1	It is easy to learn to work with the CHOOSE method.
	PEU_2	The CHOOSE method is easily controllable.
	PEU_3	The structure of the CHOOSE method is straightforward, clear, and understandable.
	PEU_4	The CHOOSE method can be applied flexibly.
	PEU_5	I feel that I will quickly get to master the CHOOSE method.
	PEU_6	The CHOOSE method is easy to use.

4.7.1.2 User Evaluations Based Quality Model

Maes and Poels (2007) contend that the basic structure of IS success models (such as the DeLone and McLean (1992) model) provides a suitable basis for a user evaluations based model of model quality (UEBQM) because the IS effectiveness or success dimensions in these success models can also be applied to assess model quality. The CHOOSE metamodel will therefore indirectly be evaluated by evaluating its model instances developed in the different case studies. UEBQM consists of four model constructs and five model relationships (Figure 4.9). Maes and Poels (2007) empirically confirmed these relationships and demonstrated the explanatory power of the model.

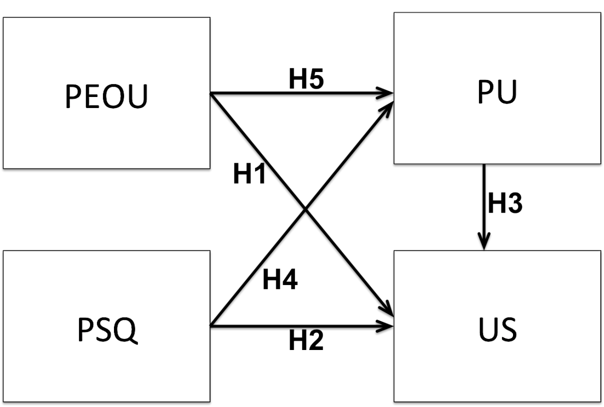

Figure 4.9: UEBQM (Maes and Poels 2007)

The model constructs are:

- Perceived Semantic Quality (PSQ): Measures how accurately and completely the model represents the reality which it intends to model, as perceived by a model user.
- Perceived Ease of Understanding (PEOU): Is defined as the degree to which a person believes that using a model for understanding the problem domain and IS requirements would be free of mental effort.
- Perceived Usefulness (PU): Is defined as how effective the model is in expressing and communicating the users' view of the domain and the IS requirements.
- User Satisfaction (US): The general evaluation of the quality of a model can be measured in terms of how satisfied users are with the model with respect to its purpose.

A multi-item measurement instrument (Table 4.4) for all four constructs was proposed (Maes and Poels 2007).

Table 4.4: UEBQM measurement instrument (Maes and Poels 2007)

$PEOU_1$	It was easy for me to understand what the CHOOSE model was trying to model
$PEOU_2$	Using the CHOOSE model was often frustrating
$PEOU_3$	Overall, the CHOOSE model was easy to use
$PEOU_4$	Learning how to read the CHOOSE model was easy
US_1	The CHOOSE model adequately met the information needs that I was asked to support
US_2	The CHOOSE model was not efficient in providing the information I needed
US_3	The CHOOSE model was effective in providing the information I needed
US_4	Overall, I am satisfied with the CHOOSE model for providing the information I needed
PU_1	Overall, I think the CHOOSE model would be an improvement to a textual description of the company
PU_2	Overall, I found the CHOOSE model useful for understanding the company modeled
PU_3	Overall, I think the CHOOSE model improves my performance when understanding the company modeled
PSQ_1	The CHOOSE model represents the company correctly
PSQ_2	The CHOOSE model is a realistic representation of the company
PSQ_3	The CHOOSE model contains contradicting elements
PSQ_4	All the elements in the CHOOSE model are relevant for the representation of the company
PSQ_5	The CHOOSE model gives a complete representation of the company

For each statement, a 7-point Likert scale with response options ranging from 'strongly disagree' to 'strongly agree' was offered (Maes and Poels 2007). This measurement instrument is used to evaluate the developed CHOOSE models by the CEOs of the case study organizations. Of course this is an indirect evaluation of the CHOOSE metamodel. A bad modeler could make a model that gets a bad evaluation, however being based on a good metamodel. Since we kept a close look at the modeling during the case studies, this influence is limited.

4.7.1.3 CHOOSE-criteria

An SME expert with good knowledge of EA and not involved in the research, evaluated the six CHOOSE models, as instances of the CHOOSE metamodel, with a Boolean variable (YES/NO) for each of the 10 initial design criteria (sections 4.2.1 and 4.2.2). This independent expert was used as a means to get an independent evaluation against the design criteria.

4.7.2 Evaluation results

4.7.2.1 Evaluation by the SMEs

The results of the method and model evaluation by the CEOs of the different case study companies are shown in Table 4.5.

Table 4.5: Results of the CEO evaluation

Evaluation / Case Study (CS)		CS 1	CS 2	CS 3	CS 4	CS 5	CS 6	Avg.
Method Evaluation (cf. Table 2) 7-point Likert scale Strongly disagree: **1** Disagree: **2** Slightly disagree: **3** Neutral: **4** Slightly agree: **5** Agree: **6** Strongly agree: **7**	PU_1	**6**	**4**	**6**	**5**	**5**	**6**	**5,61**
	PU_2	**6**	**5**	**7**	**6**	**5**	**6**	
	PU_3	**6**	**7**	**6**	**4**	**4**	**4**	
	PU_4	**6**	**6**	**7**	**4**	**5**	**6**	
	PU_5	**6**	**4**	**7**	**6**	**5**	**7**	
	PU_6	**6**	**6**	**6**	**6**	**4**	**7**	
	PEU_1	**6**	**5**	**6**	**6**	**4**	**6**	**5,11**
	PEU_2	**6**	**4**	**5**	**6**	**4**	**6**	
	PEU_3	**6**	**5**	**4**	**6**	**5**	**6**	
	PEU_4	**5**	**4**	**4**	**5**	**4**	**5**	
	PEU_5	**6**	**4**	**6**	**6**	**4**	**6**	
	PEU_6	**6**	**4**	**5**	**6**	**4**	**4**	
Metamodel evaluation (cf. Table 3) 7-point Likert scale Strongly disagree: **1** Disagree: **2** Slightly disagree: **3** Neutral: **4** Slightly agree: **5** Agree: **6** Strongly agree: **7** *Cursive:* negative statement	$PEOU_1$	**6**	**3**	**5**	**5**	**4**	**6**	**4,54**
	$PEOU_2$	***2***	***5***	***6***	***3***	***3***	***2***	
	$PEOU_3$	**6**	**4**	**5**	**5**	**4**	**5**	
	$PEOU_4$	**6**	**5**	**4**	**6**	**4**	**5**	
	US_1	**6**	**6**	**6**	**5**	**5**	**5**	**5,25**
	US_2	***2***	***3***	***3***	***3***	***3***	***3***	
	US_3	**6**	**6**	**6**	**6**	**5**	**5**	
	US_4	**6**	**6**	**5**	**6**	**5**	**6**	
	PU_1	**6**	**7**	**7**	**4**	**5**	**6**	**5,56**
	PU_2	**6**	**6**	**6**	**5**	**5**	**6**	
	PU_3	**6**	**6**	**5**	**5**	**4**	**5**	
	PSQ_1	**6**	**5**	**6**	**5**	**5**	**5**	**5,27**
	PSQ_2	**6**	**5**	**6**	**6**	**5**	**6**	
	PSQ_3	***2***	***3***	***3***	***2***	***4***	***3***	
	PSQ_4	**6**	**5**	**6**	**5**	**6**	**7**	
	PSQ_5	**5**	**5**	**5**	**5**	**6**	**6**	
General evaluation 5-point Likert scale Very bad: **1** Bad: **2** Neutral: **3** Good: **4** Very good: **5**		**4**	**5**	**4**	**4**	**4**	**4**	**4,17**

The results of the negatively formulated statements of $PEOU_2$, US_2, and PSQ_3 are interpreted as the inverse results (so 1 becomes 7, etc.) to calculate the average and interpret these results correctly.

4.7.2.1.1 General Evaluation

The CEOs evaluated the CHOOSE approach on average as ‘good’ on a 5-point Likert scale (from ‘very bad’ to ‘very good’) as a general evaluation in Table 4.5. The CEO of case study 2 is the only one who evaluated the CHOOSE approach as ‘very good’ and stated: “The CHOOSE approach is capable of structurally mapping out an SME in a clear way and from these data assess the weaknesses, strengths, and effects of changes”. The CEO of case study 3 described the value of the CHOOSE approach in a similar way, with the only addition that the CHOOSE approach can also be used to demonstrate conflicting goals. The CEO of case study 1 described the added value of the CHOOSE approach as “the ability to shift the scope on the company and to see the processes of the company in a relatively simple way and being able to evaluate these processes according to efficiency”. Both CEOs of case studies 3 and 6 have the same critical remark: “Who within the SME will make an initial EA model and will keep it up to date?”

4.7.2.1.2 Method Evaluation

The CHOOSE method was evaluated by the CEOs based on MEM (Moody 2003). To remind them of the applied method, a transcript of the applied CHOOSE method was first given before filling in the questionnaire. The adapted six-item scales of Davis (1989) (Table 4.2) of both variables (Perceived Usefulness and Perceived Ease of Use) are positively evaluated by the CEOs.

The CEOs more than slightly agree that the CHOOSE method has a high degree of Perceived Usefulness (cf. PU in Table 4.5). The CEO of case study 3 made the following statement: “The approach was positive: through a limited number of interviews a complete and accurate picture of the firm has been outlined”.

The CEOs also more than slightly agree that the CHOOSE method has a high degree of Perceived Ease of Use (cf. PEU in Table 4.5). However, this score is relatively lower than the PU, most influenced by the scores given by case studies 2 and 5. The method in case study 2 was at that time still unstructured and the interviewing time was decreased from 1 day per interview in case study 1 (of which the CEO gives a rather high score) to 2,5 hours per interview in case study 2. The relatively lower score on PEU for case study 5 is, to our experience, a result of two causes. First, the interviewees of this department found the implementation of the CHOOSE approach rather an interesting thinking exercise, making them less motivated to fully master the CHOOSE method used. Second, they did not have any business related background and were not familiar with the frameworks used (e.g., Balanced Scorecard and Porter’s Value Chain) to include all relevant elements of their department in the CHOOSE model.

4.7.2.1.3 Metamodel Evaluation

Based on UEBQM (Maes and Poels 2007), the CEOs more than slightly agree that their CHOOSE models (as instances of the CHOOSE metamodel) have a good Perceived Semantic Quality (cf. PSQ in Table 4.5). They all mentioned during the validation round of their CHOOSE model that all important elements of the company were correctly included in the model.

The CEOs less than slightly agreed with a good Perceived Ease of Understanding (cf. PEOU in Table 4.5). The PEOU received the lowest score, most influenced by the scores given by case studies 2, 3, and 5. The CEOs of case study 2 and 3 had given the remark regarding the model (i.e. the instantiation of the metamodel) that a manual of CHOOSE would increase the comprehension and readability of the metamodel. In addition, we also received the remark that the switch-over from implementation by means of interviews to the effective use of the model was quite large and difficult because during the interviews the interviewees were shielded from the actual modeling of the constructs and relationships of the CHOOSE model. We can conclude that the CEOs of the case study companies should have been more involved during the construction of their CHOOSE models.

In accordance with the causal relationships in UEBQM, this resulted in a more than slightly agreeing with a good Perceived Usefulness (cf. PU in Table 4.5) and also with a good User Satisfaction (cf. US in Table 4.5).

4.7.2.2 Evaluation by an SME expert with good knowledge of EA

The six CHOOSE models are evaluated towards the ten initial criteria for EA in an SME context (sections 4.2.1 and 4.2.2). Since the CHOOSE models are instances of the CHOOSE metamodel, the aim of this evaluation step is to indirectly evaluate the CHOOSE metamodel towards these criteria. An academic with wide consulting experience, who is an expert in the use of IT in SMEs and possesses a good knowledge of EA, but was not involved in our research, evaluated the six CHOOSE models (Table 4.6).

Table 4.6: Results of the expert evaluation

Criteria / Case Study (CS)	CS 1	CS 2	CS 3	CS 4	CS 5	CS 6
EA 1.	YES	YES	YES	NO	YES	NO
EA 2.	YES	YES	YES	NO	YES	NO
EA 3.	YES	YES	YES	YES	YES	YES
SME 4.1.	YES	YES	YES	YES	YES	NO
SME 4.2.	YES	YES	YES	YES	YES	YES
SME 4.3.	YES	YES	YES	YES	YES	YES
SME 4.4.	YES	YES	YES	YES	YES	NO
SME 4.5.	YES	YES	YES	YES	NO	NO
SME 4.6.	YES	YES	YES	YES	YES	NO
EA 5.	YES	YES	YES	YES	*NA*	NO

First of all, the CHOOSE metamodel was not able to control the complexity (EA 1.) or provide a holistic overview (EA 2.) of case study 4. The two underlying reasons are the hyper-dynamic environment of that SME (continuously strategic changing) and our lack of knowledge about the industry. During the validation round, the CEO of case study 4 made the remark that the CHOOSE model insufficiently described the 'sales and marketing'-side of the company. Secondly, since case study 5 is a department of a larger enterprise, EA 5.-criterion about an enterprise overview is not applicable (*NA*). In addition, the 'CEO' or department-responsible was not involved in the approach (SME 5.). Thirdly, case study 6 does not meet 7 out of the 10 CHOOSE criteria. Given the fact that case study 6 doubled the allowable number of employees of an SME (European Commission 2003), the CHOOSE approach was not able to control the complexity of the enterprise (EA 1.), to provide a holistic overview (EA 2.), or to enable optimization of the company as a whole (EA 5.). Besides the fact that not the CEO but the CFO was involved in the approach (SME 5.), the developed CHOOSE model of case study 6 was too complex to enable the company to time efficiently work on strategic issues (SME 1.), to describe how things are done in the company (SME 4.), or to provide added value (= expected revenues – expected costs and risks > 0) (SME 6.).

Each of the four case studies in SMEs produce very similar results and confirm the suitability of the metamodel (literal replication), except for EA criteria 1 and 2 of case study 4. The two other case studies in non-SMEs produce different results (theoretical replication), especially for the large enterprise. These results increase the external validity of this research by means of the replication logic (analytic generalization) that is used in these multiple case studies (Yin 2009).

4.8 Conclusion

In this chapter, we presented the development, refinement and evaluation of one artifact of the CHOOSE approach (Bernaert et al. 2014): the CHOOSE method. Implementing the CHOOSE method led also to a refinement and evaluation of the previously developed metamodel (Bernaert et al. 2015c; Bernaert and Poels 2011b), which is also reported in this chapter. Since the CHOOSE approach is an EA approach for SMEs (Bernaert et al. 2014), four SMEs were selected for the multiple case study action research. Additionally, a department of a large enterprise and one large enterprise were added to test if the use of CHOOSE would produce different results in the context of larger organizations.

A first artifact of the CHOOSE approach is the CHOOSE method. The developed CHOOSE method consists of a roadmap, an interview-method, and fourfold stop-criteria. The roadmap is a six-step procedure to implement the CHOOSE approach. Further, the interview-method describes our best practice to structure the interviews. Finally, the stop-criteria indicate when the input-phase of the EA model development process can be terminated.

The CHOOSE metamodel, a second artifact of the CHOOSE approach, is incrementally refined through developing and evaluating an EA model (instance of the metamodel) for each case study. The evaluation of these CHOOSE instances allowed us to make twelve adjustments to the metamodel.

The CHOOSE approach and its two artifacts are positively evaluated by the CEOs of the case study companies. Furthermore, an SME expert with good knowledge of EA evaluated the six developed CHOOSE models towards the initial criteria for EA in an SME context (Bernaert et al. 2014). This evaluation step confirmed the fit between the CHOOSE models and these initial criteria for all four SMEs and the department of a larger enterprise, with the exception of the larger enterprise.

A third artifact of the CHOOSE approach, software tool support, is currently being developed and tested in these SMEs (Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013). As a fourth artifact, a proper visualization for CHOOSE has been developed (Boone et al. 2014).

The development of the CHOOSE approach has proven to be an ongoing assessment of simplicity (for SMEs) and comprehensiveness (for EA) (Bernaert et al. 2015c), as confirmed during the action research. The impact of this research can be substantial as, to our knowledge, it is among the first efforts for bringing EA to SMEs (Bernaert et al. 2014; Dehbokry and Chew 2014; Bidan et al. 2012; Wißotzki and Sonnenberger 2012; Aarabi et al. 2011; Bernaert and Poels 2011b; Jacobs et al. 2011) by developing an EA approach specifically adapted to an SME context. Previous and related research (Bernaert et al. 2014; Dehbokry and Chew 2014; Bidan et al. 2012; Jacobs et al. 2011) clearly indicated the need for EA to be used in SMEs and the unsuitability of existing EA approaches in an SME context. However, up till now, no concrete EA artifacts had ever been developed. The key contributions of this research are thus the development and refinement of the CHOOSE method and the refinement of the CHOOSE metamodel, adapted to the characteristics of an SME context. The implications for further EA research follow from the possibility to implement EA in an SME context by using the CHOOSE method and metamodel. Other researchers can now for example assess the real contributions and pitfalls of EA for SMEs.

This research has three main limitations. First of all, the number of case studies (four SMEs, a department of a large enterprise, and a large enterprise) could be increased to result in a more robust CHOOSE method and metamodel. We noticed however, when progressing through the different case studies, that the method and metamodel were becoming more robust as gradually less need was felt for further adjustment. Second, for the evaluation of potential solutions in the solution space (for the development and refinement of the CHOOSE method and metamodel), we used design criteria from literature (Bernaert et al. 2015c; Paige et al. 2000). The evaluation of these criteria for the possible solutions was carefully conducted, though is by its very nature subjective, which is the second limitation of the study. A third limitation concerns the evaluation of the CHOOSE metamodel by the expert. The CHOOSE models of the six case studies were evaluated by only one person.

Several directions for future research are being explored. First, future research could increase the number of case studies to further test and evaluate both CHOOSE method and metamodel. Second, the expert proposed to develop a measurement instrument to measure the ten CHOOSE criteria of Bernaert et al. (2014). This will increase the validity of future expert evaluation of CHOOSE models. Third, to increase the perceived ease of understanding (PEOU) of the models, research on the development of a cognitive effective visualization based on (Moody 2009a) has been executed (Boone et al. 2014). Fourth, the CHOOSE approach worked quite well in the department of a larger enterprise. More research in this context should be performed to assess the applicability of CHOOSE in non-SME contexts. Fifth, the case study companies should be monitored on a longer term to assess the amount of effort they have to spend to keep their CHOOSE model up to date. The research presented in this chapter concerned the use of CHOOSE in developing EA models, but did not consider the management of such models.

5

Enterprise Architecture Software Tool Support for Small and Medium-Sized Enterprises: EASE

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Abstract. In the current information society increased attention is being paid to enterprise architecture (EA) and accompanying techniques, models and frameworks. CHOOSE is an EA approach focused on and adapted to the characteristics and needs of small and medium-sized enterprises (SMEs). Though these techniques could offer significant benefits to SMEs, hardly any SME uses EA. The application and implementation of EA in general and the CHOOSE approach in particular, has proven to be a complex and challenging task. This chapter describes the research-in-progress of the development of a software tool called EASE in support of the CHOOSE approach in order to maximize this disappointing rate of adoption. Furthermore, the software tool should guide the enterprise architect throughout the entire EA process and facilitate the implementation, management and maintenance of the resulting EA. A brief overview is given of the main features illustrating the added value of this research-in-progress. Finally, validation is achieved by means of multiple case studies.

Keywords*: Enterprise architecture; small and medium-sized enterprise; CHOOSE; software tool support; EASE*

5.1 Introduction

If you are about to build or rebuild a house, you will probably appeal to an architect to make sure the house fits your needs both structurally and functionally. The same can be said when starting, running or growing a business. An enterprise is a complex system of people, knowledge, fixed assets, projects, processes and many more brought together to fulfill a common shared vision (Lankhorst 2013). Enterprise architecture (EA) can help guide this process and consists of principles, methods and models to achieve its main objective, which is a coherent and consistent organizational design. Originally EA was focused on IT and its alignment with the business side. However, over the years the concept has grown into a much broader technique and is applied across the borders of IT. Although a lot of research is being done on EA, hardly anything is known about its use in the context of a small and medium-sized enterprise (SME) (Bhagwat and Sharma 2007). Some have pioneered in this field of study through the development of an EA technique adapted to the specific needs of this target group called CHOOSE (Bernaert et al. 2014; Bernaert and Poels 2011b). The application and implementation of EA in general and the CHOOSE approach in particular, has proven to be a complex and challenging task. Though these techniques could offer significant benefits to SMEs, hardly any SME uses EA and adoption is far below par. Analysis of widely accepted adoption models has shown that software tool support could significantly contribute to solving this paradox. This chapter describes the research-in-progress of the development of such a software tool in support of the CHOOSE approach called EASE ('EA SME Environment'). This software tool guides the SME's CEO in his function as enterprise architect throughout the EA process and facilitates the implementation, management and maintenance of the resulting EA. Validation by means of case studies provides the necessary proof of both the importance and efficacy of EASE. A pilot case study at a Belgian SME was first executed, confirming the importance and emphasizing the need for software tool support. Furthermore, four additional case studies supplement this validation process and were used to provide valuable insights and measurements for the evaluation of the efficacy of the developed software tool EASE.

In the first part of this chapter, a brief overview of the key elements of the CHOOSE approach is given to provide the reader with both a background story and a proof of relevance and importance of this research-in-progress. The second part elaborates on the development process of EASE. Consecutively the importance, methodology, software tool criteria and the tool under development are discussed in this section of the chapter. The end of this second part briefly discusses the validation process of EASE. Finally, the chapter ends with a succinct conclusion summarizing the key findings of this research-in-progress.

5.2 Background

5.2.1 CHOOSE: EA for SMEs

CHOOSE is an EA approach for SMEs based on the core elements of existing EA techniques following Einstein's principle: "Everything should be made as simple as possible, but not simpler". CHOOSE is an acronym for 'keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise'. Each letter refers to one of the five criteria for an EA technique derived from Lankhorst's definition and description of EA (Bernaert et al. 2014; Lankhorst 2013):

1) Control: EA should be usable as an instrument in controlling the complexity of the enterprise and its processes and systems.
2) Holistic Overview: EA should provide a holistic overview of the enterprise and be able to capture the essentials of the enterprise, which are the elements that are stable and do not vary across specific solutions found for the problems currently at hand.
3) Objectives: EA should facilitate the translation from corporate strategy to daily operations.
4) Suitable for its target audience: It needs to be an approach that is understood by all those involved, even when coming from different domains.
5) Enterprise: EA should enable optimization of the company as a whole instead of doing local optimization within individual domains.

The CHOOSE approach focuses on SMEs for two distinct reasons. First of all, this target group is often overlooked by the EA approaches currently available on the marketplace (see section 5.3.2). Secondly, the importance of SMEs in the modern economy cannot be overestimated (European Commission 2011; Small Business Administration 2011; CHI Research Inc. 2004). It is important to realize that an SME is not just a downsized large company (Welsh and White 1981). An SME operates fundamentally different from the latter, hence vindicating the need to develop an EA approach adjusted to the characteristics of this target group (criterion 4). To be able to comply with this criterion, extensive research was done with respect to the characteristics and attributes of SMEs and six well-documented criteria were identified, which can be seen as sub-criteria for criterion 4 (Suitable for its target audience) when applied to an EA approach for SMEs (Bernaert et al. 2014):

4.1) The EA approach should allow SMEs to work time-efficiently on strategic issues and challenges.
4.2) An employee with limited IT skills should be able to work seamlessly with the developed EA approach.
4.3) Few or preferably no help of external experts is required to work with the developed EA approach.

4.4) The approach should enable the company to create clear descriptions of how things are currently done in the company.
4.5) The CEO, as the central figure in SMEs, should be involved in the approach.
4.6) The expected benefits should exceed the expected costs and risks.

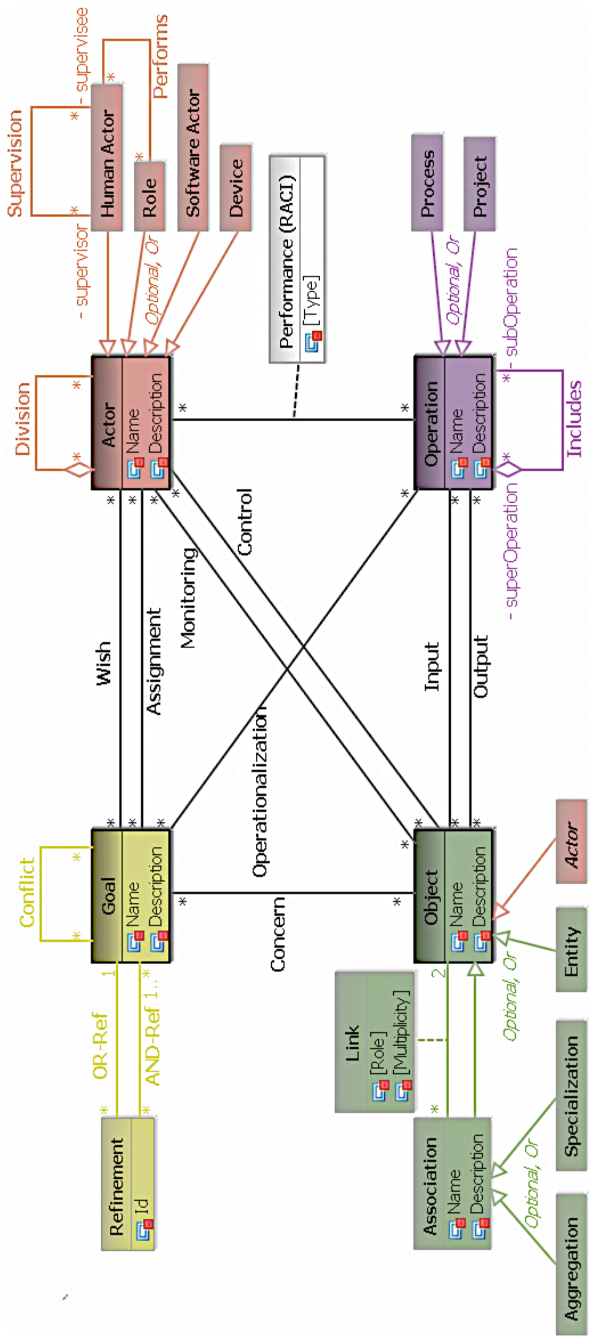


Figure 5.1: The four core dimensions of CHOOSE

Based on these criteria, the CHOOSE approach was developed. A strategic dimension (goal: why?), an active actor dimension (actor: who?), an operation dimension (operation: how?) and an object dimension (object: what?) form the core dimensions and are integrated to provide a holistic EA overview. Figure 5.1 gives an overview of the core dimensions and relations of the CHOOSE approach. Figure 5.2 gives a summarizing overview of the evaluation criteria.

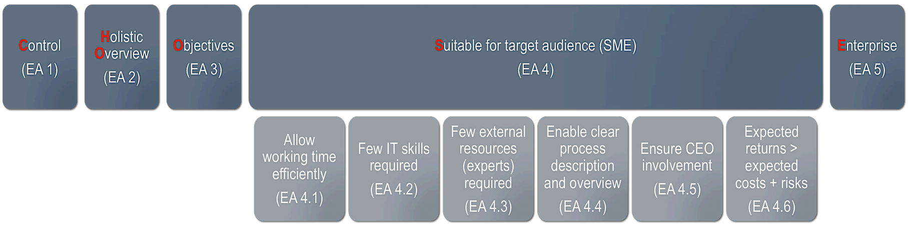


Figure 5.2: Overview evaluation criteria for an EA technique for SMEs

To provide a frame of reference for the research-in-progress discussed in this chapter, the latter can be positioned within the design science research (DSR) process (Peffers et al. 2007; Hevner et al. 2004) applied for developing the CHOOSE approach. Figure 5.3 gives a schematic overview of this process.

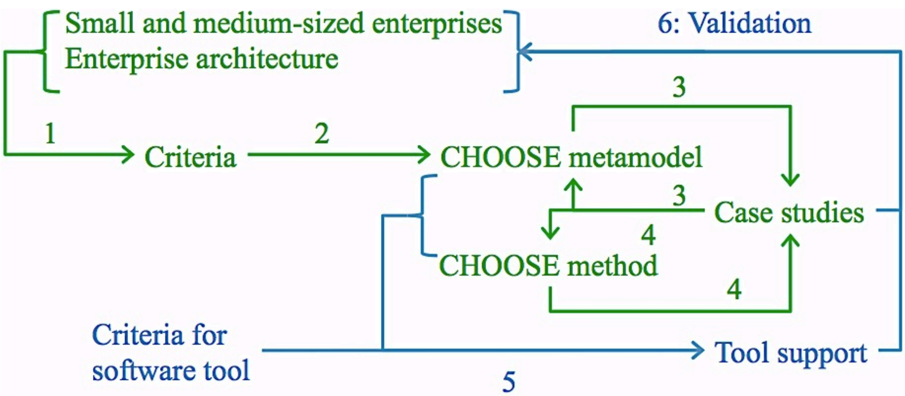


Figure 5.3: Research steps

Based on the aforementioned criteria of SMEs and EA (step 1) and the knowledge gathered throughout research steps 1 to 4 on Figure 5.3 (Bernaert et al. 2014; Bernaert and Poels 2011b), general design concepts are derived for the development of EASE in support of the CHOOSE approach (see section 5.3.4). These are then supplemented with criteria specifically related to software tools. This combination subsequently serves as a guideline for the software development process itself (step 5). Validation of EASE by means of case studies provides valuable insights with respect to the added value of the developed software tool, the degree to which the software tool conforms to the predefined criteria and the necessary adjustments that have to be made (step 6). The steps depicted in green have been performed in previous research and form the starting point of this research-in-progress (research scope indicated in blue).

5.3 CHOOSE Software tool support

5.3.1 Importance Software Tool Support

Despite the customized EA approach offered by CHOOSE with its intrinsic qualities aligned with the characteristics of SMEs, it is also very important to take the adoption of the approach into account. Techniques that are technically superior or fully customized to the needs of the user will not yield the expected benefits as long as the techniques are not effectively used in practice. To help optimize, facilitate and speed up the adoption process, one can rely on different models that explain the adoption of information systems (IS) and IS models. Of these models, the technology acceptance model (TAM) (Davis 1989) is widely used and the method evaluation model (MEM) (Moody 2003) supplements TAM to be better applicable for the evaluation of methods. TAM provides a model that helps discern external factors and their impact on the attitude, evaluation and behavior of practitioners towards the adoption of IS and IS methods, such as EA. Central determinants in this model are perceived ease of use and perceived usefulness. The conviction of the end-users that the information technology will help them better perform their job relates to the perceived usefulness. Perceived ease of use alternatively deals with the amount of effort and time needed to learn how to work with it. Both aspects influence the attitude towards the technology and subsequently the behavioral intention to use. Crucial for the adoption is that the increase in performance is perceived as being of higher influence to adoption than the effort necessary to learn the developed technology and work with it (Davis 1989).

MEM was developed as a reaction to the trend that most IS research focuses on the development of new methods rather than the evaluation of existing methods (Moody 2003). It combines the insights of the TAM with the methodological pragmatism of Rescher (1977). This model states that methods cannot be labeled as being wrong or right. Methods do not have a truth value, but a pragmatic value in the sense that they can only be evaluated based on their efficacy. The validity of a method can neither be derived inductively nor deductively but should be proven through the successful application in practice. This is called the pragmatic success of a method and is defined as the efficiency and effectiveness with which a method achieves its predefined goals. Figure 5.4 gives an overview of MEM and its main components. The biggest difference with TAM is the introduction of actual efficacy coming from Rescher (1977). This difference is subtle but nevertheless very important. It implies that when explaining human behavior, the subjective reality is often much more decisive than the objective reality and therefore perceived efficacy mediates the impact of actual efficacy on adoption in practice (Bernaert et al. 2014).

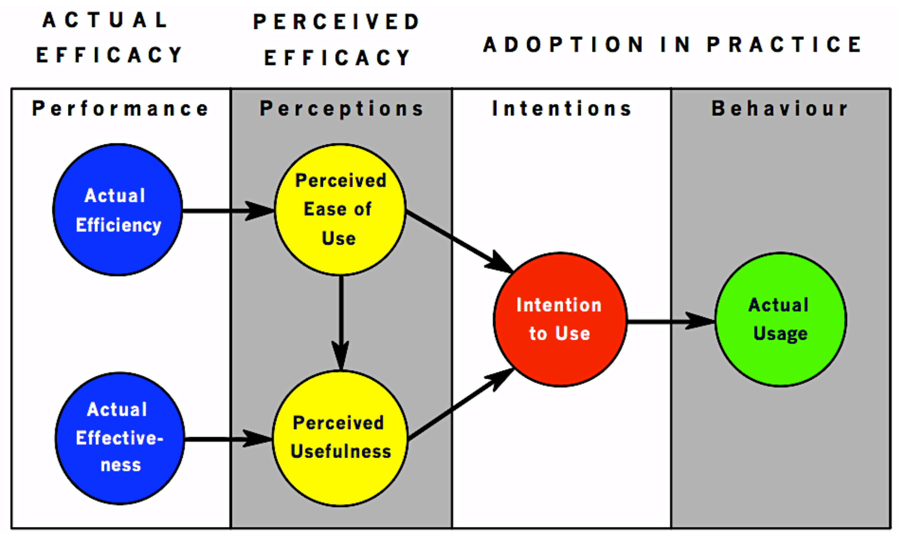


Figure 5.4: The Method Evaluation Model (from (Moody 2003))

Based on these models, guidelines can be developed to optimize the adoption of the developed IS (Bernaert et al. 2014), in this case the EA approach CHOOSE. The development of a tool supporting the application and implementation of CHOOSE could significantly contribute to the actual efficacy, leading to a higher adoption and added value through an increase in the subjective perception of this efficacy. Hence, measuring the perceived usefulness and perceived ease of use of EASE during the validation process, will provide valuable insights with respect to the ability of this software tool support to increase adoption of the CHOOSE approach.

Next to the contribution of a tool to the adoption of an approach, research concerning the implementation and use of EA in practice stresses the complexity and need for guidance by means of tool support. In general, there are three main areas where critical problems arise in the process of EA: modeling, managing and maintaining EAs (Kaisler et al. 2005). An important driver of problems in these areas is the inherent complexity of the EA process. An enormous amount of information has to be transformed using the semantics and syntax of the modeling language. Often this information is distributed over multiple people and has to be brought together to be able to create a consistent and coherent whole. This process takes a lot of energy and is often a hotbed for errors. A tool can offer the much needed support and guidance for the development, storage and analysis of an EA (Ernst et al. 2006). Furthermore, in many companies, enterprise architects are obliged to use existing methods and techniques from disparate functional domains, preventing them to realize the bigger picture that puts all these domains together in the required EA (Jonkers et al. 2006). This drawback emphasizes the importance of an integrated tool for building, analyzing and communicating the EA to all stakeholders. Other advantages of tool support include (Lankhorst 2013):

- A tool can help standardize the semantics and syntax used during the development of the EA within a company.
- The use of a tool contributes to the construction of correct and consistent architecture artifacts by guiding the development process and through the application of mistake proofing techniques. Tools can impose rules to make sure the desired practices and guidelines are followed.
- A tool can help the enterprise architect in the use of architectural patterns. Furthermore, the reuse of certain parts of the architecture or solutions that have been developed in the past is facilitated. This contributes to the efficiency of the development process.
- Tools facilitate the comparison of alternatives by providing impact of change and quantitative analysis features.

Although the aforementioned research confirms the importance of tool support, these findings cannot simply be extrapolated to the environment of SMEs and the importance of tool support for the implementation of the CHOOSE approach. However, case studies performed by Bernaert and Callaert (Bernaert et al. 2015a) confirm the need for tool support for the development of EAs in SMEs. During these case studies, the CHOOSE technique was applied in six SMEs by means of simple whiteboards and post-its. During four of these case studies, this technique was supplemented with an initial version of EASE. Comparing both clearly showed the added value of having access to a software tool supporting the EA process. Figure 5.5 shows a small fraction of the resulting EA and pinpoints the importance of a tool for the development, storage and analysis of the EA artifacts, since the use of post-its created an unmanageable EA model.

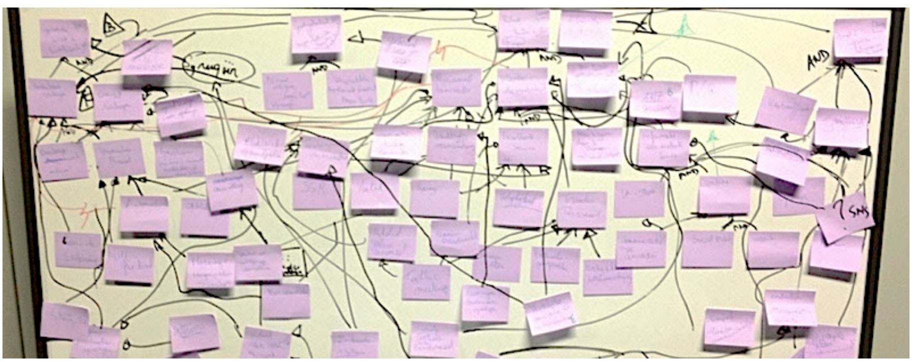


Figure 5.5: Partial EA artifact of a Belgian SME

5.3.2 Importance New Software Tool

Most tools available on the marketplace are based on EA frameworks. The Zachman framework is one of the best-known and is often used as a descriptive framework through which EA artifacts can be categorized (Zachman International 2011). Another well-known framework and method is The Open Group Architecture Framework (TOGAF) (The Open Group

2009). TOGAF is considered to have a broader application than Zachman and provides more guidance for the development of the EA. Both frameworks provide support on a high level of abstraction and primarily help to decide which business and technological domains to incorporate in the EA but they provide little assistance in creating the architectural artifacts themselves (Jonkers et al. 2006). Nevertheless, there are software tools available that help the enterprise architect in the creation of these artifacts. For example, Objectiver is a requirements engineering tool that allows the end-user to draw a part of or the entire EA on a canvas (Respect-IT 2010). However, this software tool was not developed for this specific purpose and it is based on the metamodel of KAOS, a goal-oriented software requirements engineering approach. To be applicable for the modeling of EA artifacts, some significant changes should be made. Furthermore, the focus of this and other available software tools is not on SMEs, which leads to the incorporation of unnecessary and potentially confusing features while other important features may not be available at all because they are not valued by the broader end-user base.

In general, research has identified some common weaknesses of the available software tools (Ernst et al. 2006):

- Most software tools do not support automatic visualization of data. Furthermore the semantics of these visualizations are often only defined in vague terms. A lot of these tools are plain drawing tools in which the end-users have to draw the EA on a canvas themselves. However, a variety of important functionalities, like the reuse of model components, cannot be supported by these kinds of tools (Braun and Winter 2005).
- Most software tools come with a predefined metamodel. Due to the considerable differentiation between companies, these metamodels ought to be adjusted before the architect can start developing the EA. These standard metamodels are either too small to be able to capture the entire EA or too big, impeding the ease of use and readability of the resulting model.
- Most software tools provide a metamodel but lack a method for developing the EA. The absence of a method can slow down the development process and can lead to the misinterpretation and wrongful application of the concept of the metamodel.

Based on these insights, it is safe to say that the development of a software tool adjusted to the specific needs of SMEs, based on the CHOOSE approach and incorporating these general weaknesses could substantially improve the added value of EA for SMEs.

5.3.3 Methodology

A solid methodology for the development of the software tool is indispensable and contributes to the academic and practical value of this research-in-progress. A methodology was derived from three well known methodological frameworks:

- **Conceptual Framework for the Methodological Soundness of Requirements Engineering (RE) Papers** (Wieringa and Heerkens 2006): This framework proposes a set of criteria based on which the methodological soundness of RE papers can be evaluated. As the RE domain shows substantial affinity with this research-in-progress, valuable insights were obtained from this framework.
- **Design Science Research Methodology for Information Systems Research** (Peffers et al. 2007; Hevner et al. 2004): This framework proposes a methodology for conducting design science research (DSR) in the Information Systems (IS) academic discipline. DSR aims at designing artifacts (e.g., concepts, models, methods, instantiations of these) that embed scientific knowledge about problems and their solutions. A software tool can be seen as an instantiation of a method, which in case of a modeling method is based on an underlying metamodel and concepts, through which the method can be evaluated (March and Smith 1995). Ergo, it might be a good idea to incorporate the guidelines of this framework in the methodology for developing the tool as a research artifact.
- **Software Process Models** (Sommerville 1996; Boehm 1988): A software process is an abstract collection of activities and information necessary for the development of a specific software system. Each organization has its own software process but usually these individual approaches follow some generic abstract model. These are called software process models and they provide insight in the different steps from concept up to the finished software system. By analyzing and comparing the different types of models, some valuable insights were obtained.

Through the consolidation of the relevant and valuable aspects of the aforementioned models and frameworks, a customized methodology was created for the elaboration of this research-in-progress. Figure 5.6 gives a schematic overview of this. Indicated in blue (bottom three lines) are the relevant elements of each of the underlying approaches and in red (top line) the resulting methodology used in this research. Throughout the development process of the software tool, insights in the underlying approaches can be used to maximize the academic and practical value of this research.

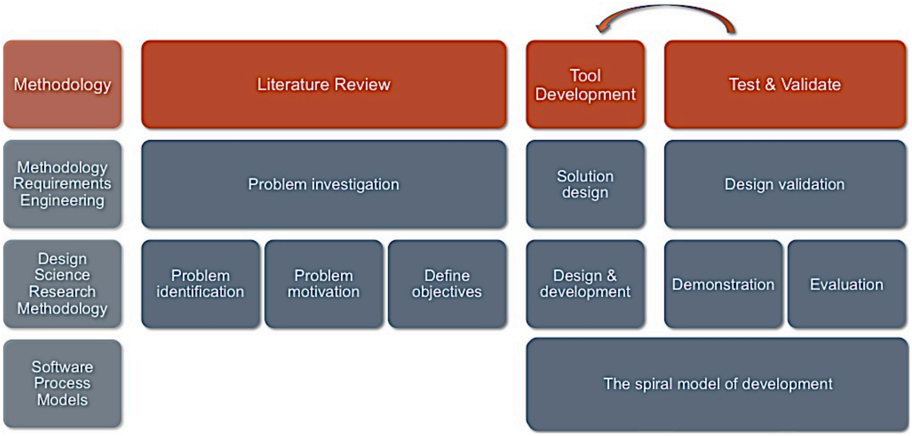


Figure 5.6: Methodology

5.3.4 EASE Criteria

The first step in the development process consists of an extensive literature review with the main objective of translating the criteria of EA and SMEs (Figure 5.2), from research step 1 in Figure 5.3, together with knowledge of the CHOOSE metamodel and method into general guidelines for tool support. In Figure 5.3, this is depicted by research step 5. These guidelines for software tool support are primarily derived from knowledge gathered by means of literature from the following fields:

- Adoption models for IS and IS models.
- Problem areas of EA implementation, management and maintenance.
- Weaknesses of current (software) tools.
- CHOOSE metamodel and method.

This results in the following design objectives for EASE, reflecting research steps 1 through 4 of Figure 5.3:

1) **Simplicity:** The tool ought to be easy to learn/use and should provide a user-friendly interface through which the end-user can access all available features. Moreover, it allows the dispersed information to be gathered from the different people involved in the EA process through interaction with a standard interface. The latter helps improve the agility and flexibility of the software tool and therefore contributes to its added value. Furthermore, the simplicity should significantly reduce the threshold for an enterprise-wide implementation (criteria 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 5).
2) **Efficiency:** The input of the end-user should be kept to a bare minimum. In particular, this means that the time, effort and costs to use EASE have to be kept as low as possible. Hence, the software tool should allow employees to work time-efficiently. Furthermore, the simplicity criterion (confer supra) contributes to the

development of a software tool with a steep learning curve, reducing the costs for education and adaption significantly (criteria 4.1, 4.6).

3) **Effectiveness:** Given the minimal input, the software tool must maximize the added value of the output. Therefore, EASE must be very flexible and transformation of the data should provide valuable information for a variety of viewpoints. Omitting irrelevant data reduces the complexity of the model significantly, allowing the end-user to keep a holistic overview. Incorporation of various constraints can help enforce generally accepted guidelines and best practices, contributing to a consistent and coherent end result (criteria 1, 2, 3, 4.4, 4.6).
4) **Business oriented:** The level of IT and EA knowledge in the environment of SMEs is quite limited. To maximize adoption, it is of utter importance that the software tool communicates using the language of the end user, in case of SMEs the business language (criteria 4.2, 4.3, 4.5, 5).
5) **Completeness:** EASE must provide guidance throughout the entire EA process. Furthermore, it is important to keep the general weaknesses in mind when developing the software tool to prevent making similar mistakes and provide a solution to the needs of the marketplace (criteria 2, 4.4, 5).

These general objectives were supplemented with criteria specifically related to software tool support and development such as adaptability, modularity, GUI design and flexibility. However, these criteria are more technical in nature and will not be discussed in detail in this chapter.

5.3.5 Tool Development

By means of a literature review of EA in practice (Lankhorst 2013; Ernst et al. 2006; Kaisler et al. 2005) and by applying the CHOOSE approach in practice in multiple case studies, the following problem areas were identified:

- **Input:** This step implies transforming the available knowledge and information into the EA through the application of the syntax and semantics provided by the CHOOSE approach. The enormous amount of information, its distributed and dynamic character and the interdependencies between the different concepts make this a time-consuming and often very complex process in need of guidance by means of tool support. Moreover, software tool support can impose constraints that contribute to the compliance with predefined guidelines, best practices and the rules of the metamodel in contrast with the previously mentioned methods in which the user is not restricted in the actions (s)he can take.
- **Storage:** Once modeled, the architecture has to be stored to be able to access, adjust or analyze it in the near future. In the absence of tool support, data is often stored physically, for example through

post-its on whiteboards, or in the best case in an in-house developed database. It is quite clear that this is a suboptimal solution, significantly reducing the user-friendliness and added value of the EA.

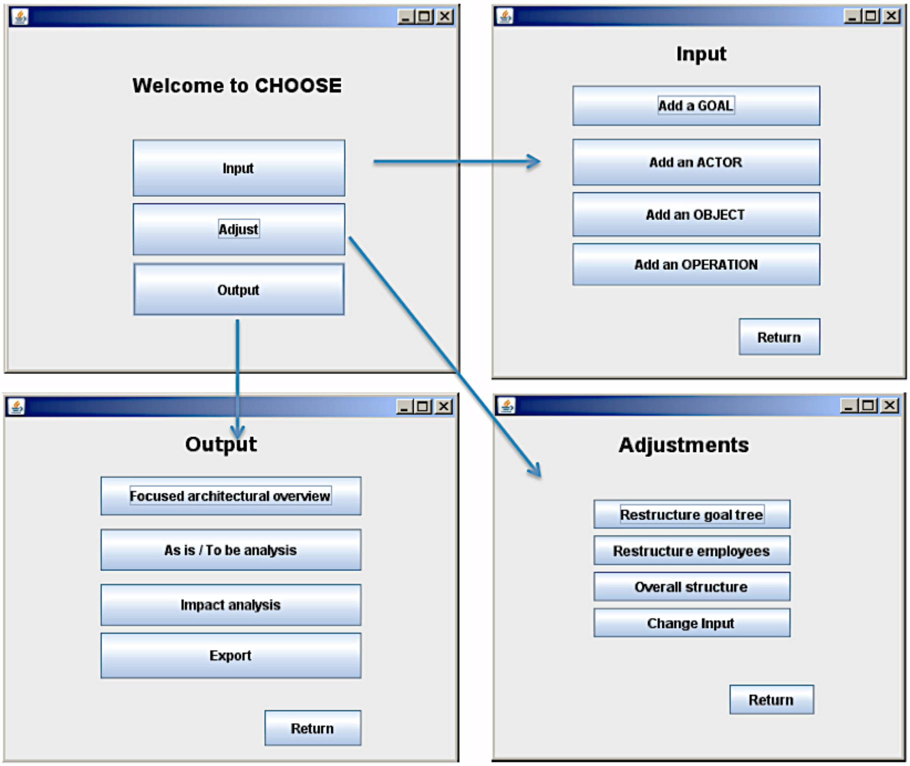
- **Adjust data:** In society today, companies are operating in highly dynamic environments in which changes occur on a daily basis. Consequently, they require their systems, including their EA, to be able to respond to this need for agility and flexibility. Software tool support allows quick and effortless adaptation of the architectural artifacts, hence contributing to this important business need.
- **Retrieving data:** Whether data ought to be adjusted or information is needed to perform a specific analysis, it is necessary to find and collect those specific elements of the EA that will help the end-user to do so. Software tool support can significantly reduce the effort required to perform this process of retrieving data, contributing to the added value of EA.
- **Analysis:** Dependent on the stakeholder involved, the degree of relevance of different aspects of the EA varies significantly. Ergo, it is very important to be able to reduce the complexity inherent to EA by omitting irrelevant data and varying the level of detail according to the background, knowledge and purpose of the end-user by means of different viewpoints. Furthermore, analysis of the EA can identify and resolve any inconsistencies and other irregularities.

In absence of tool support, the effort required in each of the aforementioned problem areas in terms of time, cost and energy would increase exponentially with the amount of data stored in the EA. Lankhorst (2013) identifies three categories of tools in support of the EA process. Each of these categories can be linked to one or more of the five problem areas discussed above:

1) **Modeling and design:** This category supports the problem area with respect to input.
2) **Reporting and publication:** This category offers a solution for the problem areas with respect to the retrieval and analysis of data.
3) **Storage and retrieval:** This category tackles the storage, retrieval and adjustment of data problem areas.

Hence, a complete and valuable software tool has to offer a solution in support of each of these problem areas. Consequently EASE has to integrate the three different categories into one umbrella tool offering end-user support for the entire end-to-end EA process.

Based on these insights, EASE was developed around three main functionalities: input, adjust and output (Figure 5.7 top). The software tool was developed using Java as programming language and MS Access as database management system (DBMS). In the remainder of this chapter, a brief overview will be given of the main features of the software tool EASE. Furthermore, a short description of the programming challenges yet to be tackled are provided. Finally, this chapter ends with a concluding remark with respect to validation.



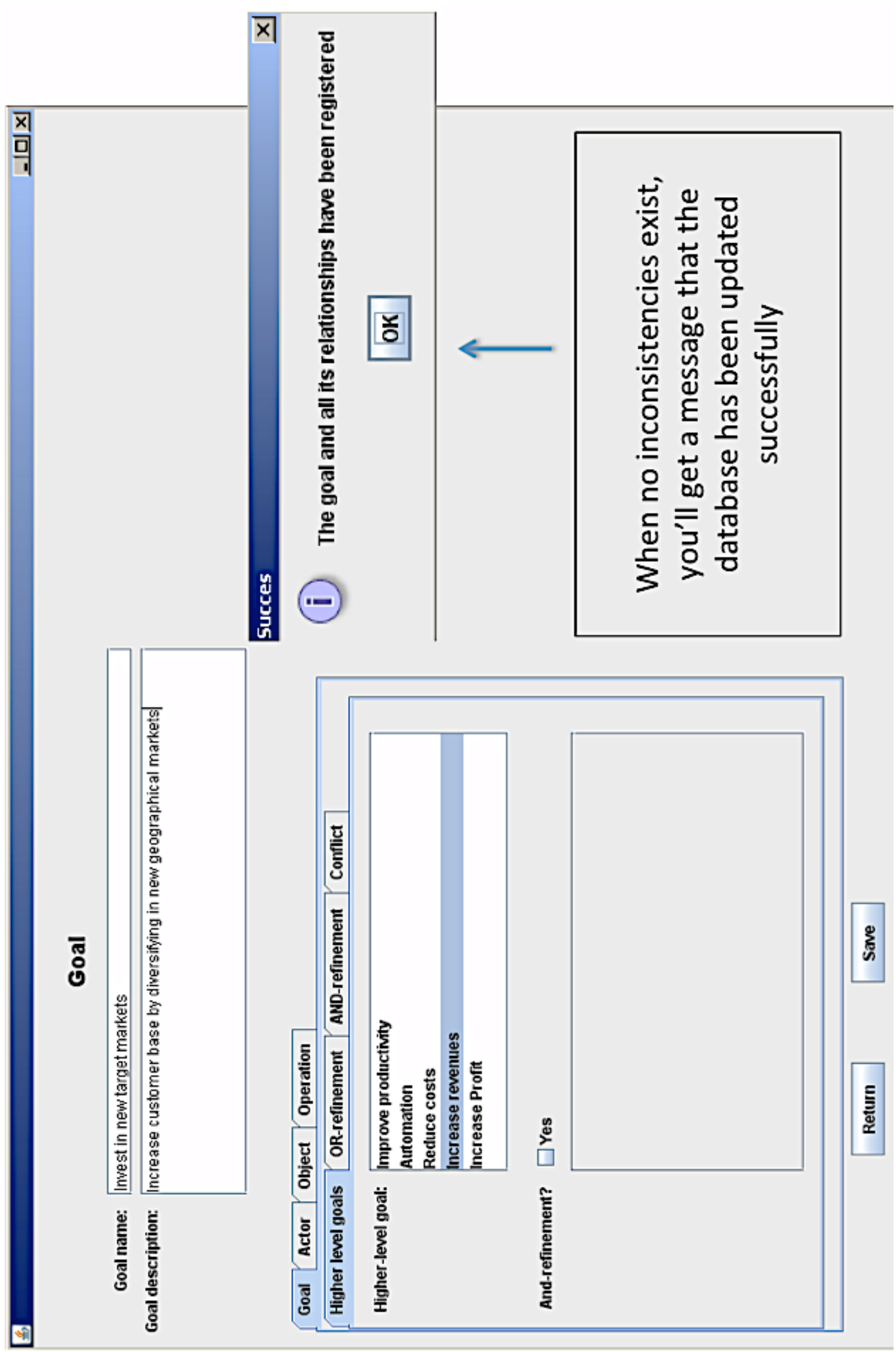


Figure 5.7: Main menu and three main functionalities (top) & Input of an entity of the goal dimension (bottom)

5.3.5.1 Input

The different elements and their interdependencies have to be modeled and stored by means of the concepts and relationships of the CHOOSE approach provided to the end-users through a user-friendly and highly intuitive interface. First, the end-user chooses the concept that (s)he wants to add and the interface provides a window that asks for the necessary information and gives an overview of all the possible relationships with other entities within the EA. The bottom part of Figure 5.7 illustrates the input of a goal using the software tool under development.

Moreover, a variety of constraints are imposed to ensure a consistent and coherent EA. The storage in the underlying database occurs automatically and is oblivious to the perception of the business user. Hence, this separation of concern ensures that in case the DBMS no longer meets the requirements, it can easily be replaced without noticeable difference for the service consumers.

5.3.5.2 Adjust

There are a number of ways through which the end-user can look up and potentially adjust entities, their attributes and their relationships within the EA. The straightforward way is just by searching for a specific entity by means of a search functionality provided by the software tool as depicted in Figure 5.8.

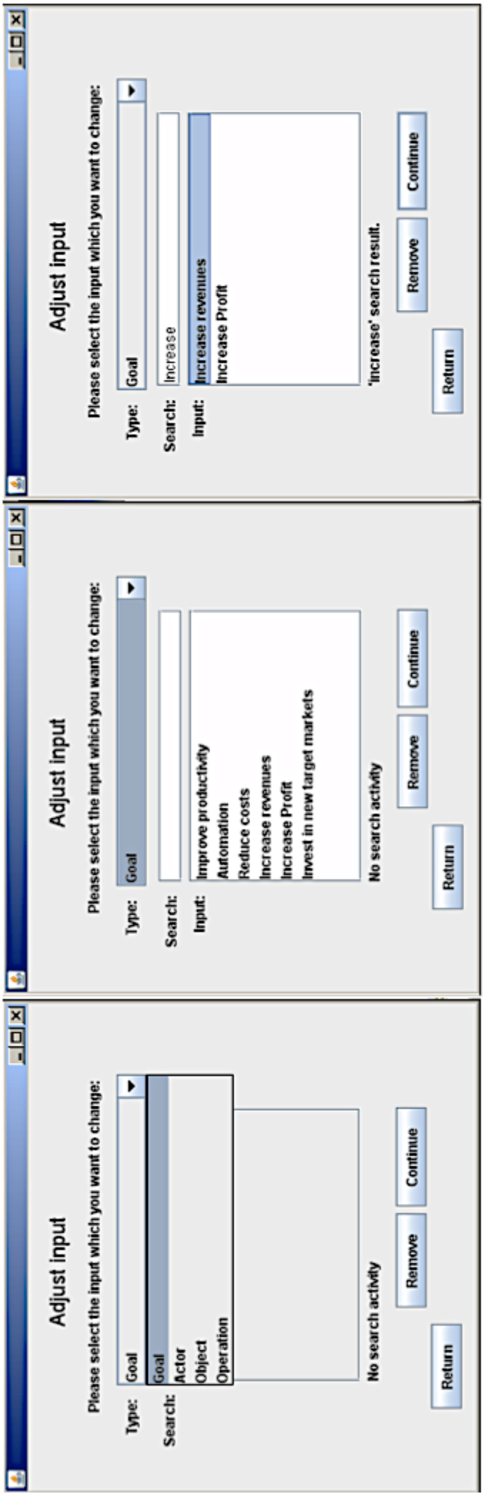
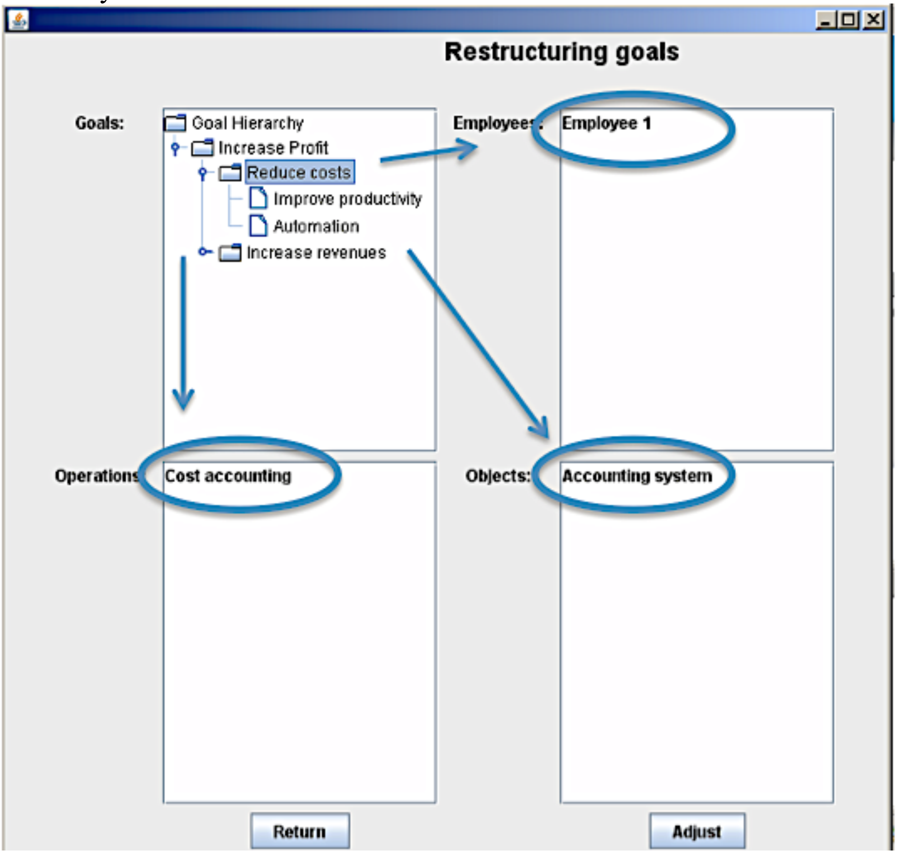


Figure 5.8: Search functionality

The software tool also provides the business user with the functionality to represent the entities per dimension of the CHOOSE approach in a tree structure. Allowing the end-user to drill down through the entities, starting at the highest level of abstraction, hence providing a holistic overview of the overall structure of the entities of one of the four core dimensions (Figure 5.9 top). Furthermore, by clicking on a specific entity, represented by a node of the tree, all connected elements are displayed following the visual representation of Figure 5.1. By consistently applying this structure, the end-user always knows where to find information concerning a specific dimension, contributing to the user-friendliness and efficiency of the software tool.



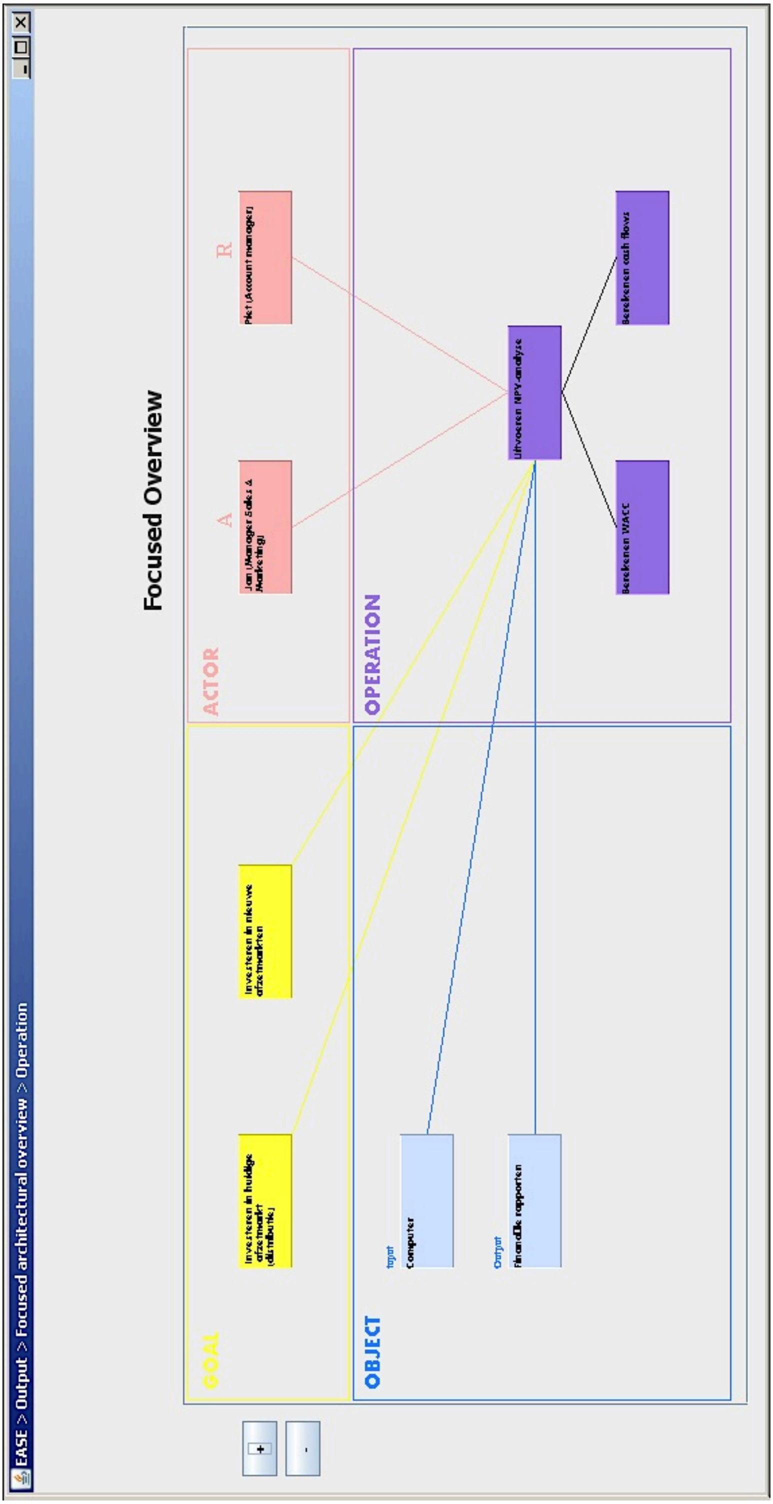


Figure 5.9: Tree structure overview (top) & Focused architectural overview (bottom)

5.3.5.3 Output

The output part of the software tool is currently still under development. A brief description will be given of those features that are currently operational. **The focused architectural overview** provides the business user with the possibility to zoom in on a specific entity of the EA including its immediate environment, offering an automatic visualization functionality that allows the creation of a plethora of viewpoints. This feature tackles one of the general weaknesses of the current tool landscape as described earlier. For the development of a clear, understandable and effective visualization, insights were obtained by means of an extensive literature review with respect to visual perception and the syntax of modeling tools (Lankhorst 2013; Moody 2009a). The bottom part of Figure 5.9 gives an example of the focused architectural overview feature.

Case studies have revealed that MS Excel remains an important tool within the environment of SMEs for the communication, transformation and analysis of data (Osadnik and Landryova 2011). Hence, incorporating a functionality allowing the **export of data** from the Access to the Excel environment, proved to improve the added value of the software tool. The data can either be exported in the form of lists as they are stored in the database or they can be transformed into a meaningful representation. An example of the latter is the combination of data of the actor and operation dimension resulting in the construction of a RACI chart (ISACA 2012).

Currently still under development are an as-is/to-be analysis and an impact-of-change analysis functionality. The former should allow starting from the as-is situation and adjusting the EA to incorporate the changes necessary to achieve a desired future state. Comparison of both models identifies the steps that ought to be undertaken to accomplish this transformation. The latter can be used to investigate the impact of a specific change on the different dimensions and the EA as a whole.

5.3.6 Validation

5.3.6.1 Approach

As stated by MEM, the validity of a method should be proven through the successful application in practice. Hence, a first pretest stressed the importance of tool support and provided us with a preliminary feedback on tool functionalities. Subsequently CHOOSE was implemented in four Belgian SMEs, which will be further elaborated here. These companies were submitted to the situation in which software tool support was initially not available, but later in the EA process they were given the beta version of EASE to support them in managing and maintaining their EA. Therefore, these companies can clearly judge the added value of EASE as they have been exposed to both situations without and with software tool support.

5.3.6.2 Main Results

By means of a survey, the CEOs of each of the participating companies were asked to evaluate the perceived usefulness and perceived ease of use of EASE through the adapted six-item scales of Davis (1989) for measuring both variables (Figure 5.10). On average the companies *perceive* it as more than slightly likely that EASE has a high degree of *usefulness* (PU) and *ease of use* (PEU). Furthermore variability is low which means that EASE scores consistently well throughout the four case studies. EASE, however, is not yet fully developed. Nevertheless, these results confirm its potential of improving the adoption of CHOOSE through an increase in the PU and PEU.

		CS1	CS2	CS3	CS4	Avg.
Technology acceptance model: Perceived usefulness (PU) 7-point Likert scale: Extremely likely: 7 Quite likely: 6 Slightly likely: 5 Neither: 4 Slightly unlikely: 3 Quite unlikely: 2 Extremely unlikely: 1	PU1	6	4	5	5	**5,375**
	PU2	6	5	6	5	
	PU3	6	4	4	6	
	PU4	6	5	6	5	
	PU5	6	4	5	6	
	PU6	6	5	7	6	
	Avg.	**6**	**4,5**	**5,5**	**5,5**	

		CS1	CS2	CS3	CS4	Avg.
Technology acceptance model: Perceived ease of use (PEU) 7-point Likert scale: Extremely likely: 7 Quite likely: 6 Slightly likely: 5 Neither: 4 Slightly unlikely: 3 Quite unlikely: 2 Extremely unlikely: 1	PEU1	6	5	5	7	**5,625**
	PEU2	6	5	5	7	
	PEU3	6	4	5	6	
	PEU4	6	4	4	6	
	PEU5	6	5	6	7	
	PEU6	6	5	6	7	
	Avg.	**6**	**4,67**	**5,17**	**6,67**	

Figure 5.10: Evaluation perceived usefulness and perceived ease of use

Besides the perceived efficacy, feedback was obtained with respect to the evaluation of the CHOOSE (Figure 5.2) and EASE (section 5.3.4) criteria. Criteria 4.5 and 4.6 were not evaluated, since the CEO was always involved (4.5) and the adoption was already assessed in Figure 5.10 (4.6). In general, the CEOs positively evaluated the contribution of EASE to and the compliance of EASE with the predefined criteria (Figure 5.11). Especially the reduction of the inherent complexity of an EA and the improved overview are considered valuable assets of EASE. The contribution of EASE to criterion 5 (EA 5) is less straightforward. A potential explanation for this is that EASE has a limited impact on the scope on which CHOOSE is applied and CHOOSE has to be used in combination with other approaches (e.g., business process modeling languages) in order to see every detail of the enterprise.

		CS1	CS2	CS3	CS4
CHOOSE criteria 5-point Likert scale: Strongly agree: ++ Agree: + Neutral: +/- Disagree: - Strongly disagree: --	EA 1	++	+	++	+
	EA 2	++	+	++	+
	EA 3	++	+/-	+	+
	EA 4.1	++	+	+/-	+
	EA 4.2	++	+/-	+	+
	EA 4.3	++	+	+/-	+/-
	EA 4.4	++	+/-	+	+
	EA 5	+	+/-	+/-	+/-

		CS1	CS2	CS3	CS4
EASE criteria 5-point Likert scale: Strongly agree: ++ Agree: + Neutral: +/- Disagree: - Strongly disagree: --	Simplicity	++	+	+	+
	Efficiency	++	+	+	+
	Effectiveness	+	+	+	+
	Business oriented	+	+	+	++
	Completeness	++	+	+	++

Figure 5.11: Evaluation CHOOSE and EASE criteria

5.4 Conclusion

This research-in-progress has investigated the need for a software tool in support of the implementation of EA in the environment of SMEs as pioneered by the CHOOSE approach. Both literature review and case studies have confirmed this need and the chapter presented a software tool under development (EASE) in support of this need based on criteria for EA, criteria for SMEs and criteria for tool support. An overview of the main features of EASE was given and an initial validation by means of four case studies has confirmed the potential of the software tool in increasing the adoption of CHOOSE and providing the much needed guidance and support.

Furthermore, EASE has reached its goals through the contribution to and the compliance with the predefined criteria. Nevertheless, EASE is still under development and the case studies have identified multiple improvement paths to be tackled. Further research with respect to additional valuable functionalities is required and continuous fine-tuning will contribute to the overall added value of EASE in support of CHOOSE.

6

Evaluating and Improving the Visualization of CHOOSE, an Enterprise Architecture Approach for SMEs

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Abstract. Enterprise architecture (EA) serves as a means to improve business-IT and strategy-operations alignment in an organization. While it is a fairly mature domain in large enterprises, the need for EA in small and medium-sized enterprises (SMEs) has only been recently addressed. As SMEs have different characteristics and cope with specific problems, a different approach is essential to enable a successful adoption of EA. In order to meet these particular requirements of SMEs, the EA approach CHOOSE has been developed. In previous research, emphasis has been put on refining the method and metamodel of CHOOSE and on the development of supporting software tools. However, the visual notation of CHOOSE has not been investigated yet, while the form of representation has a great impact on the cognitive effectiveness of a diagram. This chapter assesses the current visualization of CHOOSE, describes alternatives and conducts an experimental comparison.

Keywords: *Enterprise architecture; business architecture; small and medium-sized enterprises; CHOOSE; visualization*

6.1 Introduction

Enterprise Architecture (EA) is a structural approach to improve a company's business-IT and strategy-operations alignment (Maes 2007). Besides, it is a key instrument in controlling the complexity of an organization (Bernaert et al. 2014). This is achieved by creating a holistic overview of the organization through describing and controlling the structure, processes, applications and technology in an integrated way (Lankhorst 2013). Although EA is a fairly mature domain in large enterprises, the adoption in small and medium-sized enterprises (SMEs) is lagging behind due to the complexity involved in using the current EA approaches (Bhagwat and Sharma 2007). SMEs often lack the expertise required to implement these approaches and do not have the financial resources to hire consultants (Dehbokry and Chew 2014; Jacobs et al. 2011). In order to tackle this issue, Bernaert et al. (2014) have developed a new approach called CHOOSE, which is adapted to the needs of the target group (section 6.2.1). In previous research, the method and metamodel of CHOOSE have been refined and tool support has been developed (Bernaert et al. 2015c; Bernaert et al. 2013; Dumeez et al. 2013; Ingelbeen et al. 2013; Zutterman et al. 2013). These investigations have already put a lot of emphasis on the comprehensibility of the approach for inexperienced enterprise modelers. However, up to now the visual notation of CHOOSE has not been evaluated nor improved, while the form of representation has an important impact on the cognitive effectiveness of a diagram (Moody 2009a; Larkin and Simon 1987). This impact is especially crucial in the case of novice users, which makes it very worthwhile to investigate the visual notation of CHOOSE (Moody 2009a). The research in this chapter therefore focuses on how CHOOSE should be visualized in order to allow the users to interpret the diagrams in a cognitively effective way. Besides, the effect of the form of representation on the perceived ease of use, perceived usefulness and the intention to use is investigated as well. The result should enable effective and time efficient communication about the EA within SMEs.

Section 6.2 provides the theoretical background needed to conduct this research. First, the EA approach CHOOSE is briefly explained (Bernaert et al. 2015c). Next, Moody's Physics of Notations (Moody 2009a), a theory for visual notation design, is discussed. Last, related work is shortly summarized. The actual research consists of three major parts: first, the current visualization is assessed based on the principles of the Physics of Notations (section 6.3) (Moody 2009a). Second, alternative representations are developed (section 6.4). Third, an experiment is conducted to verify which visualization has the best outcomes in terms of cognitive effectiveness on the one hand and perceived ease of use, perceived usefulness and intention to use on the other hand (sections 6.5 and 6.6).

6.2 Background

6.2.1 CHOOSE for EA in SMEs

Implementing EA allows SMEs to create an overview of the company. In order to guide them in this process, Bernaert et al. have developed the CHOOSE approach (Bernaert et al. 2014). CHOOSE is an acronym for 'keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise', which refers to the essential requirements for implementing EA in an enterprise (Bernaert et al. 2014). Especially the term 'Simple' deserves some additional attention in the context of SMEs, because the word reflects six specific criteria an EA approach must satisfy in order to enable successful adoption in SMEs (Bernaert et al. 2015c):

1) The approach should enable SMEs to time efficiently deal with strategic issues.
2) A person with limited IT skills should be able to apply the approach.
3) It should be possible to apply the approach with little assistance of external experts.
4) The approach should enable making descriptions of the processes in the company.
5) The CEO must be involved in the approach.
6) The expected revenues of the approach must exceed the expected costs and risks.

The metamodel of CHOOSE incorporates these criteria, which means it enables SMEs to create simple, yet comprehensive models (Bernaert et al. 2015c). These models represent an overview of the business architecture layer, integrating elements of the information systems and technology layers (Bernaert et al. 2015c; Bernaert et al. 2013). They consist of four viewpoints: goals (why), actors (who), operations (how) and objects (what) (Figure 6.1).

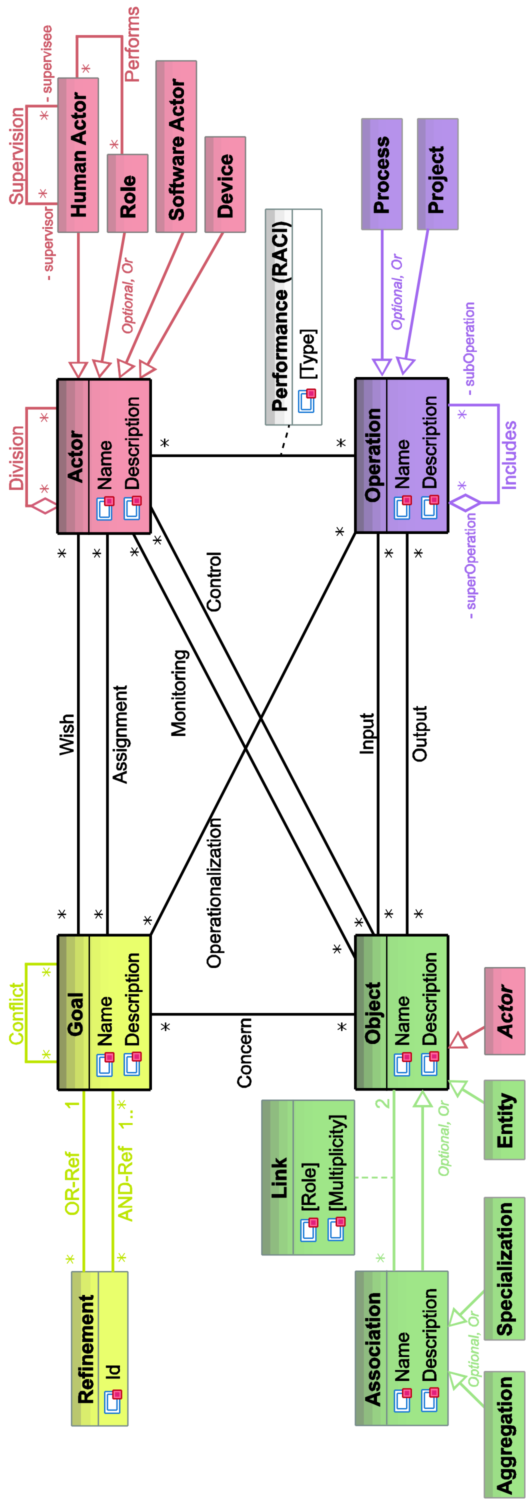


Figure 6.1: CHOOSE metamodel (Bernaert et al. 2015c)

An example of a model that has been created with CHOOSE is demonstrated in Figure 6.2. As the content is rather straightforward, the reader is encouraged to analyze the diagram making use of the legend (Figure 6.8). At the same time, the example shows the current visual notation of CHOOSE. As will become clear in section 6.3, there is still a lot of room for improvement with respect to this visual notation.

6.2.2 Moody's Physics of Notations

Numerous papers cover the evaluation of a notation on the semantic level (e.g. (Recker et al. 2005; Opdahl and Henderson-Sellers 2002)). However, as stated in the introduction, the visual syntax of a notation has a great impact on the cognitive effectiveness of it as well (Moody 2009a; Larkin and Simon 1987). A couple of theories for evaluating the visual syntax of notations have been developed, such as the Cognitive Dimensions of Notations (CDs) framework (Green et al. 2006), the semiotic quality (SEQUAL) framework (Krogstie et al. 2006) and Moody's Physics of Notations (Moody 2009a). Genon et al. (2011b) argue that the first two frameworks lack theoretical and empirical foundations concerning the visual aspects of notations. Besides, in Moody's evaluation of the CDs framework, several additional shortcomings of that framework can be found (Moody 2009b). Therefore, Moody's Physics of Notations is used as a basis for this research.

Moody (2009a) states that a clear design goal needs to be identified before a visual notation can be developed. Common design goals are e.g. simplicity and expressiveness. However, these goals are considered to be vague and subjective. A more objective and scientific goal is cognitive effectiveness, which is the speed, ease and accuracy with which a representation can be processed (Larkin and Simon 1987). To enable designers to create cognitively effective visual notations, Moody (2009a) has defined nine principles. These are explained in the next paragraphs together with their relevance for this chapter.

Semiotic Clarity. Each semantic construct should be represented by exactly one graphical symbol, and vice versa. Four kinds of anomalies can occur in a notation:

- *Symbol redundancy*: a semantic construct is represented by multiple symbols
- *Symbol overload*: one symbol represents more than one semantic construct
- *Symbol excess*: a symbol is created that does not represent any semantic construct
- *Symbol deficit*: there is no symbol provided for a certain semantic construct

This principle is incorporated in this chapter with the intention to obtain an unambiguous notation that inherently avoids misconceptions.

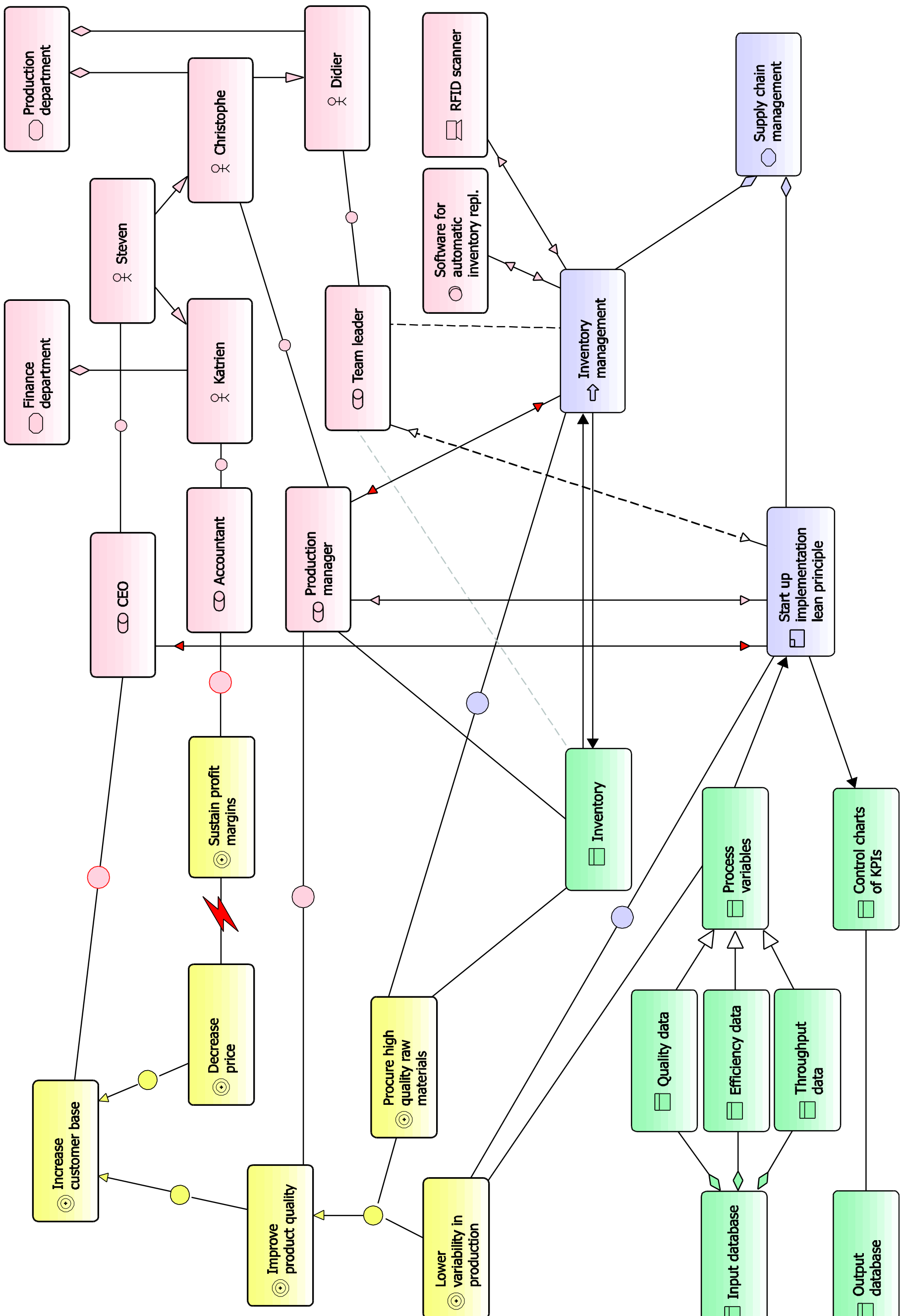


Figure 6.2: Model created with the current visual notation of CHOOSE

Perceptual Discriminability. It should be possible to easily and accurately distinguish between different symbols. This is determined by the number of visual variables on which symbols differ, combined with the magnitude of the differences. A greater visual distance between symbols leads to a faster and more accurate recognition. Shape is a detrimental factor in distinguishing between symbols. Therefore, it should be used as the primary visual variable. Perceptual discriminability is very important in the case of CHOOSE, because this notation is used by novices and the requirements for discriminability are higher for novices than for experts.

Semantic Transparency. The representation of a construct should suggest its meaning. One way to design semantic transparent symbols is by using icons, which lead to a faster recognition and recall of the constructs. Besides, they especially enhance the comprehensibility of the notation for novice users, which makes it very worthwhile to incorporate this principle in this research.

Visual Expressiveness. This is determined by the number of visual variables used in a notation and the extent to which they are used. While perceptual discriminability is a measure for the pairwise discrepancy between symbols, visual expressiveness measures the diversity of the visual vocabulary as a whole. Colour is a strong mechanism for enhancing the visual expressiveness of a notation, as contrast in colour is seen faster than differences in other variables. However, it should only be used in a redundant way, because differences disappear when diagrams are printed in grayscale.

Complexity Management. Diagrammatic complexity is measured by the number of elements in a diagram. This type of complexity can be reduced in two ways. First, the diagram can be split into smaller sub diagrams, which is called modularization. Furthermore, diagrams can be hierarchically structured to limit the levels of detail. This principle is very important in the case of CHOOSE, because novices have more difficulties dealing with complexity than experts (Sweller 1994).

Dual Coding. According to Moody, text can be used as a supplement for graphics. However, it is still important that symbols are distinguishable based on the graphics rather than the text. Labels can be used to distinguish between symbol instances, not between symbol types (Moody 2009a). Therefore, this principle is somewhat less addressed here.

Cognitive Integration. The notation should enable integrating information from different diagrams. Although this principle should not be neglected, it is not incorporated in this research. As CHOOSE targets novices in enterprise modeling, one notation to model everything is preferred. Besides, when SMEs grow and more detail needs to be added to the EA models, it might be useful to map the CHOOSE models on the ArchiMate standard (The Open Group 2012). Bernaert et al. have already conducted a research on this (2015b), which makes it less relevant to include it in this chapter.

Graphic Economy. The number of symbol types in a notation should be limited. This principle can be adopted in three ways. First, semantic constructs can be removed. However, the number of constructs in CHOOSE is already limited to the bare minimum. Second, symbol deficit can be introduced, but this harms the semiotic clarity of the notation (see above).

Third, visual expressiveness can be used. Manipulating multiple visual variables reduces the need to lower the amount of symbols. In this research, this third action is applied in order to pursue graphic economy. Therefore, the principle by itself will not be individually investigated.

Cognitive Fit. Cognitively effective notations for novices might not be cognitively effective for experts, and vice versa. This principle therefore states that different audiences need different notations. CHOOSE targets SMEs, which is a very diverse audience in terms of expertise. However, this principle is not included in this research because in general most users of the target group are novices in enterprise modeling.

6.2.3 Related Work

Several visual notations such as UML (Moody and Hillegersberg 2009), i* (Moody et al. 2010), BPMN (Genon et al. 2011b) and UCM (Genon et al. 2011a) have been evaluated based on the principles of the Physics of Notations. These studies constitute a useful basis for this chapter, because they demonstrate a methodology to identify shortcomings in a notation. This methodology is also applied for evaluating the CHOOSE visualization (section 6.3). However, the four articles have two limitations in common: the suggested improvements have not been thoroughly elaborated and the findings have not been empirically evaluated.

Gopalakrishnan et al. (2010) have compared two notation alternatives for process modeling by conducting a controlled experiment. Although similar goals as in this research are pursued, they do not use the concept of cognitive effectiveness. Furthermore, Huang et al. (2009) have conducted an experiment to compare different graph visualizations, based on a cognitive load perspective. Their research does not focus on visual notations, but several aspects of the test design provide useful insights for the experiment described in this chapter.

6.3 Analysis of the CHOOSE Visualization

In this section, the current visual notation of CHOOSE is evaluated based on five principles from Moody's theory. As mentioned in the previous section dual coding, cognitive integration, graphic economy and cognitive fit are not covered.

Semiotic Clarity. Currently, there is no symbol redundancy, excess or deficit. The only anomaly that occurs is symbol overload, which can cause misinterpretation (Moody 2009a). For CHOOSE, the relationships *association*, *concern* and *control* are represented by the same symbol, which is also the case for *input* and *output* (Figure 6.8). For these latter two, the problem is not tremendous, since they represent the same content in the opposite direction. For *association*, *concern* and *control*, it is important to resolve this anomaly because the meaning of these relationships cannot be linked.

Perceptual Discriminability. Shape is a very important factor in distinguishing between different symbols. However, all ten entities are represented by one shape: a rounded rectangle. Besides, many relationships have equal shapes as well. For the total of 32 semantic constructs, only 12 different shapes are used. This is a crucial shortcoming that will have to be eliminated when designing alternative visualizations.

Semantic Transparency. There is clearly a lot of room for improvement regarding this principle. Only four symbols show a certain presence of semantic transparency, which are the symbols of *goal*, *conflict*, *human actor* and *device*. This means 28 symbols do not suggest the meaning of their construct at all.

Visual Expressiveness. In total, there are eight visual variables that can be modified: shape, size, colour, brightness, orientation, texture, horizontal and vertical position (Moody 2009a). Currently, the variables shape, colour, brightness, horizontal and vertical position are used, which is better than most visual notations (Moody et al. 2010). However, some of them are more adequately used than others. Constructs belonging to the same viewpoint are e.g. represented by one colour and they are grouped into the same corner. These variables are properly utilized. Brightness on the other hand is categorized as a used variable, because *informed* and *monitor* are represented in a slightly different grey. One could doubt whether the variable is utilized in the right context, because *informed* and *monitor* do not have any meaning in common.

Complexity Management. Currently, all information is modeled in one diagram. This means no mechanisms are provided for managing complexity. However, diagrams can quickly become too complex for novices (Moody 2009a). Hence, integrating this principle would benefit the cognitive effectiveness of the notation. As the metamodel of CHOOSE clearly distinguishes between four viewpoints, it can be useful to apply the mechanism of modularization and as such split the diagram into sub diagrams.

6.4 Alternative Visualizations Development

The evaluation of the current visual notation served as a basis for the development of three alternatives. During the establishment of the first alternative, special attention was paid to the principles of semiotic clarity, perceptual discriminability, semantic transparency and visual expressiveness. When, as a little exploratory research, the resulting diagram was presented to four CEOs of SMEs, the major remark was the lack of uniformity in style. Although this aspect is not incorporated in the Physics of Notations, the interview revealed that it should not be neglected. Besides, the research of Sonderegger and Sauer (2010) showed that aesthetics have a positive influence on the users' performance and the perceived usability. It is therefore worthwhile to incorporate this in the visualization. Hence, a second visualization alternative was developed with the intention to achieve this uniformity in style. After this, complexity management was integrated, which resulted in a third visualization alternative.

In the first alternative, some essential problems of the original notation are handled (Figure 6.3). First of all, it is made sure that every semantic construct corresponds with exactly one graphical symbol, and vice versa. Only the relationships *input* and *output* are still represented by the same symbol, for reasons stated in section 6.3. Second, different constructs within one viewpoint are represented by symbols that have the same shape, while the shapes differ between the viewpoints. The contrast between the viewpoints is further enlarged by using clearly distinguishable colours. Third, icons are used in order to improve the semantic transparency of the symbols. *Operations* are represented by a gear, the relationship *monitor* by an eye, *control* by a steering wheel, etc. Last, visual variables are used in a consistent way. The variable brightness is only used when it can have a meaningful contribution. In the case of the symbols of *RACI,* relationships that involve a higher responsibility are represented by a darker colour.

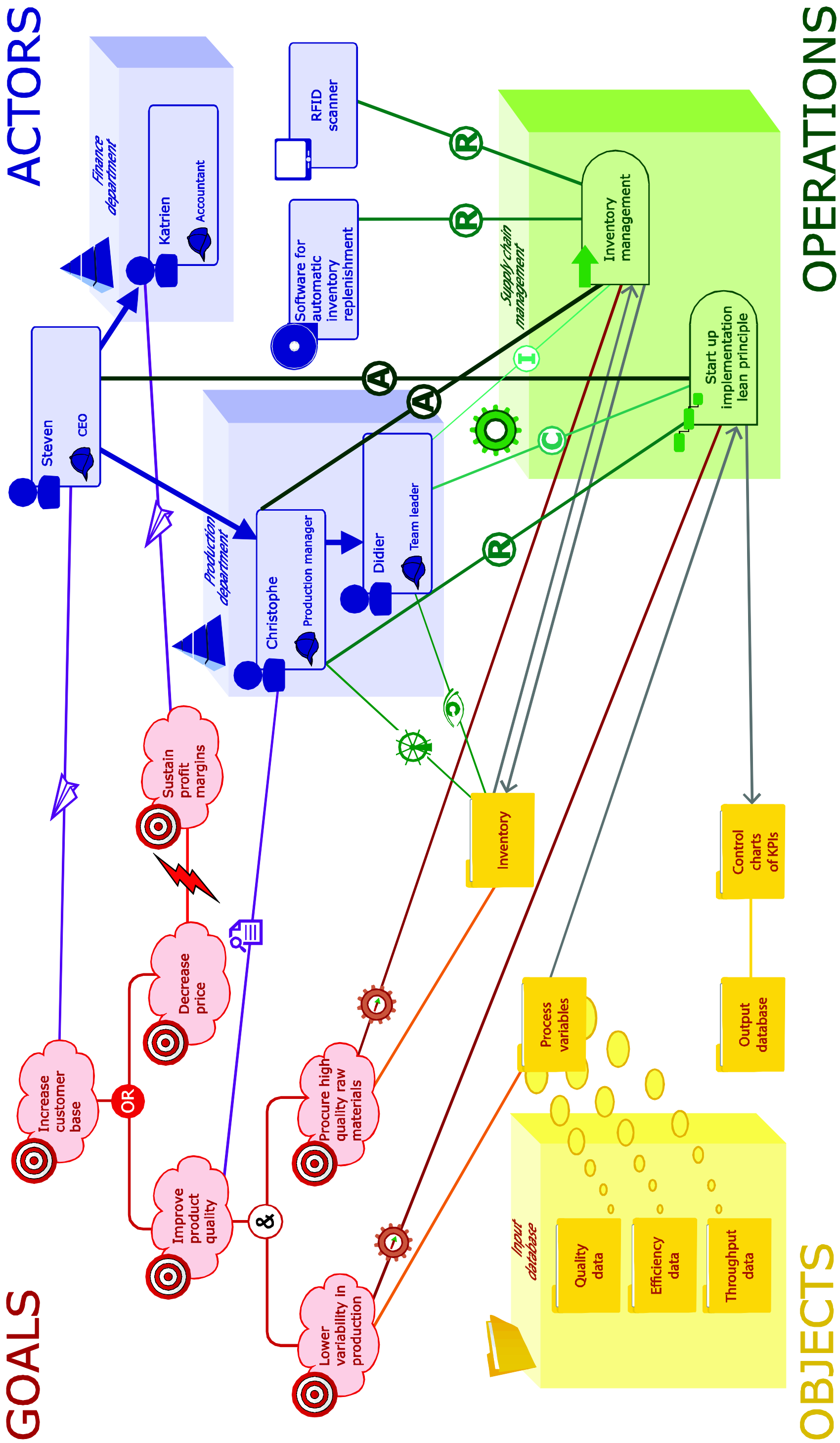


Figure 6.3: Model created with the first alternative visual notation

In order to develop the second alternative visualization, the first alternative is used as a starting point. This notation does not add any improvements in terms of Moody's principles. However, as explained above, it is developed in order to obtain uniformity in style. The result can be seen in Figure 6.4.

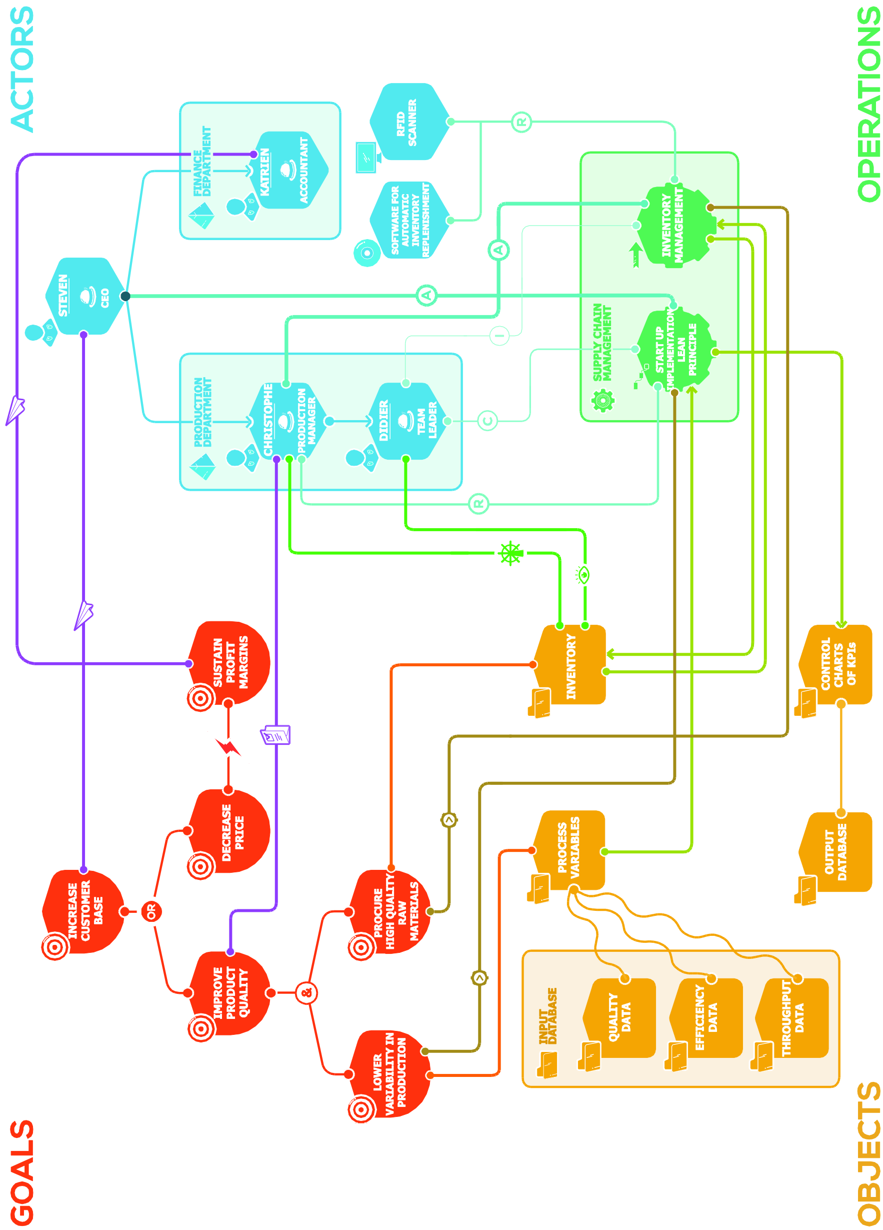


Figure 6.4: Model created with the second alternative visual notation

The previous alternatives display all information in one diagram. However, even for a small example as in the images in this chapter, relationships between the viewpoints turn the diagram into a complicated maze of information. Therefore, incorporating mechanisms to enable complexity management might improve the comprehensibility of the notation. Several functionalities are hence applied on the previous alternative. First of all, it is made possible to interpret a single viewpoint at a time (Figure 6.5). Second, relationships between viewpoints can be analyzed in a diagram that only displays the elements of two viewpoints and their interconnections (Figure 6.6).

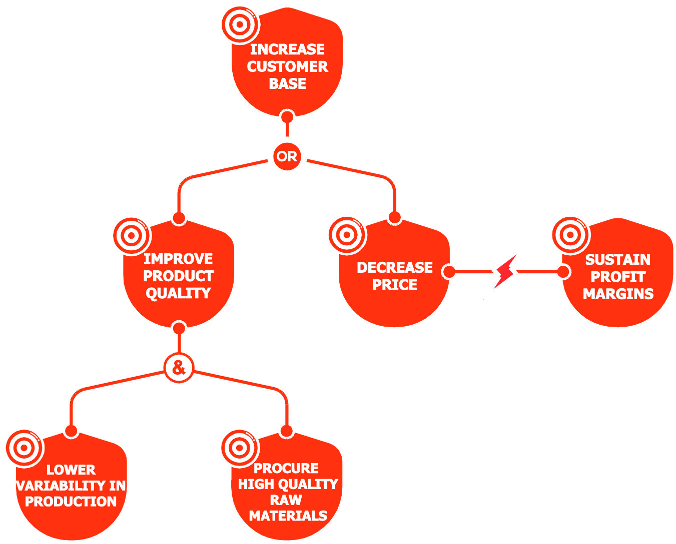


Figure 6.5: Single viewpoint

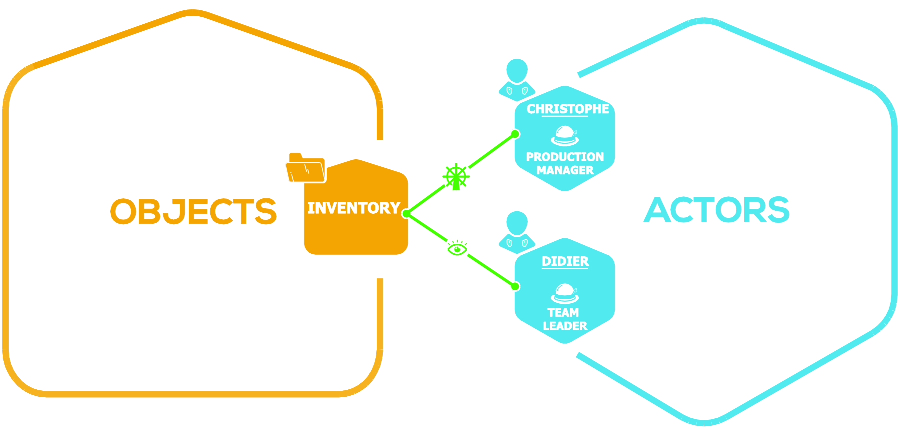


Figure 6.6: Pairwise relationships

These two measures drastically reduce the number of graphical elements displayed, which should lead to an easier and faster understanding of the content. However, if these two representations would be the only ways to access the content, the overview might get lost. This should be avoided because attaining a holistic overview is one of the major advantages of implementing CHOOSE in an organization. It should therefore still be possible to access the entire diagram. Hence, a third functionality is added. When the entire diagram is displayed, and the user places the cursor on an element in the diagram, that specific element is highlighted together with all adjacent elements (Figure 6.7). The combination of these three additional functionalities should lead to better results during the controlled experiment.

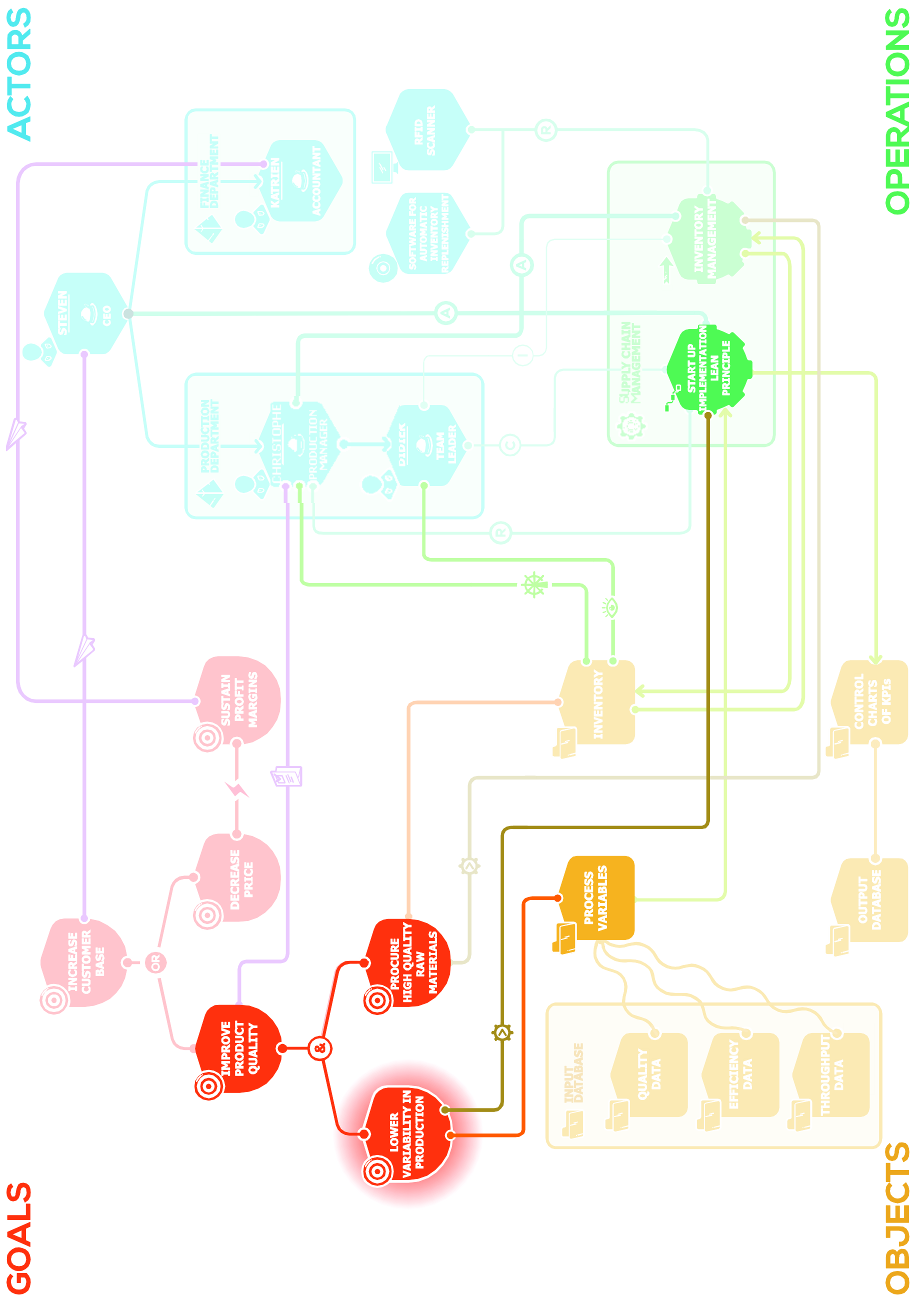


Figure 6.7: Entire view with cursor on the goal ‘Lower variability in production’

6.5 Evaluation

6.5.1 Test Design

In order to determine which representation of CHOOSE is the most comprehensive one, a controlled experiment is conducted. This approach is more appropriate than carrying out case studies because it would be impossible to compare different notations based on a real-life example of an SME without generating learning effects. Yet, it is difficult to execute an experiment of this magnitude within the target group of CHOOSE (i.e. SMEs). Therefore, the test is conducted appealing to a homogeneous group of (on average) 20-year old business engineering students without enterprise modeling experience, as they have many similar characteristics.

Once this is known, the decision needs to be made whether a within-subjects or a between-subjects design is used. A major advantage of a within-subjects design is the need for fewer subjects (Brown and Melamed 1990). However, this design would dramatically increase the duration of the survey, which could lead to a fatigue bias in the results. Therefore, a between-subjects design is applied. This means the students are divided into four groups, and each group receives the same survey but with another visual notation.

The goal of the survey is to examine whether the newly established visualizations result in a better cognitive effectiveness on the one hand and in improved perceived ease of use (PEOU), perceived usefulness (PU) and intention to use (IU) on the other hand. These last variables originate from the Technology Acceptance Model (TAM), which states that improvements in these variables increase the chance of adoption (Davis 1989). TAM is used in accordance to the research of Gopalakrishnan et al. (2010).

As shortcomings are gradually managed within the developed visualizations, it is expected that each alternative outperforms the previous one. The overall hypotheses are described below. Null hypotheses are not mentioned due to limited space.

- $\mathbf{H_a}$: notation i outperforms notation i-1 in terms of cognitive effectiveness (i = 1 to 3)
- $\mathbf{H_b}$: notation i outperforms notation i-1 in terms of PEOU, PU and IU (i = 1 to 3)

Cognitive effectiveness (CE) is a variable composed out of three other variables: accuracy, time and mental effort. Accuracy (A) is expressed as the percentage of correct answers in the survey. Time (T) is expressed as the average time used to answer a question, while the subjects are asked to report the mental effort (ME) needed to answer a content question on a 9-point Likert scale (Paas 1992). Since these variables are expressed in different units of measurement, the variables are standardized before they are combined into the formula of cognitive effectiveness. Analogous to (Tuovinen and Paas 2004), CE is then calculated as follows:

$$Cognitive\ effectiveness = \frac{Z(A) - Z(T) - Z(ME)}{\sqrt{3}}$$

The survey[1] consists of three parts. In the first part, general questions are asked to verify the students' prior knowledge regarding enterprise architecture and conceptual modeling. As a between-subjects design is used, these questions are important to avoid an accidental group selection bias (Gopalakrishnan et al. 2010). The second part comprises 12 questions to examine the understanding of the diagram(s), which are all accompanied by a question that inquires for the mental effort needed to answer the content question. The question groups (content + mental effort) are randomized in order to avoid obtaining overall better results for the last questions. The third and last part consists of 14 questions based on (Gopalakrishnan et al. 2010) that gauge the PEOU, PU and IU. The answers are measured on a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'.

6.5.2 Experiment Results

In total, 120 useful observations can be analyzed. Six results are omitted, because there are clear indications that those students have not conscientiously filled in the survey. The four sample sizes are slightly different, ranging from 29 responses to 32. Descriptive statistics for each variable can be found in Table 6.1.

Table 6.1: Descriptive statistics per group

	Current notation (N=29)		Alternative 1 (N=30)		Alternative 2 (N=29)		Alternative 3 (N=32)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CE	-1.0353	0.9941	-0.4365	1.0696	-0.3956	1.0331	0.7080	0.8134
A	0.8276	0.1230	0.8810	0.1344	0.8916	0.1303	0.9665	0.0544
T	35.6616	8.6862	31.6336	6.3017	33.4239	5.7900	27.7378	4.6965
ME	3.3736	1.0176	3.4333	1.0941	3.1695	1.0323	2.7891	0.9499
PEOU	3.2690	0.3752	3.1533	0.4862	3.2138	0.6255	3.4375	0.4172
PU	3.6621	0.5017	3.6533	0.7482	3.5448	0.6277	4.0250	0.3619
IU	3.0776	0.7621	3.0750	0.7689	3.3707	0.5733	3.5625	0.5198

The variable CE satisfies all criteria to be analyzed by means of an ANOVA. The other variables violate at least one of the assumptions. Therefore, these variables are examined with the Kruskal-Wallis test and the Mann-Whitney U test. These tests assume that the distributions of the different groups have equal shapes. It should be mentioned however that this assumption is not entirely satisfied for the variables ME and PEOU. Hence, these variables should be cautiously analyzed. All analyses have been conducted with a significance level of 5%. The results in Table 6.2 demonstrate that the third alternative has a significantly higher cognitive effectiveness than the other visual notations, while the differences between the other notations are not significant. These results can be explained by

[1] The survey questions can be accessed using the following link: http://www.mis.ugent.be/choose/electronicappendix.pdf

analyzing the component variables of cognitive effectiveness. All three alternatives have better scores for accuracy than the current notation, but alternative 3 outperforms alternative 1 and 2. Next to this, the average time needed to answer a question is tremendously lower for alternative three than for the other alternatives. And last, only for the third alternative, the mental effort required to interpret the notation is significantly lower than for the current notation. For the variable PEOU, the only significant result that can be observed is the difference between alternative 1 and 3. The boxplots reveal that alternatives 2 and 3 have a higher median than the current notation and the first alternative, yet the differences are not significant. Possibly, the true significance level has shifted due to the unequally shaped distributions (Skovlund and Fenstad 2001). Regarding PU, alternative 3 has significantly better results than the other notations. Finally, the IU is significantly better for alternative 3 than for the current notation and for 2 and 3 than for the first alternative.

Table 6.2: Test results of the pairwise comparisons

Variable	Test statistic	0 – 1	0 – 2	0 – 3	1 – 2	1 – 3	2 – 3
CE	MD	0.5988	0.6397	1.7433***	0.0409	1.1445***	1.1036***
A	U	311*	263**	128***	429	296**	279**
T	U	275**	337	182***	333	284**	214***
ME	U	406.5	370.5	310*	352	312.5**	379
PEOU	U	323.5	361.5	356.5	320	310.5**	382
PU	U	402	369	271**	373	365*	260**
IU	U	400.5	286.5	267.5**	286.5**	273**	360

Note: MD = mean difference (Tukey HSD); U = Mann-Whitney U
*P<0.05; **P<0.01; ***P<0.001.

6.6 Discussion

The experiment results demonstrate that the last visual notation is clearly the best alternative. First of all, this notation is cognitively more effective than the others. Besides, the respondents of this notation have indicated a high perceived usefulness and intention to use. It is therefore advised to implement this notation.

Several statements can be made in the context of this experiment:

1) When alternative 1 is compared to the current notation, the conclusion can be made that incorporating semiotic clarity, perceptual discriminability, semantic transparency and visual expressiveness improves the accuracy and speed of the answers. However, the change in cognitive effectiveness is not significant due to the variable mental effort, which is not significantly improved.
2) When, on top of these principles, complexity management is applied, an impressive difference can be observed. Adding this principle results in a significant increase in the cognitive effectiveness of the notation. This can be concluded when alternative 3 is compared to the other visualizations.

3) Enhancing the aesthetics of the notation does not improve the cognitive effectiveness of it, nor one of its component variables (alternative 2 vs. 1).
4) However, ameliorating the aesthetics does lead to a higher intention to use. The results for this variable are significantly better for alternative 3 compared to the current notation and for 2 and 3 compared to the first alternative.
5) Integrating all five considered principles leads to a higher perceived usefulness of the notation. As the PU is not improved when the first four principles are applied, the idea rises that complexity management causes the increase in PU.

Overall, it can be said that both Moody's principles and aesthetics have a positive influence on the notation, and this in a complementary way. Moody's principles improve the comprehensibility of the notation and lead to an increase in perceived usefulness. Aesthetics on the other hand augment the intention to use the notation.

6.7 Conclusion and Future Research

This research has investigated the visual notation of CHOOSE, which is an EA approach developed by Bernaert et al. (2015c) with the aim to facilitate the implementation of EA in the context of SMEs. The current visual notation has been evaluated and alternatives have been established, after which the different visualizations have been compared in an experiment. Based on this experiment, an advice has been made to implement one of the notations in the CHOOSE approach.

The result of the investigation facilitates a cognitively effective interpretation of CHOOSE diagrams on the one hand, and improves the perceived usefulness and the intention to use the notation on the other hand. In practice, this should lead to an effective and time efficient way to deal with EA and hence improve its adoption rate in SMEs. However, as the experiment is conducted appealing to students, this aspect is ought to be further analyzed in future work by means of executing case studies or experiments in SMEs. Although the students subjected to the experiment have several characteristics in common with employees of SMEs – they have for example a keen interest in business topics and are novices in enterprise modeling – it is difficult to extrapolate the results of this investigation to the target group of SMEs.

Besides these practical implications, this chapter also provides a validation for the Physics of Notations. The research reveals that applying its principles significantly improves the comprehensibility of the notation. On top of this, it becomes clear that aesthetics should not be neglected, as this increases the intention to use the notation.

At last, this chapter suggests a methodology to evaluate visual notations and develop improved versions. Although this research is conducted in the context of CHOOSE, the positive outcome of this case might motivate researchers to consider following the same path.

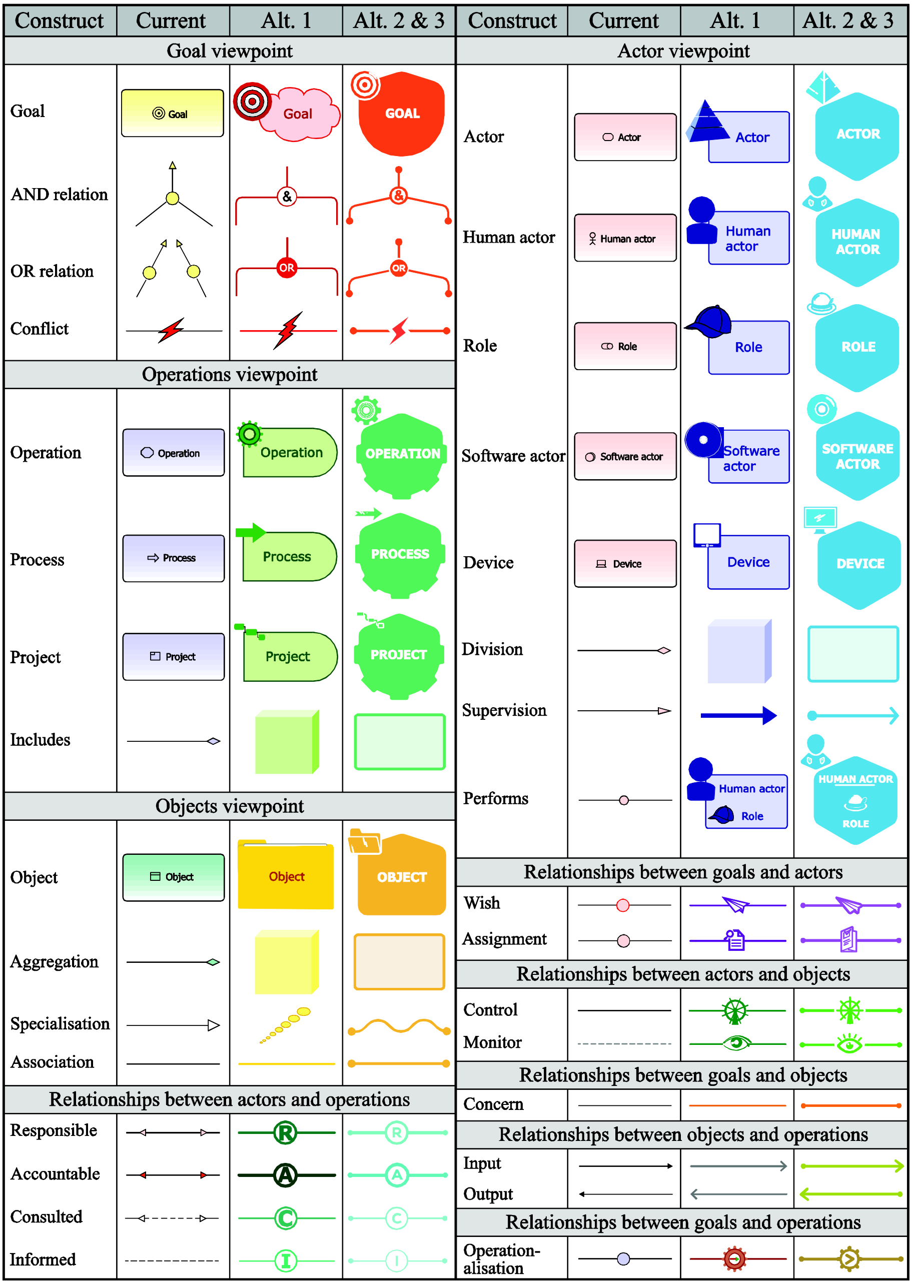


Figure 6.8: Legend: symbols applied in the different visual notations

7

Conclusion

This chapter summarizes the conclusions that were obtained throughout the problem analysis of EA in SMEs and the construction of the four CHOOSE artifacts during this PhD. Section 7.1 presents the main research results. The implications of these results for researchers and practitioners are discussed in section 7.2. Finally, section 7.3 describes limitations that provide opportunities for future research.

7.1 Research Results

In the last decades, Enterprise Architecture (EA) has evolved from a means for bringing structure in a company's IT landscape (IT architecture) to a means for bringing structure and coherence in different facets of a company.

The overall objective of our PhD research was to bridge the gap between EA and small and medium-sized enterprises (SMEs) by first analyzing the current state before proposing an EA technique customized to the requirements of SMEs.

In the first part of this dissertation, the *problem analysis* (Chapter 2), we wanted to acquire knowledge about problems occurring in SMEs and solutions EA could provide. Further, existing research on EA for SMEs was studied.

In the second part of this dissertation, the *solution design* (Chapters 3-6), we aimed to contribute to the EA body of knowledge by developing an EA technique for SMEs, consisting of four artifacts. A first artifact to be developed was a metamodel to capture and specify the EA data in a structured way (Chapter 3). A second artifact was a method, in order to provide steps, guidelines, tips, a roadmap, and stop criteria in order to be able to support the EA model development and management process (Chapter 4). A third artifact was the development of software tool support, to facilitate the implementation of our approach (Chapter 5). By enabling easy input and management of the EA model, the perceived ease of use of CHOOSE increased. By facilitating further possibilities for easy output and analysis of the CHOOSE model, the perceived usefulness could be increased. Both contribute to a higher intention to adopt, which is a good predictor of the later adoption (Moody 2003). The fourth artifact was an improved visualization for the CHOOSE models (Chapter 6).

For each of the developed CHOOSE artifacts (Chapters 3-6), a *solution validation* was made, focusing on increasing the chance of adoption of EA in SMEs by focusing on an optimal balance between simplicity (perceived ease of use) and comprehensiveness (perceived usefulness) of the CHOOSE approach within an SME context.

7.1.1 Problem Analysis of EA and SMEs (Chapter 2)

In this chapter, a better understanding is gained about EA and SMEs. Insight is provided in the requirements for an EA approach for SMEs, in order to increase the adoption rate, since EA can provide for a solution to problems that SMEs are facing due to a lack of structure and overview of the company. A plan with research steps is given that led to the development of the CHOOSE artifacts.

7.1.2 CHOOSE Metamodel (Chapter 3)

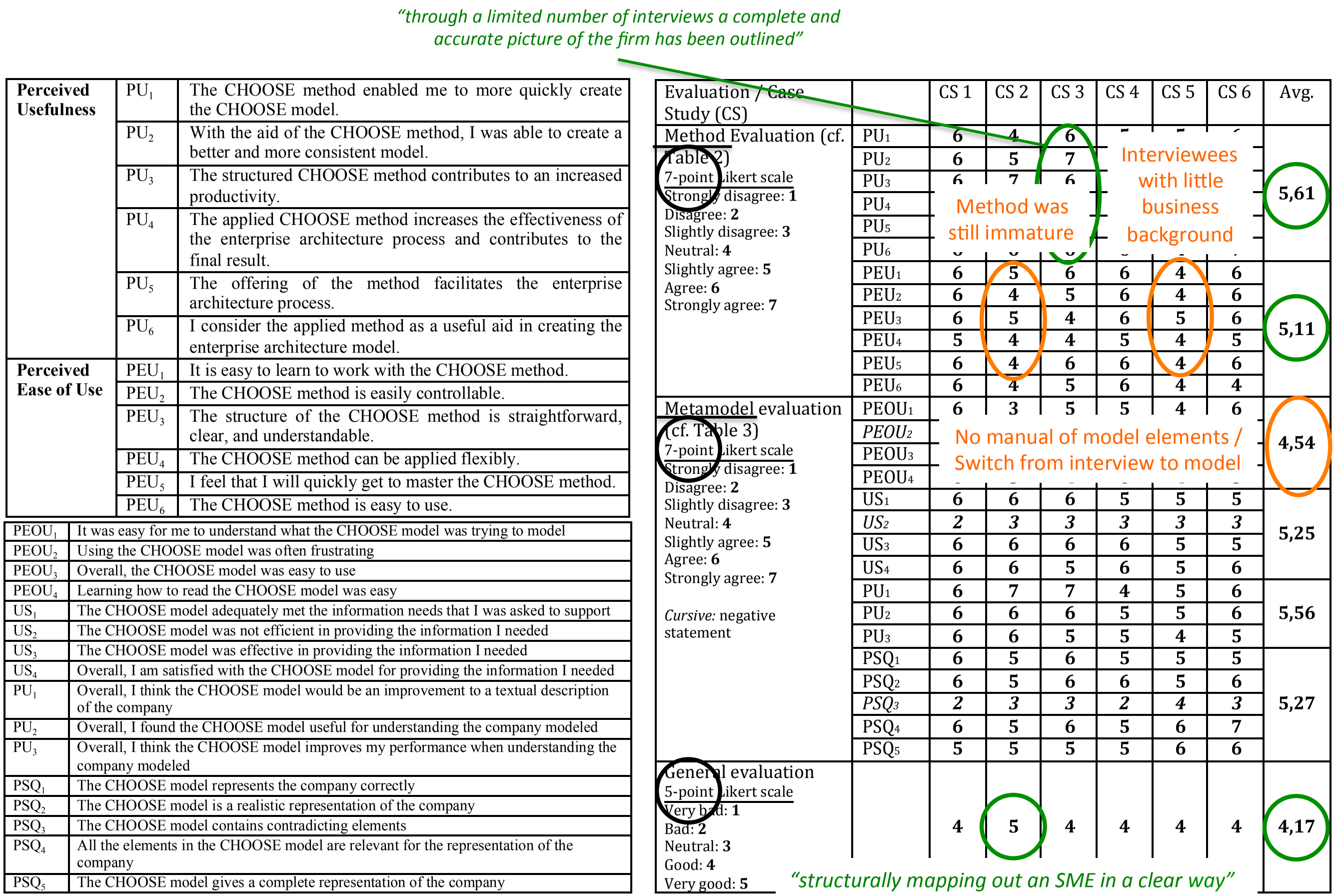
The CHOOSE metamodel is the first and most important artifact being designed, according to the requirements for EA in an SME context. It enables SMEs to create instantiations of the metamodel in the form of an EA model of their company in a structure that is simple, but very powerful for analyses. It can be considered as the first EA metamodel specifically tailored to SMEs.

This metamodel became robust by using it to model the EA of six companies. We noticed the potential of its use in SMEs, however, we still could increase adoption chances by constructing a CHOOSE method to guide the EA development process.

7.1.3 CHOOSE Method (Chapter 4)

The CHOOSE method is the second artifact and supports the SMEs in the process of creating (and to a lesser extent also managing) their EA model, based on the CHOOSE metamodel. It consists of a roadmap (a procedure to implement the CHOOSE approach), an interview-method (a best practice to structure the interviews) and stop-criteria (to indicate when the input-phase of the EA model development process can be terminated).

The CHOOSE method increases the intention to adopt the CHOOSE approach, since it significantly decreased the required effort to construct the SME's EA model and increased the completeness of the EA model. As shown in Figure 7.1, the perceived ease of understanding could however further be increased, especially since the CEOs perceived a big hurdle when they had to use CHOOSE themselves. During the action research, the researchers were guiding the interviews and making the EA models after interviewing the CEOs, but at the end of the action research, the CEOs had to do the same without any further guidance and knowledge of the CHOOSE metamodel's constructs and relationships. Software tool support could however provide a solution to guide the CEOs throughout the modeling process and provide them with a glossary explaining the meaning of the different CHOOSE constructs and relationships.



Perceived Usefulness	PU_1	The CHOOSE method enabled me to more quickly create the CHOOSE model.
	PU_2	With the aid of the CHOOSE method, I was able to create a better and more consistent model.
	PU_3	The structured CHOOSE method contributes to an increased productivity.
	PU_4	The applied CHOOSE method increases the effectiveness of the enterprise architecture process and contributes to the final result.
	PU_5	The offering of the method facilitates the enterprise architecture process.
	PU_6	I consider the applied method as a useful aid in creating the enterprise architecture model.
Perceived Ease of Use	PEU_1	It is easy to learn to work with the CHOOSE method.
	PEU_2	The CHOOSE method is easily controllable.
	PEU_3	The structure of the CHOOSE method is straightforward, clear, and understandable.
	PEU_4	The CHOOSE method can be applied flexibly.
	PEU_5	I feel that I will quickly get to master the CHOOSE method.
	PEU_6	The CHOOSE method is easy to use.

$PEOU_1$	It was easy for me to understand what the CHOOSE model was trying to model
$PEOU_2$	Using the CHOOSE model was often frustrating
$PEOU_3$	Overall, the CHOOSE model was easy to use
$PEOU_4$	Learning how to read the CHOOSE model was easy
US_1	The CHOOSE model adequately met the information needs that I was asked to support
US_2	The CHOOSE model was not efficient in providing the information I needed
US_3	The CHOOSE model was effective in providing the information I needed
US_4	Overall, I am satisfied with the CHOOSE model for providing the information I needed
PU_1	Overall, I think the CHOOSE model would be an improvement to a textual description of the company
PU_2	Overall, I found the CHOOSE model useful for understanding the company modeled
PU_3	Overall, I think the CHOOSE model improves my performance when understanding the company modeled
PSQ_1	The CHOOSE model represents the company correctly
PSQ_2	The CHOOSE model is a realistic representation of the company
PSQ_3	The CHOOSE model contains contradicting elements
PSQ_4	All the elements in the CHOOSE model are relevant for the representation of the company
PSQ_5	The CHOOSE model gives a complete representation of the company

Evaluation / Case Study (CS)		CS 1	CS 2	CS 3	CS 4	CS 5	CS 6	Avg.
Method Evaluation (cf. Table 2) 7-point Likert scale Strongly disagree: **1** Disagree: **2** Slightly disagree: **3** Neutral: **4** Slightly agree: **5** Agree: **6** Strongly agree: **7**	PU_1	**6**	**4**	**6**	[illegible]	[illegible]	[illegible]	**5,61**
	PU_2	**6**	**5**	**7**	[illegible]	[illegible]	[illegible]	
	PU_3	**6**	**7**	**6**	[illegible]	[illegible]	[illegible]	
	PU_4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	PU_5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	PU_6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	PEU_1	**6**	**5**	**6**	**6**	**4**	**6**	**5,11**
	PEU_2	**6**	**4**	**5**	**6**	**4**	**6**	
	PEU_3	**6**	**5**	**4**	**6**	**5**	**6**	
	PEU_4	**5**	**4**	**4**	**5**	**4**	**5**	
	PEU_5	**6**	**4**	**6**	**6**	**4**	**6**	
	PEU_6	**6**	**4**	**5**	**6**	**4**	**4**	
Metamodel evaluation (cf. Table 3) 7-point Likert scale Strongly disagree: **1** Disagree: **2** Slightly disagree: **3** Neutral: **4** Slightly agree: **5** Agree: **6** Strongly agree: **7** *Cursive:* negative statement	$PEOU_1$	**6**	**3**	**5**	**5**	**4**	**6**	**4,54**
	$PEOU_2$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	$PEOU_3$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	$PEOU_4$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	US_1	**6**	**6**	**6**	**5**	**5**	**5**	**5,25**
	US_2	***2***	***3***	***3***	***3***	***3***	***3***	
	US_3	**6**	**6**	**6**	**6**	**5**	**5**	
	US_4	**6**	**6**	**5**	**6**	**5**	**6**	
	PU_1	**6**	**7**	**7**	**4**	**5**	**6**	**5,56**
	PU_2	**6**	**6**	**6**	**5**	**5**	**6**	
	PU_3	**6**	**6**	**5**	**5**	**4**	**5**	
	PSQ_1	**6**	**5**	**6**	**5**	**5**	**5**	**5,27**
	PSQ_2	**6**	**5**	**6**	**6**	**5**	**6**	
	PSQ_3	***2***	***3***	***3***	***2***	***4***	***3***	
	PSQ_4	**6**	**5**	**6**	**5**	**6**	**7**	
	PSQ_5	**5**	**5**	**5**	**5**	**6**	**6**	
General evaluation 5-point Likert scale Very bad: **1** Bad: **2** Neutral: **3** Good: **4** Very good: **5**		**4**	**5**	**4**	**4**	**4**	**4**	**4,17**

Figure 7.1: Interpretation of the evaluation of CHOOSE metamodel and method

7.1.4 CHOOSE Software Tool Support (Chapter 5)

Different software tools were developed as a third artifact to guide the user throughout the entire EA process and facilitate the implementation, management and maintenance of the resulting EA. The software tools are based on the requirements for EA in an SME context and on criteria for tool support. The evaluation in different SMEs confirmed the potential of the software tool in increasing the adoption of CHOOSE and providing the much needed guidance and support.

In comparison with the CHOOSE approach without any software tool support, the EASE tool increased the perceived ease of use in the action research companies (Figure 7.2). Regarding the perceived usefulness, the EASE tool however provided no answer to more quickly create the CHOOSE model, to make a better and more consistent model, and to facilitate the EA process. This can be explained since this EASE tool did not incorporate the CHOOSE method and was not yet complete regarding analyses and output possibilities using the CHOOSE model. As explained in the introduction (section 1.3.3.4), each of the developed software tools have proved to have their own benefits and should further be analyzed and combined into a best-of-breed software tool to have the best effect on the adoption rate of CHOOSE in SMEs.

Perceived Usefulness	PU_1	The CHOOSE method enabled me to more quickly create the CHOOSE model.
	PU_2	With the aid of the CHOOSE method, I was able to create a better and more consistent model.
	PU_3	The structured CHOOSE method contributes to an increased productivity.
	PU_4	The applied CHOOSE method increases the effectiveness of the enterprise architecture process and contributes to the final result.
	PU_5	The offering of the method facilitates the enterprise architecture process.
	PU_6	I consider the applied method as a useful aid in creating the enterprise architecture model.
Perceived Ease of Use	PEU_1	It is easy to learn to work with the CHOOSE method.
	PEU_2	The CHOOSE method is easily controllable.
	PEU_3	The structure of the CHOOSE method is straightforward, clear, and understandable.
	PEU_4	The CHOOSE method can be applied flexibly.
	PEU_5	I feel that I will quickly get to master the CHOOSE method.
	PEU_6	The CHOOSE method is easy to use.

Technology acceptance model: Perceived usefulness (PU)		CS1	CS2	CS3	CS4	Avg.
7-point Likert scale: Extremely likely: 7 Quite likely: 6 Slightly likely: 5 Neither: 4 Slightly unlikely: 3 Quite unlikely: 2 Extremely unlikely: 1	PU1	6	4	5	5	5,375
	PU2	6	5	6	5	
	PU3	6	4	4	6	
	PU4	6	5	6	5	
	PU5	6	4	5	6	
	PU6	6	5	7	6	
	Avg.	6	4,5	5,5	5,5	

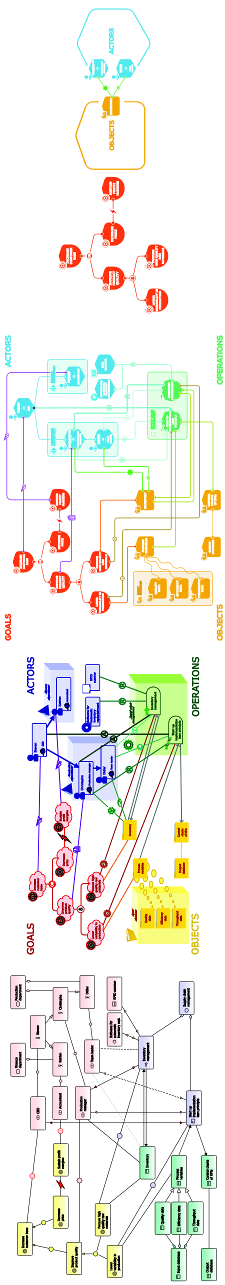
Technology acceptance model: Perceived ease of use (PEU)		CS1	CS2	CS3	CS4	Avg.
7-point Likert scale: Extremely likely: 7 Quite likely: 6 Slightly likely: 5 Neither: 4 Slightly unlikely: 3 Quite unlikely: 2 Extremely unlikely: 1	PEU1	6	5	5	7	5,625
	PEU2	6	5	5	7	
	PEU3	6	4	5	6	
	PEU4	6	4	4	6	
	PEU5	6	5	6	7	
	PEU6	6	5	6	7	
	Avg.	6	4,67	5,17	6,67	

Figure 7.2: Interpretation of the evaluation of the EASE software tool

7.1.5 CHOOSE Visualization (Chapter 6)

As the last artifact of the CHOOSE approach presented in this PhD, the visualization is developed, since it has a great impact on the cognitive effectiveness of a CHOOSE model. The chosen visualization proved to be the best alternative, since it significantly showed a higher cognitive effectiveness than the others and the respondents indicated a higher perceived usefulness and intention to use. A combination of implementing Moody's (2009a) principles (with special attention to complexity management) and aesthetics, proved to be the best cocktail for an improved visualization to deal with EA in an effective and time efficient way and hence improve its adoption rate in SMEs.

The visualization has thus proved to be very helpful in increasing the chances of adoption of EA in SMEs (Figure 7.3). Especially the complexity management (e.g. working with different viewpoints instead of showing the entire model), has a great effect and should be further elaborated to enhance the CHOOSE approach with a decent set of viewpoints and associated (automatic) visualizations.



Variable	Current notation (N=29)		Alternative 1 (N=30)		Alternative 2 (N=29)		Alternative 3 (N=32)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
COGNITIVE EFFECTIVENESS	-1.0353	0.9941	-0.4365	1.0696	-0.3956	1.0331	0.7080	0.8134
ACCURACY	0.8276	0.1230	0.8810	0.1344	0.8916	0.1303	0.9665	
TIME	35.6616	8.6862	31.6336	6.3017	33.4239	5.7900	27.7378	
MENTAL EFFORT	3.3736	1.0		41	3.1695	1.0323	2.7891	
PERCEIVED EASE OF USE	3.2690	0.3		62	3.2138	0.6255	3.4375	0.4172
PERCEIVED USEFULNESS	3.6621	0.5017	3.6533	0.7482	3.5448	0.6277	4.0250	0.3619
INTENTION TO USE	3.0776	0.7621	3.0750	0.7689	3.3707	0.5733	3.5625	0.5198

Moody's "visual" principles increase accuracy and speed

"Complexity management" has the best results

"Uniformity in style" seems to impact intention to use

Figure 7.3: Interpretation of the evaluation of the visualization

7.2 Implications

7.2.1 Implications for Practitioners

EA might offer SMEs a solution to typical problems related to a lack of overview, strategic awareness, IT planning, and business-IT alignment. However, neither academia nor practice demonstrated the existence and use of EA in SMEs. The CHOOSE approach is specifically developed for EA in SMEs and is to our knowledge the first effort for bridging the gap between EA and SMEs.

By increasing the adoption of EA in SMEs, SMEs can now benefit from the advantages that EA could bring. Some of these benefits are given as an example. First of all, EA makes it possible to clearly describe a competitive strategy (Porter 1985) as part of the business architecture and to align the company with this strategy to achieve a competitive advantage. Second, a clearly defined EA model could make it easier to find an ERP system that best fits the current business. Third, an explicit business architecture model can show the links between operations and strategy and enables an entrepreneur to communicate with the employees. Fourth, a job description can be queried from the relationships of employees with operations. Fifth, by explicitly linking strategic and operational items, it becomes easier to achieve and maintain alignment of the processes with the strategy. Sixth, these links make it possible to perform change impact analysis. Seventh, linking goals in a goal hierarchy and including goals from different stakeholders makes it possible to develop a global goal hierarchy and see which goals are conflicting. These conflicts can be resolved by balancing the different desires and goals (Heyse et al. 2012). Eighth, relevant knowledge of the company and the entrepreneurial knowledge can be made explicit in the EA model by modeling these concepts in the business layer, making it easier for employees and successors to gain insight in this knowledge.

Each of the tests of implementing CHOOSE in SMEs proved to offer benefits for the SMEs, which were presented throughout this PhD dissertation.

7.2.2 Implications for Researchers

The impact of this research is substantial as, to our knowledge, it is among the first efforts for bringing EA to SMEs (Bernaert et al. 2014; Chew and Dehbokry 2013; Bidan et al. 2012; Wißotzki and Sonnenberger 2012; Aarabi et al. 2011; Bernaert and Poels 2011b; Jacobs et al. 2011), and to our knowledge the first effort to actually develop an EA approach specifically adapted to the SME context. Previous and related research (Bernaert et al. 2014; Chew and Dehbokry 2013; Bidan et al. 2012; Jacobs et al. 2011) clearly indicated the need for EA to be used in SMEs and the unsuitability of existing EA approaches in an SME context. However, up till now, no concrete EA artifacts have ever been developed. The key contributions of this research are the development of the CHOOSE metamodel, method, software tool support and visualization as a coherent set of artifacts adapted to the characteristics of an SME context and overall positively evaluated by SMEs. The implications for further EA research follow from the possibility to implement EA in an SME context by using the CHOOSE artifacts. Other researchers can now for example assess the real contributions and pitfalls of using EA in SMEs. For instance, longitudinal research about the long-term effects of EA in SMEs could now be performed, similar to the recent research of Lange et al. (2015) about the factors and measures of EA management success.

There are some examples of researchers that already elaborated on the research that has been done regarding CHOOSE. For instance, Hollander (2014) (Master student Open University Utrecht, the Netherlands) elaborated on the problem analysis of EA in SMEs (Chapter 2) and performed an evaluation of suitable EA approaches for an SME context. CHOOSE appeared to be very suitable to be used for business architecture in SMEs. Dehbokry (Dehbokry and Chew 2014) (PhD University of Technology, Sydney, Australia), Mohammed Alhassan Enagi (PhD Associate University of Cape Town, South Africa), Dimitry Kudryavtsev (Professor Saint-Petersburg State Polytechnical University, Russia), Jessica Weve (Master student University of Liège, Belgium), Martin Blechta (Master student Aarhus University, Denmark), Ronald Honhoff (Master student Open University Utrecht, the Netherlands), Raja Sekhar Vasa (startup "SketchEA" to provide EA services to SMEs, India), and Phil Mizzi (Operations director 360 Degrees Focus, Australia) are in contact to elaborate on CHOOSE, since they started performing research for EA in SMEs in their countries.

7.3 Limitations and Future Work

There are also some limitations and directions for future research. Although the CHOOSE approach was successfully applied in different SMEs, more extensive research can be done to test the approach in different types of SMEs, for example divided according to size, market segment, education of the CEO (good business analytic skills are needed), growth rate, etc. The hypothesis can be tested that the approach offers the greatest benefits in SMEs that are becoming larger and need more structure in order to be able to keep growing.

Further, the CHOOSE approach worked quite well in the business unit of a larger enterprise and is at the moment already used for more than 2 years in a business unit of a large Belgian bank. More research in the context of business architecture in larger enterprises should be performed and together with De Clercq we are doing a first attempt (De Clercq et al. 2015).

SMEs can also be followed during a longer term, in order to see the long-term influence of the approach and how it enables enterprise architecture management (EAM). This could contribute to the recent work of

Lange et al. (2015) about the factors and measures of EA management success.

Another area for future research involves comparing the different software tools (Rosez et al. 2015) and develop a best-of-breed multiplatform tool (Machtelinckx et al. 2015). This would enable an easier interface for SMEs to input, adjust, and analyze their EA model. At present, we are also working on different possibilities to make as-is and to-be models and analyses, and are testing which best meet the needs of the SMEs.

We already noticed that after a while, CEOs started working with the software tool themselves. The ultimate goal is to further develop the CHOOSE approach so that any need for external help is reduced to a minimum.

Incorporating performance management in the CHOOSE approach is done in cooperation with Moons (2015) and could be further explored and evaluated.

Related to the research on the essentials of EA frameworks in chapter 3, the first effort towards a domain ontology for EA has been done (Carron et al. 2014).

Finally, a mapping on ArchiMate is being developed. This would allow users to switch from CHOOSE to ArchiMate if a more elaborate EA approach is needed to increase effectiveness for experienced EA users (Rossi and Brinkkemper 1996) (e.g., if a more detailed representation of the IT architecture would be needed), or to switch from ArchiMate to CHOOSE. It will then also become possible to map this model via ArchiMate onto different other models (such as process languages) which already have a mapping onto ArchiMate.

First attempts have been made (Bernaert et al. 2015b; Roose et al. 2013) and are currently further elaborated (Scheldeman et al. 2015). A short insight into this work is given in the following section.

7.3.1 Mapping CHOOSE – ArchiMate

ArchiMate is an Open Group standard (Lankhorst 2013; The Open Group 2012) for the modeling of EAs, emphasizing a holistic view of the enterprise. Because of its inherent holistic nature, ArchiMate has a rather extensive metamodel in comparison with CHOOSE's more simple metamodel.

An SME starting with EA to get a business overview (strategy, operations, organization, products, resources, and software, data, and devices) could benefit from using the CHOOSE approach that is specifically adapted to an SME context where time, budget, and expertise constraints are very high. However, during the lifecycle of this company, it could develop a need for a more elaborated EA language when more specific business-IT alignment support is needed and the IT architecture has to become more structured. On the other hand, it could also be possible that some people in a larger company (or a particular target audience, for example in the business) want to use a more simple EA modelling approach than ArchiMate. This could be a choice for the whole company when IT is of less importance, but could also be a need when business experts are actively involved in EA modeling. In the latter case, CHOOSE could be used by business line managers and their staff for business architecture modeling and ArchiMate could be used by the IT department for developing application and IT architectures and integrating them with the business architecture into the overall enterprise architecture. This need has for example been expressed by one of Belgium's largest banks, in which CHOOSE is currently tested to be an alternative EA modeling approach for business managers (De Clercq et al. 2015).

As part of our future research we envision, we want to design transformations between CHOOSE and ArchiMate models in both directions, in terms of a formal mapping of the metamodels underlying these approaches and a systematic application of these mapping rules to transform a CHOOSE model to an ArchiMate model and vice versa. We wish to stress that the mapping between both metamodels makes sense from a pragmatic point of view. We acknowledge the added value of both CHOOSE and ArchiMate and are not claiming either one is incorrect, but instead we are pointing out that CHOOSE limits itself to an SME or managerial context where a simple business overview is needed, while ArchiMate focuses on a more holistic EA overview, also fully representing the application, data, and technological infrastructure domains. The need for being able to map back and forth between both formats is also expressed by one of the SMEs in the work of Hollander (2014).

As a concrete case, one of the largest Belgian banks, although being strongly IT focused and not being an SME, encountered difficulties with aligning its business structure and operations (processes, projects, people, and products) to its strategy. Especially because of the multi-layered organizational structure (from CEO at group level, over CEO at department level, over different layers of middle management, to the actual operational layer), it became a key focus to overcome this strategic fit gap (Henderson and Venkatraman 1993). After hearing a presentation of CHOOSE, the managers of the bank became charmed by its simple way of aligning goals on different layers with processes and projects. Although ArchiMate is the de facto standard as EA language and now also includes a motivational extension, they perceived it as being very useful for the IT department, however being too complex to keep up to date by the managers. In fact, no manager had ever made an ArchiMate model and they were only using PowerPoint presentations and Excel sheets. Research of Schekkerman (2005) confirms that a lot of companies use Microsoft Office (29% of respondents) (e.g., Word, Excel, PowerPoint) or Visio (33% of respondents) to model their EA. The managers of the Belgian bank faced problems both with strategic fit and the functional integration of business and IT. First, the managers and consultants made PowerPoint presentations showing the general strategic overview, however, no explicit links were made with the business structure and operations (processes, projects, people, and products), hampering strategic fit. Second, the IT department uses ArchiMate for its IT architecture, however, the business managers are not closely involved with the business layer models, because they do not use ArchiMate. This hampers the functional integration of business and IT.

To cope with this strategic fit problem, the bank started test cases with CHOOSE (De Clercq et al. 2015). The feedback of the managers on the first small-scale test was very positive and if approved by the executive committee, CHOOSE will be deployed throughout the entire department first and maybe later throughout the entire company.

To cope with the business-IT functional integration problem, an optimal situation should be that both CHOOSE and ArchiMate models are aligned with each other. The bidirectional translation between CHOOSE and ArchiMate proposed as a future research direction of this PhD enables this alignment with little loss of information. If properly managed and deployed, both CHOOSE and ArchiMate models could be at all time aligned by automatically translating changes from one model to the other if the attributes of each metamodel's object include a reference to the original concept it was mapped from, to allow for reverse mapping.

In this future research, we describe different scenarios in which a switch between CHOOSE and ArchiMate would be appropriate. We define our problem as the lack of a translation between CHOOSE and ArchiMate in order to serve the EA needs of a company throughout its lifecycle from SME to a larger enterprise or to serve the EA needs of different stakeholders in different contexts within a company. We introduce a formal mapping between the CHOOSE and ArchiMate modeling techniques in both directions, and show how this metamodel mapping can be used to consistently transform between instantiations of these metamodels. We exemplify the translation using an extract from a CHOOSE model of a Belgian SME. Further, we provide a proof-of-concept software implementation of parts of the proposed model transformation, to provide computational assessment of the proposed model transformation. Finally, we evaluate both mappings based on an ontological analysis method.

The first results reveal that although CHOOSE's metamodel is a small, essential set, as opposed to ArchiMate's richness of EA elements, it is still comprehensive enough to make mappings to ArchiMate without much excess or overload. However, there is a large amount of redundancy in translating from CHOOSE to ArchiMate, which hampers the automatic translation from CHOOSE to ArchiMate unless if in CHOOSE's metamodel's object attributes a reference is included to the ArchiMate concept it was originally mapped from, to allow for reverse mapping. The mapping from ArchiMate to CHOOSE has little redundancy and is thus easier to automate. We can conclude that it is recommended to always include in each metamodel's object attributes a reference to the original concept it was mapped from, to allow for reverse mapping.

For future research, we believe the next step is to expose these models to the EA community where they can be validated, and, in particular, can be used to promote discussion about the use of CHOOSE and ArchiMate in different contexts and by different stakeholders. We further intend to practically validate our model transformation with an interested large Belgian bank. In addition, we intend to also validate our model transformation for SMEs using CHOOSE and that intend to use ArchiMate as a more elaborated EA approach to provide more specific business-IT alignment support or more support to structure the IT landscape.

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A
Appendix Chapter 3

A.1 Appendix 1: KAOS Metamodel

Each viewpoint is discussed separately and then the integrated KAOS metamodel is presented in Figure A.6. Concepts from the goal, agent, operation, object, and behaviour viewpoints will be respectively coloured in yellow, red, purple, green, and grey. Attributes between square brackets are optional attributes.

A.1.1 KAOS Goal Viewpoint

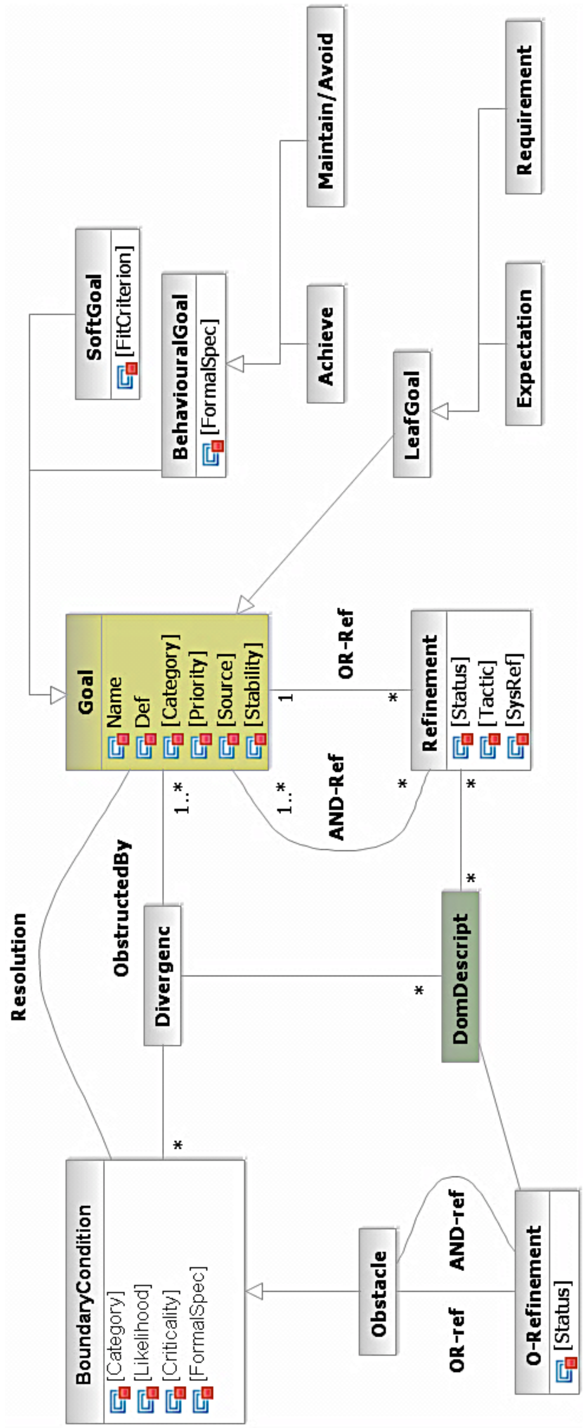

Figure A.1: KAOS goal viewpoint

The central element of the KAOS goal viewpoint is a *Goal*. A *Goal* is a prescriptive statement of intent that the system should satisfy through the cooperation of its *Agents*. The formulation is declarative, unlike *Operational* procedures to implement it. A *Goal* can be of a specific type (*SoftGoal* or *BehaviourGoal* (*Achieve* or *Maintain/Avoid*)) and of a specific *[Category]* (functional or non-functional).

Goal Refinement is enabled by refining higher-level *Goals* in zero or more *Refinements* (*OR-Ref*) that group (*AND-Ref*) one or more lower-level *Goals*. An *AND-Ref* (*OR-Ref*) means that the parent *Goal* can be satisfied/satisficed by satisfying/satisficing all (one or more) child *Goals* in the *Refinement*. A *LeafGoal* is a *Goal* that can be under the *Responsibility* of exactly one *Agent* and is a *Requirement* or *Expectation*, depending on the type of *Agent* that has a *Responsibility* relationship with it (respectively *SoftwareToBeAgent* and *EnvironmentAgent*).

Domain properties (*DomInvar*) or hypotheses (*DomHyp*) are descriptive statements (*DomDescript*) holding regardless of how system *Agents* behave. Domain properties typically correspond to physical laws that cannot be broken.

Goals can be *ObstructedBy Obstacles* or can be a *Resolution* for *Obstacles*. *Obstacles* can be refined by *O-Refinements* in the same way as *Goals* can be refined by *Refinements*. *Conflict* links may interconnect *Goal* nodes to capture potential *Conflicts* among them. They are not explicitly represented in the metamodel, but are captured in the *Divergence* relation, which captures a potential *Conflict*, where some statements become logically inconsistent if a *BoundaryCondition* becomes true.

A.1.2 KAOS Agent Viewpoint

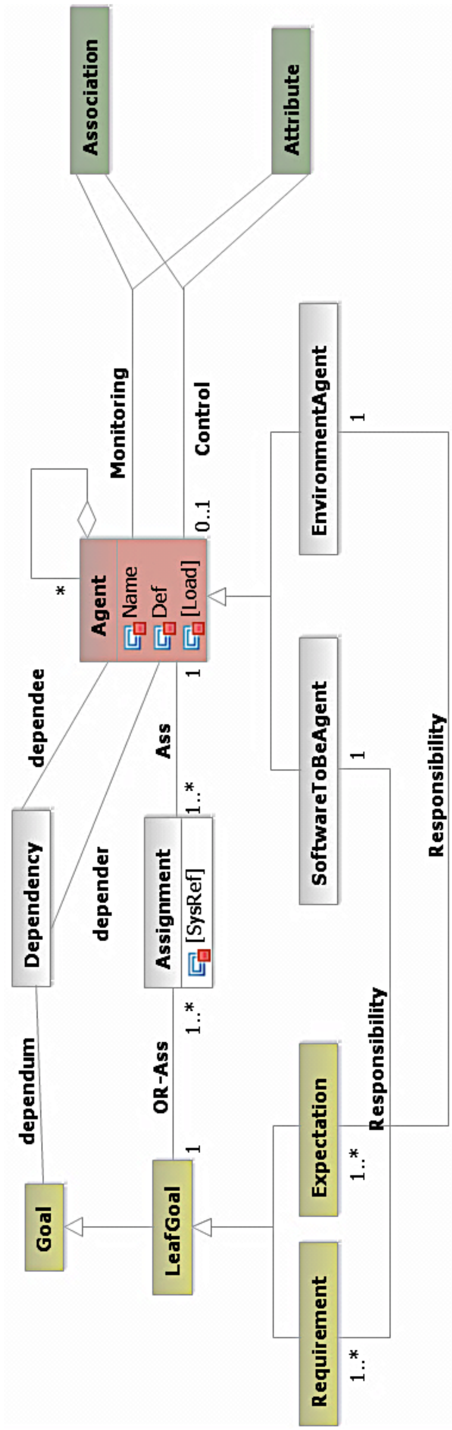

Figure A.2: KAOS agent viewpoint

The central element of the KAOS agent viewpoint is an *Agent*. *Agents* are active system *Objects* that are responsible for the *LeafGoals* in a goal model. An *Agent* is responsible for a *Goal* by a *Responsibility* relationship if restricting its individual behaviour by adequate control of system items is sufficient for ensuring *Goal* satisfaction/satisficing.

From an operational standpoint, an *Agent* can be defined as a processor that performs (*Performance*) *Operations* under restricted conditions to satisfy the *Goals* for which it is responsible (*Responsibility*). For an *Agent* to be assigned (*Assignment*) to a *Goal*, the *Goal* must be realizable by the *Agent* in view of its capabilities. *Agent* capabilities are defined in terms of *Object Attributes* and *Associations* that the *Agent* can *Monitor* or *Control*. *Monitor* means that an *Agent* can get the values of the *Attribute* or can evaluate whether the *Association* holds, while *Control* means that an *Agent* can set values for this *Attribute* or can create or delete an *Association*.

An *Agent* can be decomposed into finer-grained ones with finer-grained *Responsibilities* through the recursive *Aggregation* relationship. An *Agent* may be related to other *Agents* through *Dependency* links. A *depender* depends on a *dependee* for a *Goal*, if a *dependee's* failure to get this *Goal* satisfied/satisficed can result in a *depender's* failure to get one of its *Assigned Goals* satisfied/satisficed.

An agent model defines the boundary between the software-to-be and its environment, as an *Agent* can be a *SoftwareToBeAgent* or an *EnvironmentAgent*. An *Agent* can be of a different *[Category]*, while this is not explicitly visible in the metamodel: *NewSoftwareAgents* to be developed, *ExistingSoftwareAgents* with which the software-to-be will have to interoperate, *Devices*, and *HumanAgents* playing specific *Roles*.

The *Wish* meta-relationship is not shown in the metamodel. It links *Goal* and *HumanAgent* and captures the fact that this *HumanAgent* would like the *Goal* to be satisfied/satisficed.

A.1.3 KAOS Operation Viewpoint

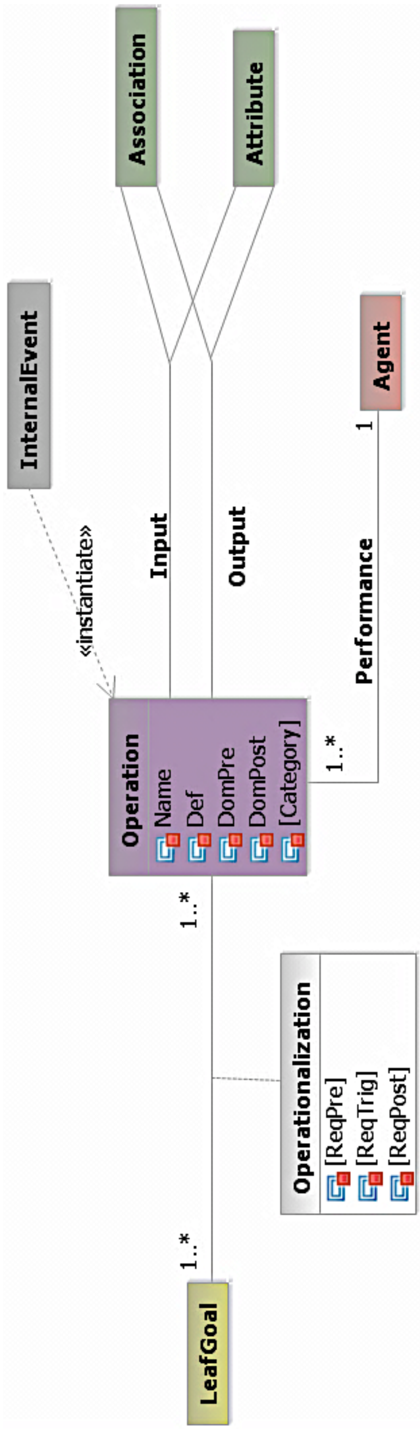

Figure A.3: KAOS operation viewpoint

The operation viewpoint captures the functional services that the target system should provide in order to meet its *Goals*. An *Operation* is a binary relation over system *States*. Is has a tuple of *Input* variables and a tuple of *Output* variables defining its signature. An *Input* variable designates an *Object* instance to which the *Operation* applies. The *State* of this instance affects the application of the *Operation*. An *Output* variable designates an *Object* instance on which the *Operation* acts. The *State* of this instance is changed by the application of the *Operation*. An *Input* variable can be an *Output* variable for the same *Operation*. A particular application of the *Operation* yields a *State Transition* from a *State* in *InputState* to a *State* in *OutputState*.

An *Agent* performs (*Performance*) an *Operation* if the applications of this *Operation* are activated by instances of the *Agent*. Every *Operation* is *Performed* by exactly one *Agent*. *Operationalization* refers to the process of mapping *LeafGoals*, under the *Responsibility* of single *Agents*, to *Operations* ensuring them. Each such *Operation* is performed (*Performance*) by the responsible (*Responsibility*) *Agent* under restricted conditions for satisfaction/satisficing of its *Goals*. While a single *Operation* may operationalize (*Operationalization*) multiple *Goals*, a single *Goal* will in general be operationalized (*Operationalization*) by multiple *Operations*.

It is important to notice the difference between a *Goal* and an *Operation*. A *Goal* is an intentional specification: it leaves the *Operations* realizing it implicit, whereas an *Operation* is an operational specification: it leaves the intentions underlying it implicit. A *Goal* has a higher stability than an *Operation* (van Lamsweerde et al. 1995). A *Goal* captures an objective that the system should satisfy and is specified declaratively. An *Operation* captures a functional service that the system should provide to satisfy such an objective and maybe others and is specified by conditions characterizing its applicability and effect. Semantically speaking, a *BehaviouralGoal* constrains entire sequences of system *State Transitions*, while an *Operation* constrains single *State Transitions* within such sequences.

In KAOS, *Operations* are atomic and cannot be decomposed into finer-grained ones. *Goal Refinements* will be favored, from which fine-grained *Operations* are derived, over *Goal*-free *Operation* refinement in an operational model (Letier and van Lamsweerde 2002).

A.1.4 KAOS Object Viewpoint

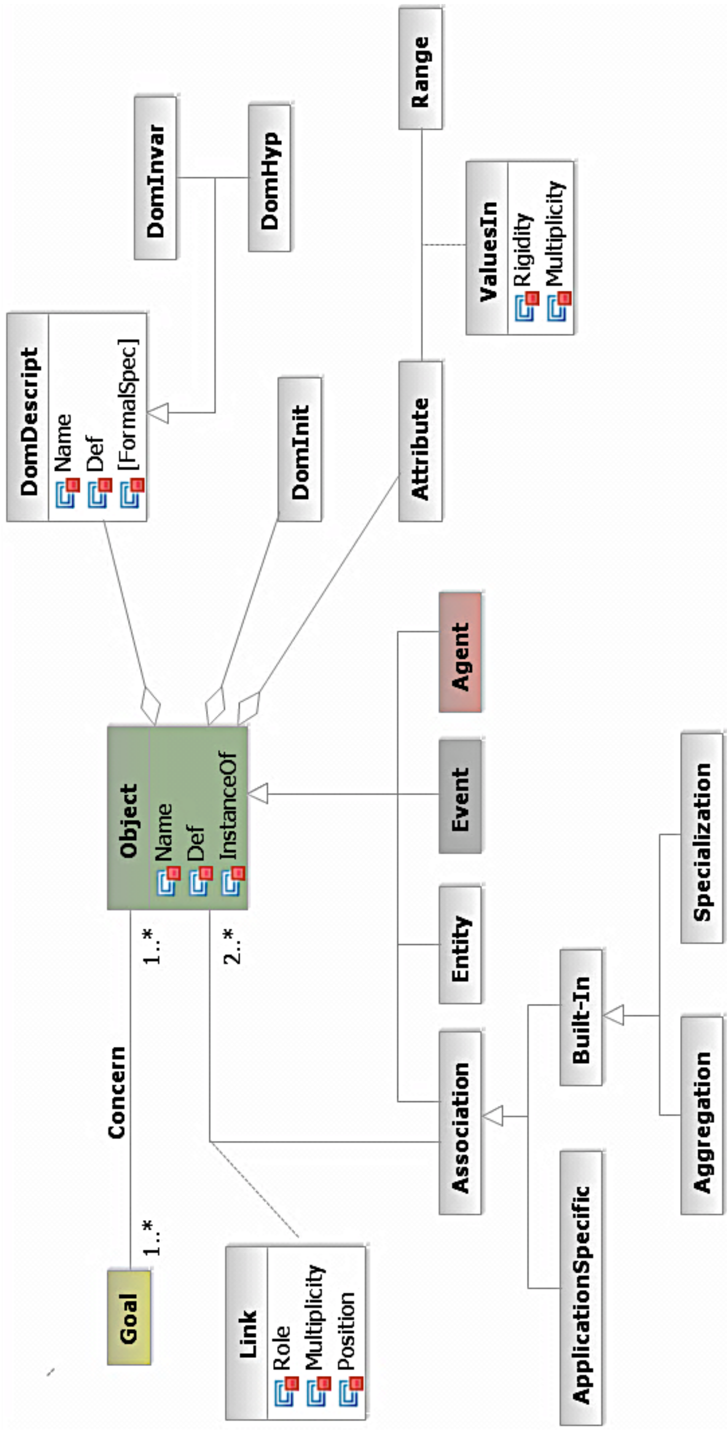

Figure A.4: KAOS object viewpoint

The object viewpoint provides a structural view of the system and is represented by entity-relationship diagrams using the UML class diagram notation. *Entities* and the structural features of *Events* and *Agents* will be represented as *Operation*-free UML classes and *Associations* will be represented as UML associations. The object model gathers all concept definitions and domain properties used in the goal, agent, operation, and behaviour models and introduces a common vocabulary to refer to. The object model can later on provide a basis for generating a database schema and for elaborating a software architecture.

A conceptual *Object* is a discrete set of instances of a domain-specific concept that are manipulated by the modeled system. These instances are distinctly identifiable, can be enumerated in any system *State*, share similar features, and may differ from each other in their individual *States* and *State Transitions*. The set of instances that are members of an *Object* will thus generally change over time. The semantic *InstanceOf* relation is kept implicit in the metamodel. This built-in semantic relation allows determining which individuals are instances of the *Object* in the current *State*.

An *Object* can be an *Association*, an *Entity,* an *Event*, or an *Agent*. An *Entity* is an autonomous and passive *Object*. An *Association* is a passive *Object* dependent on other *Objects* that it *Links* and it is also used under the synonymous term relationship. Each *Linked Object* plays a specific *Role* in the *Association*. An *Event* is an instantaneous *Object*. An *Agent* is as already mentioned an autonomous and active *Object*. It is important to notice that an *Agent* is a subtype of an *Object* and inherits the relationships of an *Object* (Dardenne et al. 1993). An *Association* can *Link* two or more *Objects*, can be reflexive, can have different *Multiplicities* and can be a *Specialization*, an *Aggregation*, or an *ApplicationSpecific* type. An *Association* can have a *Name*, so a user can define different *Associations* with different *Names*. *Concern* links connect *Goal* nodes to the *Objects* to which they refer.

An *Attribute* is an intrinsic feature of an *Object* regardless of other *Objects* in the model. It has a *Name* and a *Range* of values.

A.1.5 KAOS Behaviour Viewpoint

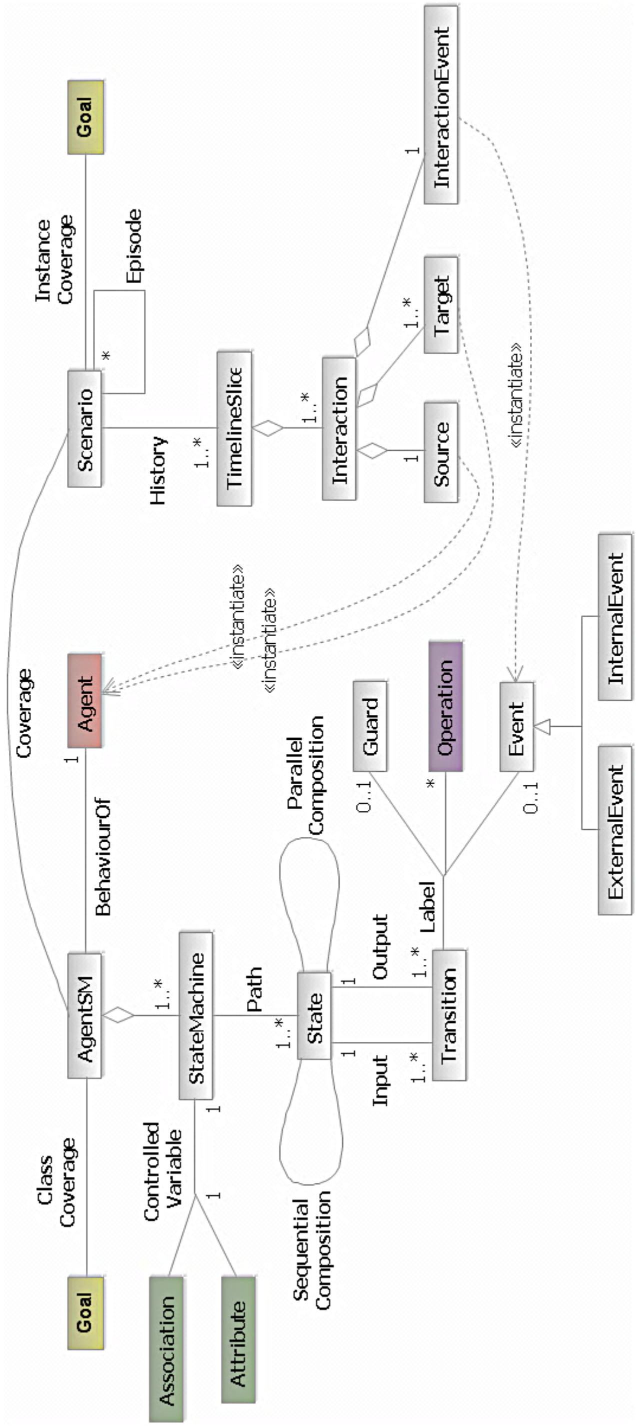

Figure A.5: KAOS behaviour viewpoint

The behaviour viewpoint completes the static representation of system functionalities by capturing the required system dynamics. An operation model focuses on classes of *Input-Output State Transitions*, an object model declares and structures the variables undergoing *State Transitions*, and an agent model indicates which variable is controlled by which *Agent*.

Since this behaviour viewpoint will not be included in the CHOOSE metamodel, it is not further explained.

A.1.6 Integrated KAOS Metamodel and Adaptation to the CHOOSE Metamodel

The viewpoints (excluding the behaviour viewpoint) can be combined to form the integrated KAOS metamodel (Figure A.6). The core element is each time represented in the corresponding colour. In Figure A.7, the green parts of the KAOS metamodel are the ones that were retained in the CHOOSE metamodel. Figure A.8 depicts how these elements were either used as such (green) or adapted (orange), or where new elements were added (purple) to form the CHOOSE metamodel.

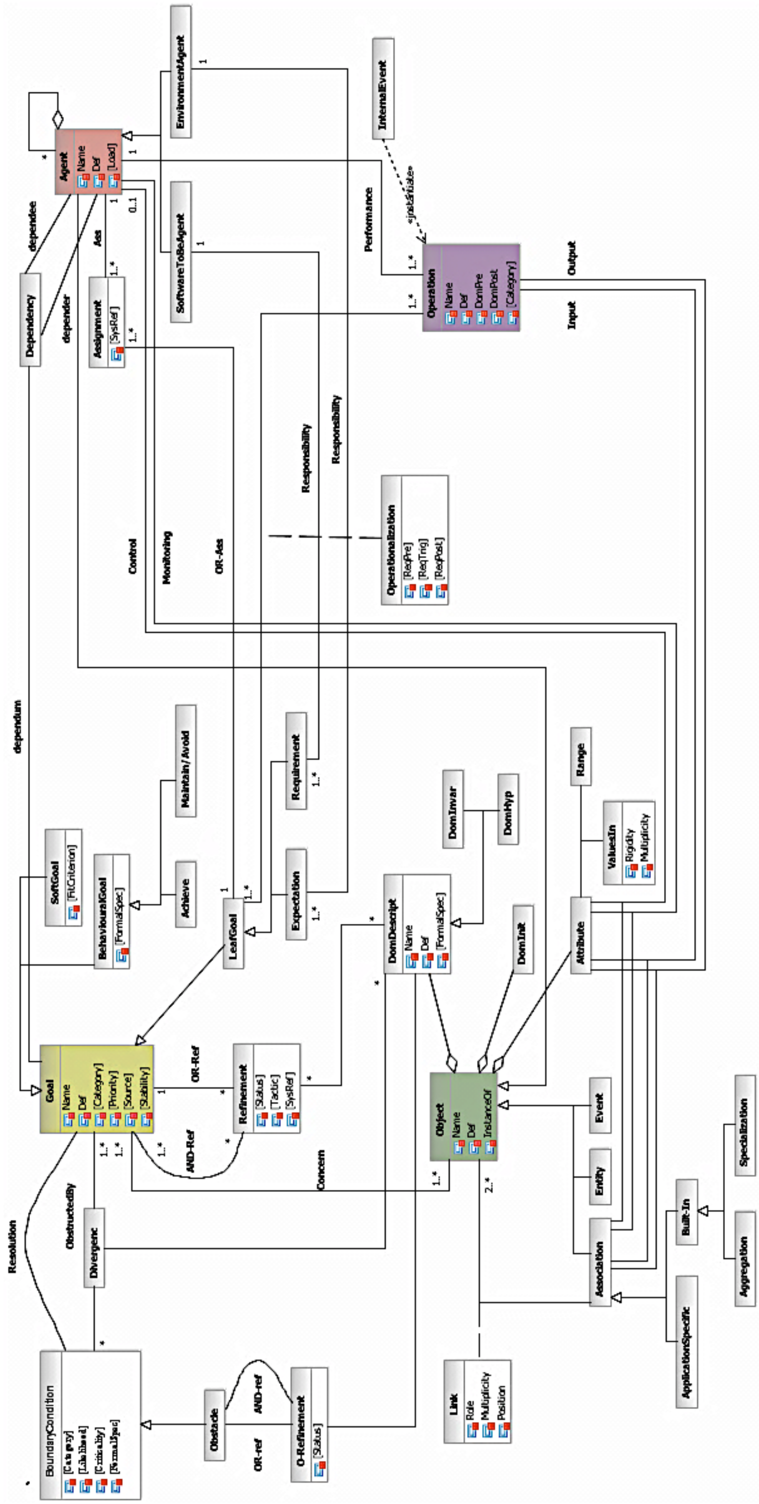

Figure A.6: KAOS integrated metamodel

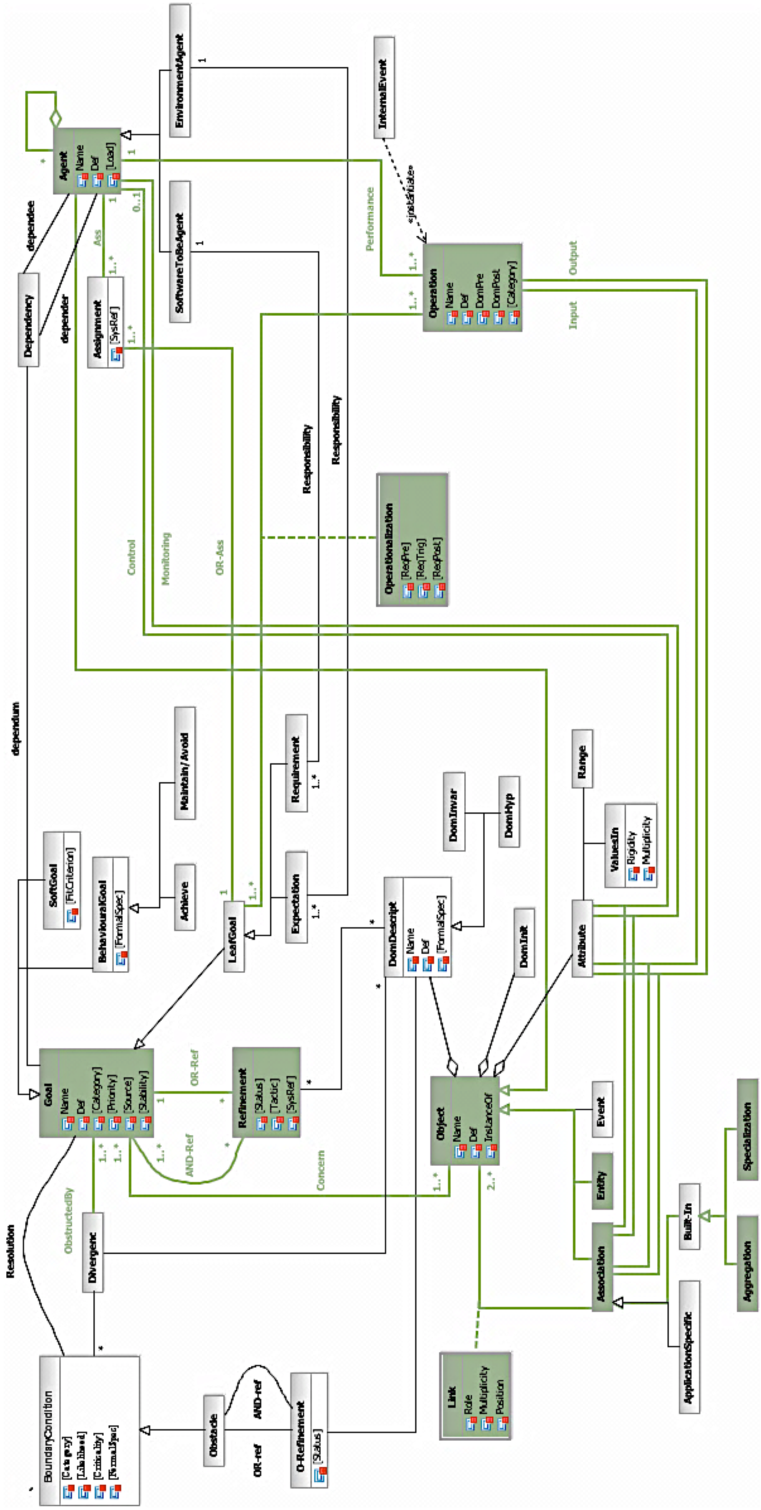

Figure A.7: KAOS elements being retained in CHOOSE

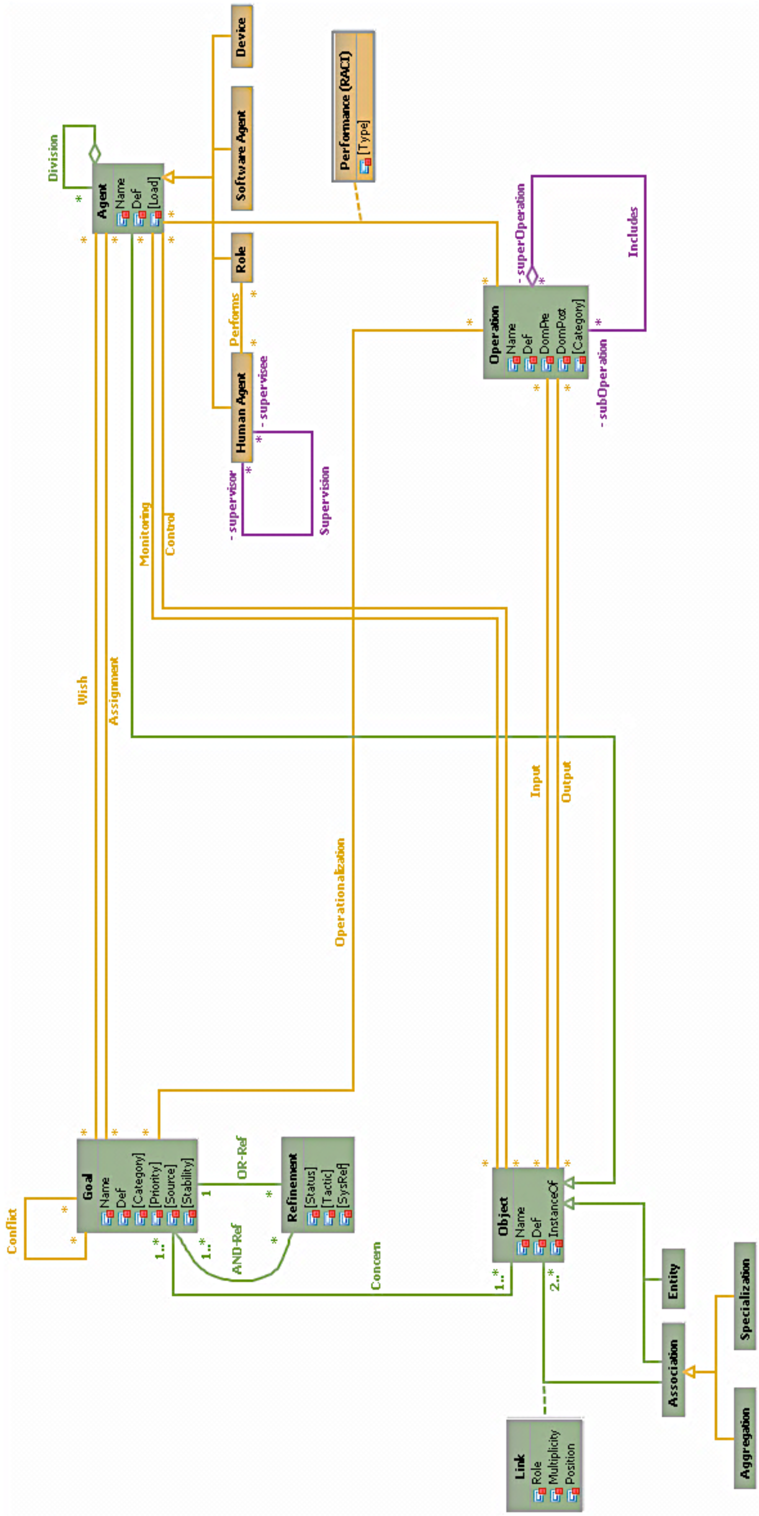

Figure A.8: Adjusting and adding elements from KAOS to CHOOSE

A.2 Appendix 2: OCL Constraints

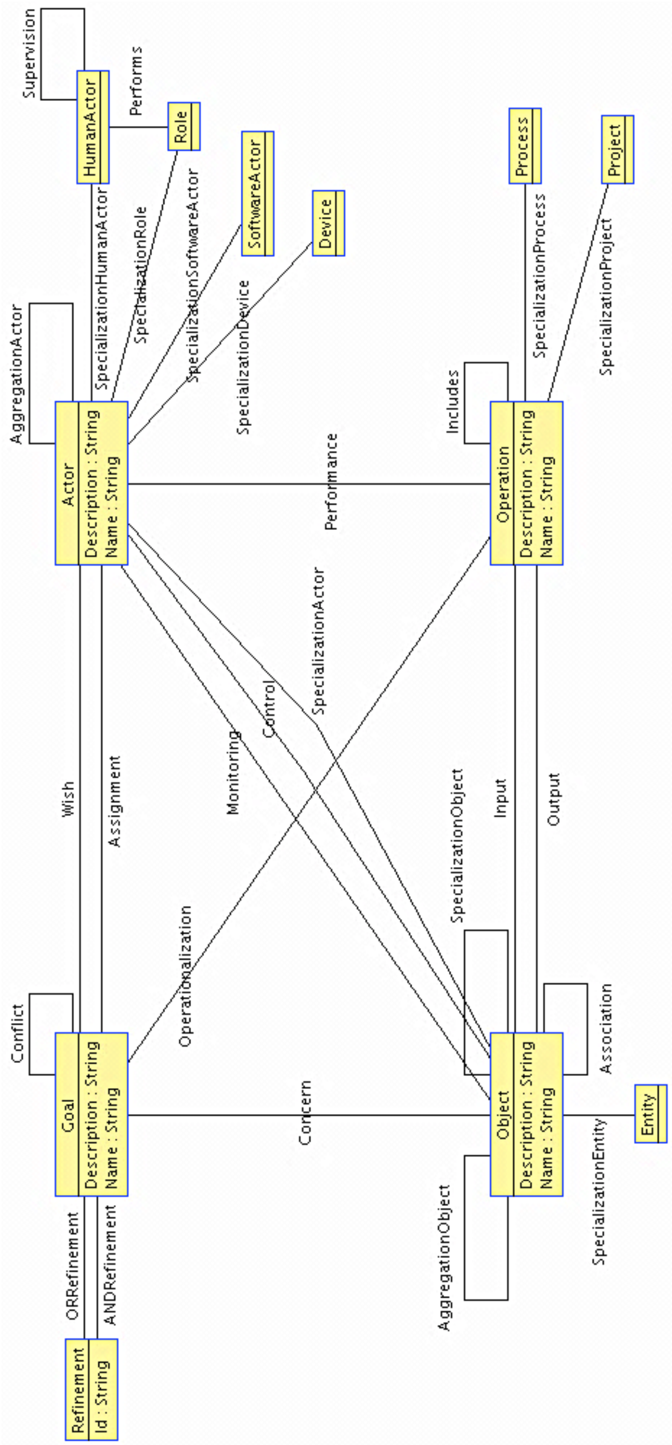

Figure A.9: CHOOSE metamodel in USE tool

The complete CHOOSE metamodel's classes and associations were input in the USE tool (Figure A.9). Next, constraints were added and tested by instantiating the metamodel in the tool. In Table A.1 the metamodel including constraints is presented as a text file serving as an input for the USE tool. The objectified relationships *Association*, *Aggregation*, and *Specialization* are defined as normal relationships and the association class of *Link* and *Performance* is not shown. Due to tool limits, both aggregation and specialization relationships are modeled as normal associations. If interested, this text file can be used directly as an input for the USE tool following the guidelines on (Database Systems Group 2013) to test the metamodel and OCL constraints.

Table A.1: CHOOSE metamodel and constraints as input for the USE tool

```
model CHOOSE
-- CLASSES

        -- GOAL
class Goal
attributes
        Name : String
        Description : String
--Define the recursive upward operation to include all higher-level Goals
operations
        closureGoal(s : Set(Goal)) : Set(Goal) =
                if s->includesAll(s.ANDRefinement.ORGoal->asSet) then s
                else closureGoal(s->union(s.ANDRefinement.ORGoal->asSet)) endif
        allHigherGoals() : Set(Goal) = closureGoal(self.ANDRefinement.ORGoal->asSet)
end
class Refinement
attributes
        Id : Integer
end
        -- ACTOR
class Actor
attributes
        Name : String
        Description : String
-- Define the recursive upward operation to include all Whole Actors
operations
        closureActor(s : Set(Actor)) : Set(Actor) =
                if s->includesAll(s.WholeActor->asSet) then s
                else closureActor(s->union(s.WholeActor->asSet)) endif
        allWholeActors() : Set(Actor) = closureActor(self.WholeActor->asSet)
end
class HumanActor
-- Define the recursive upward operation to include all Supervisors
operations
        closureHumanActor(s : Set(HumanActor)) : Set(HumanActor) =
                if s->includesAll(s.Supervisor->asSet) then s
                else closureHumanActor(s->union(s.Supervisor->asSet)) endif
        allSupervisors() : Set(HumanActor) = closureHumanActor(self.Supervisor->asSet)
end
class Role
end
class SoftwareActor
end
```

```
class Device
end
            -- OPERATION
class Operation
attributes
            Name : String
            Description : String
-- Define the recursive upward operation to include all SuperOperations
operations
            closureOperation(s : Set(Operation)) : Set(Operation) =
                        if s->includesAll(s.SuperOperation->asSet) then s
                        else closureOperation(s->union(s.SuperOperation->asSet)) endif
            allSuperOperations() : Set(Operation) = closureOperation(self.SuperOperation->asSet)
end
class Process
end
class Project
end
            -- OBJECT
class Object
attributes
            Name : String
            Description : String
-- Define the recursive upward operation to include all upper SuperObjects
operations
            closureObject(s : Set(Object)) : Set(Object) =
                        if s->includesAll(s.SuperObject->asSet) then s
                        else closureObject(s->union(s.SuperObject->asSet)) endif
            allSuperObjects() : Set(Object) = closureObject(self.SuperObject->asSet)
end
class Entity
end
```

-- ASSOCIATIONS

```
            -- GOAL
association ORRefinement between
            Goal[1..1] role ORGoal
            Refinement[*] role ORRefinement
end
association ANDRefinement between
            Goal[1..*] role ANDGoal
            Refinement[*] role ANDRefinement
end
association Conflict between
            Goal[*] role ConflictGoal1
            Goal[*] role ConflictGoal2
end
            -- GOAL-ACTOR
association Wish between
            Goal[*] role WishGoal
            Actor[*] role WishActor
end
```

```
association Assignment between
        Goal[*] role AssignmentGoal
        Actor[*] role AssignmentActor
end
        -- GOAL-OPERATION
association Operationalization between
        Goal[*] role OperationalizationGoal
        Operation[*] role OperationalizationOperation
end
        -- GOAL-OBJECT
association Concern between
        Goal[*] role ConcernGoal
        Object[*] role ConcernObject
end
        -- ACTOR
association AggregationActor between
        Actor[*] role WholeActor
        Actor[*] role PartActor
end
association SpecializationHumanActor between
        Actor[*] role SuperHumanActor
        HumanActor[*] role SubHumanActor
end
association SpecializationRole between
        Actor[*] role SuperRole
        Role[*] role SubRole
end
association SpecializationSoftwareActor between
        Actor[*] role SuperSoftwareActor
        SoftwareActor[*] role SubSoftwareActor
end
association SpecializationDevice between
        Actor[*] role SuperDevice
        Device[*] role SubDevice
end
association Supervision between
        HumanActor[*] role Supervisor
        HumanActor[*] role Supervisee
end
association Performs between
        HumanActor[*] role PerformsHumanActor
        Role[*] role PerformsRole
end
        -- ACTOR-OPERATION
association Performance between
        Actor[*] role PerformanceActor
        Operation[*] role PerformanceOperation
end
        -- ACTOR-OBJECT
association Monitoring between
        Actor[*] role MonitoringActor
        Object[*] role MonitoringObject
end
```

```
association Control between
        Actor[*] role ControlActor
        Object[*] role ControlObject
end
        -- OPERATION
association Includes between
        Operation[*] role SuperOperation
        Operation[*] role SubOperation
end
association SpecializationProcess between
        Operation[*] role SuperProcess
        Process[*] role SubProcess
end
association SpecializationProject between
        Operation[*] role SuperProject
        Project[*] role SubProject
end
        -- OPERATION-OBJECT
association Input between
        Operation[*] role InputOperation
        Object[*] role InputObject
end
association Output between
        Operation[*] role OutputOperation
        Object[*] role OutputObject
end
        -- OBJECT
association Association between
        Object[*] role AssociationObject1
        Object[*] role AssociationObject2
end
association AggregationObject between
        Object[*] role WholeObject
        Object[*] role PartObject
end
association SpecializationObject between
        Object[*] role SuperObject
        Object[*] role SubObject
end
association SpecializationEntity between
        Object[*] role SuperEntity
        Entity[*] role SubEntity
end
association SpecializationActor between
        Object[*] role SuperActor
        Actor[*] role SubActor
end
```

-- CONSTRAINTS

```
        -- GOAL
--Constraint 1) Hard constraint: a Goal cannot have a Conflict with itself
context Goal
inv GOALSELFCONFLICT: (self.ConflictGoal1->union(self.ConflictGoal2))->excludes(self)
```

```
--Constraint 2) Soft constraint: the Goal model may not contain Refinement cycles
context Goal
inv GOALCYCLICREFINEMENT: self.allHigherGoals()->excludes(self)
        -- GOAL-ACTOR
--Constraint 3) Soft constraint: favour Assignments of Goals to Actors Wishing one of the related higher-level Goals
context Actor
inv WISHASSIGNMENT:
        if self.AssignmentGoal->notEmpty
        then
                if self.WishGoal->notEmpty
                then self.AssignmentGoal.allHigherGoals().WishActor-
>union(self.AssignmentGoal.WishActor)->includes(self)
                else true endif
        else true endif
--Constraint 4) Hard constraint: a Role, SofwareActor or Device cannot have a Wish relationship with a Goal
context Goal
inv ACTORWISH: self.WishActor.SubRole->isEmpty and self.WishActor.SubSoftwareActor->isEmpty
and self.WishActor.SubDevice->isEmpty
--Constraint 5) Soft constraint: if an Actor has an Assignment relationship with a Goal and is part of
another Actor, then the encompassing Actor should have an Assignment relationship with the same or a
related higher-level Goal
context Actor
inv ASSIGNMENTAGGREGATION:
        if self.AssignmentGoal->notEmpty
        then
                if self.WholeActor->notEmpty
                then ((self.AssignmentGoal.allHigherGoals().AssignmentActor-
>union(self.AssignmentGoal.AssignmentActor))->intersection(self.allWholeActors()))->notEmpty
                else true endif
        else true endif
--Constraint 6) Soft constraint: if a HumanActor has an Assignment relationship with a Goal, then one of
its Supervisors should have an Assignment relationship with the same or a related higher-level Goal
context HumanActor
inv ASSIGNMENTSUPERVISION:
        if self.SuperHumanActor.AssignmentGoal->notEmpty
        then
                if self.Supervisor->notEmpty
                then
((self.SuperHumanActor.AssignmentGoal.allHigherGoals().AssignmentActor.SubHumanActor-
>union(self.SuperHumanActor.AssignmentGoal.AssignmentActor.SubHumanActor))-
>intersection(self.allSupervisors()))->notEmpty
                else true endif
        else true endif
        -- GOAL-OPERATION
--Constraint 7) Soft constraint: an Operation should Operationalize one or several Goals
context Operation
inv OPERATIONOPERATIONALIZATION: self.OperationalizationGoal->notEmpty
--Constraint 8) Soft constraint: every leaf Goal should be Operationalized by at least one Operation
context Goal
inv GOALOPERATIONALIZATION:
        if self.ORRefinement->isEmpty
        then self.OperationalizationOperation->notEmpty
        else true endif
```

```
--Constraint 9) Soft constraint: an Operation should not Operationalize a Goal that itself or a related
higher-level Goal is in Conflict with another Goal or related higher-level Goal of another Goal that is
also been Operationalized by that Operation or one of its SuperOperations
context Operation
inv OPERATIONALIZATIONCONFLICT:
let X=((self.OperationalizationGoal.allHigherGoals().ConflictGoal1-
>union(self.OperationalizationGoal.ConflictGoal1))-
>union(self.OperationalizationGoal.allHigherGoals().ConflictGoal2-
>union(self.OperationalizationGoal.ConflictGoal2))) in
let Y=(self.allSuperOperations().OperationalizationGoal->union(self.OperationalizationGoal)) in
        if self.OperationalizationGoal->notEmpty
        then X->intersection(Y)->isEmpty
        else true endif
        -- GOAL-ACTOR-OPERATION
--Constraint 10) Soft constraint: an Actor having an Assignment relationship with a Goal should have a
Performance relationship with all Operations Operationalizing that Goal
context Actor
inv GOALACTOROPERATION:
        if self.AssignmentGoal->isEmpty
        then true
        else (self.AssignmentGoal.OperationalizationOperation->asSet) =
(self.PerformanceOperation->asSet) endif
--Constraint 11) Soft constraint: avoid allocating an Operation to an Actor if the Operation, or a child of
it, Operationalizes a Goal that itself or a related higher-level Goal Conflicts with the Goals Wished by
the Actor
context Operation
inv OPERATIONWISHCONFLICT:
        if self.OperationalizationGoal->isEmpty or self.PerformanceActor->isEmpty
        then true
        else
(self.OperationalizationGoal.allHigherGoals().ConflictGoal1.WishActor.PerformanceOperation-
>union(self.OperationalizationGoal.ConflictGoal1.WishActor.PerformanceOperation))-
>union(self.OperationalizationGoal.allHigherGoals().ConflictGoal2.WishActor.PerformanceOperation-
>union(self.OperationalizationGoal.ConflictGoal2.WishActor.PerformanceOperation))->excludes(self)
endif
        -- GOAL-ACTOR-OBJECT
--Constraint 12) Soft constraint: if an Object is referred to by a Goal under the Assignment of an Actor,
the Object must be Monitored or Controlled by this Actor
context Object
inv GOALACTOROBJECT:
        if self.ConcernGoal.AssignmentActor->isEmpty
        then true
        else (self.ConcernGoal.AssignmentActor->asSet)=(self.MonitoringActor-
>union(self.ControlActor)->asSet) endif
        -- ACTOR
--Constraint 13) Hard constraint: the HumanActor model may not contain Supervision cycles (a
HumanActor cannot Supervise itself)
context HumanActor
inv HUMANACTORCYCLICSUPERVISION: self.allSupervisors()->excludes(self)
```

*--Constraint **14**) Hard constraint: a HumanActor cannot Aggregate other Actors*
context Actor
*inv **HUMANACTORWHOLE**: self.WholeActor.SubHumanActor->isEmpty*

*--Constraint **15**) Hard constraint: an Actor can only be Aggregated by other unspecialized Actors*
context Actor
*inv **ACTORAGGREGATION**:*
if self.SubHumanActor->isEmpty and self.SubRole->isEmpty and self.SubSoftwareActor->isEmpty and self.SubDevice->isEmpty
then self.WholeActor.SubHumanActor->isEmpty and self.WholeActor.SubRole->isEmpty and self.WholeActor.SubSoftwareActor->isEmpty and self.WholeActor.SubDevice->isEmpty
else true endif

*--Constraint **16**) Hard constraint: a HumanActor can only be Aggregated by unspecialized Actors*
context HumanActor
*inv **HUMANACTORAGGREGATION**: self.SuperHumanActor.WholeActor.SubHumanActor->isEmpty and self.SuperHumanActor.WholeActor.SubRole->isEmpty and self.SuperHumanActor.WholeActor.SubSoftwareActor->isEmpty and self.SuperHumanActor.WholeActor.SubDevice->isEmpty*

*--Constraint **17**) Hard constraint: a Role can only be Aggregated by other Roles or unspecialized Actors*
context Role
*inv **ROLEAGGREGATION**: self.SuperRole.WholeActor.SubHumanActor->isEmpty and self.SuperRole.WholeActor.SubSoftwareActor->isEmpty and self.SuperRole.WholeActor.SubDevice->isEmpty*

*--Constraint **18**) Hard constraint: a SoftwareActor can only be Aggregated by other SoftwareActors or unspecialized Actors*
context SoftwareActor
*inv **SOFTWAREACTORAGGREGATION**: self.SuperSoftwareActor.WholeActor.SubHumanActor->isEmpty and self.SuperSoftwareActor.WholeActor.SubRole->isEmpty and self.SuperSoftwareActor.WholeActor.SubDevice->isEmpty*

*--Constraint **19**) Hard constraint: a Device can only be Aggregated by other Devices or unspecialized Actors*
context Device
*inv **DEVICEAGGREGATION**: self.SuperDevice.WholeActor.SubHumanActor->isEmpty and self.SuperDevice.WholeActor.SubRole->isEmpty and self.SuperDevice.WholeActor.SubSoftwareActor->isEmpty*

*--Constraint **20**) Hard constraint: the Actor model may not contain Aggregation cycles (an Actor cannot contain itself)*
context Actor
*inv **ACTORCYCLICAGGREGATION**: self.allWholeActors()->excludes(self)*

-- ACTOR-OPERATION

*--Constraint **21**) Soft constraint: every Operation should be under the Performance of at least one Actor*
context Operation
*inv **OPERATIONPERFORMANCE**: self.PerformanceActor->notEmpty*

*--Constraint **22**) Soft constraint: if an Actor has a Performance relationship with an Operation and is part of one or more Actors, then at least one of those other Actors should have a Performance relationship with the same Operation, or one of its SuperOperations*
context Actor
*inv **PERFORMANCEAGGREGATION**:*
if self.PerformanceOperation->notEmpty
then
if self.WholeActor->notEmpty
then ((self.PerformanceOperation.allSuperOperations().PerformanceActor->union(self.PerformanceOperation.PerformanceActor))->intersection(self.allWholeActors()))->notEmpty
else true endif
else true endif

-- ACTOR-OPERATION-OBJECT

*--Constraint **23**) Soft constraint: the Inputs of an Operation Performed by an Actor should be Monitored by the Actor*
context Actor
*inv **ACTOROPERATIONOBJECTINPUT**:*

```
        if self.PerformanceOperation.InputObject->isEmpty
        then true
        else (self.MonitoringObject->intersection(self.PerformanceOperation.InputObject)->asSet)=(self.PerformanceOperation.InputObject->asSet) endif
```

*--Constraint **24**) Soft constraint: the Outputs of an Operation Performed by an Actor should be Controlled by the Actor*
context Actor
*inv **ACTOROPERATIONOBJECTOUTPUT**:*

```
        if self.PerformanceOperation.OutputObject->isEmpty
        then true
        else (self.ControlObject->intersection(self.PerformanceOperation.OutputObject)->asSet)=(self.PerformanceOperation.OutputObject->asSet) endif
```

-- OPERATION

*--Constraint **25**) Hard constraint: the Operation model may not contain Includes cycles (Operation cannot Include itself)*
context Operation
*inv **OPERATIONCYCLICINCLUDES**: self.allSuperOperations()->excludes(self)*

-- OBJECT

*--Constraint **26**) Hard constraint: the Object model may not contain Specialization cycles (Object cannot Specialize itself)*
context Object
*inv **OBJECTCYCLICSPECIALIZATION**: self.allSuperObjects()->excludes(self)*

B

Appendix 1 Chapter 5

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Development of Software Tool Support for Enterprise Architecture in Small and Medium-Sized Enterprises

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Abstract. Throughout recent years a lot of research has been done to develop enterprise architecture (EA) approaches for large and complex enterprises. Consequently, an array of tools has been developed for these large enterprises to aid in EA management. However, traditional small and medium-sized enterprises (SMEs), which are very important for economy, have to a great extent been neglected. Recently research has been done towards a new EA approach for SMEs. The approach is called CHOOSE. As tool support is almost indispensable in complex environments, the need for tool support was quickly experienced while doing case studies in SMEs. Unfortunately, tool support is already rated low on usability by EA practitioners in large companies. A different approach was required to provide tool support for managers in SMEs. The developed software tool already received positive feedback from managers.

Keywords: Enterprise architecture, software tool support, small and medium-sized enterprise, CHOOSE.

1 Introduction

A common analogy is often made between enterprise architecture (EA) and architecture in construction. When an architect is asked to design a house, the focus will be on where the staircase has to be or how many rooms or balconies there have to be. The specifics of the color or brand of paint are not of interest yet. The future habitant agrees on some kind of blueprint, a master plan that will serve as the starting point for more detailed decisions. This high level blueprint will show the major functions of the house and how these have to be constructed. As future occupant of the house this high level and abstract representation is probably the most informative. On the other hand, the engineer or constructor is probably more interested in a detailed elaboration.

When companies became bigger and more complex the need for EA arose. The advantages of EA for large enterprises have been widely acknowledged in practice and literature [1]. Landenberg and Wegmann [2] investigated which aspects of EA were being researched. One of their conclusions was that interest in the field is currently growing, given the increase in publications. Furthermore, Ernst et al. [3] found in their survey that in practice, EA is also of growing importance. However, most of this research is targeted towards architecture in large enterprises. But while small and medium-sized enterprises (SMEs) are considered the backbone of our economy [4], little research has been done towards EA approaches for those SMEs. In a literature research concerning information systems in SMEs [5], not one paper was found from 1979 to 2008 about EA in SMEs.

In response to this lack of research about EA for SMEs, Bernaert and Poels proposed a new EA approach for SMEs [6; 7]. A metamodel was created, focusing on the essential dimensions and characteristics of EA in the context of SMEs. The metamodel was called the CHOOSE metamodel, which is an acronym for "keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise".

Just as tool support is widely considered indispensable in large companies, the need for it was also quickly identified in SMEs by several case studies. However, as existing tools are already considered low on usability by EA practitioners, a different approach is proposed in this research: a software application for tablets. As SMEs usually rely on insight from the CEO and do not have any enterprise architects on staff, this software application had to be useable for management.

In the next chapter, the problem statement and goal of this research are discussed. In chapter three, existing tool support is first considered. In the fourth chapter, our solution towards a user-friendly tool for the EA approach CHOOSE is then proposed. The last chapter concludes with a summary and future research directions.

2 Problem Statement and Goal of the Research

2.1 Specific Research Problem

While developing the EA approach CHOOSE, case studies were performed in SMEs. Even after the first tests, it was clear that tool support was indispensable. Working on a whiteboard with post-its was not practicable (Fig. 1).

Fig. 1. Need for tool support during case studies

First of all, input was very slow, having to write every element on a separate post-it. If a goal had to be corrected, a new post-it had to be made. Once the model was finished, it was impractical to store away three whiteboards and present it on a meeting the week after. More importantly, finding an element could take a while and making any sort of analysis was out of the question. Academic sources also widely support the necessity of software tool support.

"For EAs to be useful and provide business value, their development, maintenance, and implementation should be managed effectively and supported by tools." [8]

"EA management should be supported by tools, which support distributed access to consistent data, offer the possibility to structure the information managed, and also aid users in filling out their role in the EA management process." [3]

3 Related Research

3.1 Existing Tool Support

Kurpjuweit and Winter [9] identify three different objectives for which tools can be used. They can be used to document and communicate, they can be used to analyze and explain or they can be used to design the EA. Typically after selecting an EA approach and selecting the preferred modeling language, there are software tools available to model your enterprise. Several options are available on the market, for example IBM's system architect [10] or Metis from Troux technologies [11]. However most of these tools are focused on the design aspect and are solely used to model the enterprise.

Based on a survey performed by the university of Munich, Ernst et al. summarize how different tools perform according to different criteria and different scenarios [3]. They came up with a kiviat diagram, showing the minimum, maximum, and median score obtained by the different tools (Fig. 2). We can see that even for EA practitioners, the average usability of the different tools scores rather low. One reason was that all tools came with predefined metamodels. Some came with up to 400 entities with corresponding associations. Even for daily practitioners this is perceived to be very complex, making the tools hard to work with in practice. Especially the visualization needed improvement. Two major issues occur when visualizing an EA with existing tools. First, the automated generation of adequate visualization is mostly not possible. The second issue is that the semantics of those visualizations are often not properly defined. This leaves a lot of room for interpretation. These issues are both explained by the simple fact that most tools are drawing tools where visualizations are manually created. This often causes practitioners to use certain symbols or links out of context. Although the model is understandable for the creators of the model, the tool can no longer interpret the results correctly. The result is a drawing rather than a model. A nice quote from this paper that summarizes this paragraph: "drawing is no management".

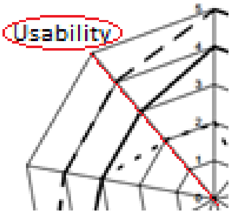

Fig. 2. Diagram showing a low usability rating

The graphical user interface of a typical EA tool is usually composed of three different components (Fig. 3 from left to right). The content explorer, a canvas to do the modeling itself, and a concept explorer with the different modeling language constructs. Often this works by dragging and dropping the different constructs from the concept explorer to the canvas and thus slowly building up the different models.

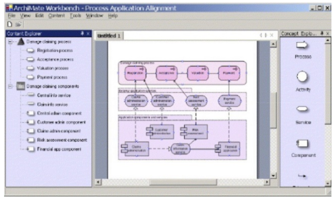

Fig. 3. Typical EA tool

4 Solution Approach

While it has been made clear that tool support is needed, one of the key words in the abbreviation CHOOSE was ‘Simple’. Given the resource poverty of SMEs [12], they are unable to staff an enterprise architect, or pay expensive consulting fees. As described above, modeling tools are typically aimed towards enterprise architects. So while developing a tool for this new approach, it was clear that contrary to the above tools, a different approach would be required for SMEs. Even practitioners in big companies rated the existing tools rather poor in usability. Furthermore these tools expect the users to be fully aware of the models and modeling languages.

To find an approach towards tool development, a methodology that is aimed to achieve user-friendly interfaces was adopted from Cooper et al [13]. He was one of the first to criticize traditional software development processes and was the first to pioneer a software development process that was based on the users’ needs. How could a good product be created when it did not take into account the users’ goals, needs and motivations? The improved software development process that he proposed now emphasizes the design aspect (Fig. 4).

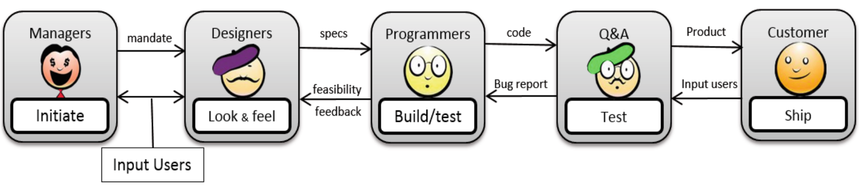

Fig. 4. Software development process

The first step, called ‘initiate’, is the step where the need for a certain program is identified. The need for tool support has already been discussed as being necessary to support an EA approach. The necessity of this new EA approach has also been shortly dealt with in the introduction. As the tool is currently still under development (build phase), the last two steps in the process will not be dealt with in this paper. The technicalities of the building itself are also beyond the scope of this paper. In the next section we will thus focus on the design step. An approach towards design is introduced in the next section.

4.1 Goal-Directed Design

The task of the design step in Fig. 4 should not only be about the appearance of a product. When properly deployed it should identify user requirements and take into account his/her behavior. Design should be about product definition, based on the goals of users, needs of the business and the constraints of technology. Design is defined in a broader sense.

Just as we made an analogy with architecture when arguing that EA is needed, a similar reasoning can be made here. In the case of an architect, he/she will have to understand how the people live and work before he/she can start designing a house. He/she then should sketch the spaces to support and facilitate those behaviors. For the architect, designing a house is more than making the house look pretty.

This broader approach towards design is called ‘interaction design’. Interaction design is more than making sure something looks pretty; interaction design is about understanding the users and knowing cognitive principles.

An approach to implement this design philosophy is proposed by Cooper et al. [13]. In short, this approach is called ‘goal-directed design’. The main steps followed in a goal-directed design approach are shown in Fig. 5.

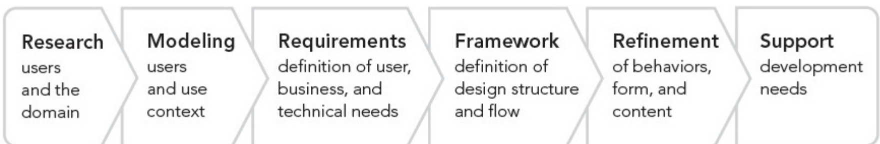

Fig. 5. Goal-directed design process

Research. The research phase consists mainly of understanding the future user and knowing who that future user will be. In the research done to develop the CHOOSE approach it was already clear that the CEO would have to be closely involved. There are two reasons illustrating the need for the CEO’s involvement.

Firstly in SMEs, employees generally do not know the structure, let alone know why they are doing something. It is generally only the entrepreneur who knows the whole working of the company and this distinguishes SMEs from larger companies, because a CEO can have an overview of its SME. Secondly, in SMEs, the job description for employees is often vaguely defined and an overview of tasks or responsibilities is often missing [14].

In a study performed by Hankinson et al. [15], managers responded that they worked between 50 and 60 hours a week. Most time was spent in meetings and informal interactions (50%) and on the phone (40%). The remainder was spent travelling. Only 5 hours or less than 10% of time was used on strategic issues, personal analysis, and analyzing results. Notably, managers generally indicated that their time management was poor. To get a better insight in the lifestyle of the manager, a small amount of managers was asked to keep a very detailed schedule of their workweek. In this small-scale test, the results, stated above, could be verified. We clearly saw that managers were very busy with day-to-day activities. This left little time in between for working on strategic issues [16].

Another important factor to keep in mind is that managers are not expert technology users. According to [17], users can be divided in three types: experts, willing adopters and mainstreamers. Mainstreamers are people who do not use technology to use the technology. They use it to get something done. They use just a few key features and do not care about any other.

Modeling. In the modeling step, a persona is defined, which is the portrait of what the ideal user would be. Additionally a list of goals of what the user is interested in is composed. This is usually input from the research step. By completely defining a 'persona', programmers and designers always keep focus on who they are making the program for. Usually, programmers talk about 'the end user'. By making the end user an actual person, it restricts them of stretching the 'end user' to fit the situation. 'This is easy' might be true for the programmers, but may not be the case for the defined persona, and obliges programmers to rethink their approach to fit the persona's needs.

Because a complete persona definition is beyond the scope of this paper, a small summary is offered. Our target user is a manager in an SME, who is generally not technology savvy. He/she often does not know about the specifics of EA. Though, if he/she would use an EA approach, he/she would want it to be simple while still offering value. It would have to aid in keeping an oversight of the company.

Requirements Definition. While developing the CHOOSE approach, a list of eleven main criteria were found for EA in an SME context [7]. As the tool is used to support this approach it should at least be able to achieve these criteria. These criteria will serve as a guideline when setting requirements for the tool.

Requirements for tools can be thought of as consisting of objects, actions, and contexts. For example, for a calling application this might be something like: 'Call (action) a person (objects) directly from an appointment (context)'. As it can be quite difficult to extract information in this format, it is easier to separate them into data, functional and contextual requirements [18].

Data Requirements. These requirements are the objects and information that our users want from our tool. As can be identified by the criteria from EA, we need data output that can give an overview of the company. Furthermore a description of how things are done in the company is needed. A focused view will provide a more detailed view. This output furthermore has to be usable in other often-used programs like Excel and PowerPoint.

Functional Requirements. A mobile application was chosen to fit the busy schedule of a manager. Since there is little time to work on strategic matters during the day, the only adoption of an application would happen if it could be used during downtime. It has to be useable when they have a few minutes spare time in a waiting room or maybe five minutes before they go to bed. Showcased by the popularity of the iPad and other Android tablets, tablets are on the rise. Even in SMEs, it is becoming the standard tool that every manager has with him/her [19]. A tablet was chosen over a mobile phone because it offers almost the same mobility while giving more screen estate.

Contextual Requirements

- Business Requirements: It has to be cheap to implement [12].
- Experience Requirements: If we want managers to spend their precious time on EA and use this tool, it has to be appealing and fun.
- Technical Requirements*:* It has to work on a platform that can complement a manager his/her usage pattern. As the CHOOSE metamodel is still being refined, the software architecture should be flexible to allow changes to be adapted quickly.

Summary of Tool Criteria. The following list of five criteria is proposed for this tool. These will be used as guidance when developing the application:

1. Offer a focus view of enterprise components
2. Offer a holistic overview of the firm
3. Simplicity, the tool has to be easy to use
4. Fit in day-to-day activities of manager
5. Fun and appealing

Design Framework. Considering usability was an issue with existing tools for EA practitioners, making the tool usable for managers would be challenging. If we go back to the roots of usability, Vitruvius is considered as being the first student of ergonomics and usability [17]. His questions were based around three key words:

- Firmitas: How durable is the design and does it have strength?
- Utilitas: How useful is the design and does it fit the user's needs?
- Venustas: How beautiful is the design?

What Vitruvius did not suggest was how to achieve these objectives. However, directions to achieve these objectives are offered by Davidson et al. [20]. They found an important link between mental models and usability.

Norman [21], an academic researcher in interface design, argues that design is often constrained by culture. People want to be able to foresee what an object will do. When an interaction with a system is deeply engrained through cultural learning it is hard to change the way people interact with an object. The easiest way to make an interface design consistent with how a user expects it to behave is by mimicking the physical product. For example, calculator applications or calendar applications often mimic the behavior of the physical products. Unfortunately, as is the case with our application, there is not always a physical object that can be mimicked. The insight to decrease the discrepancy between how an object behaves and how a user expects it to behave is offered by Norman [22], Cooper et al. [13] and IBM [23]. They have discerned three models of a system:

- Mental Model: How a user perceives that a product works.
- Implementation Model: Actual way the system works internally (programmer's perspective).
- Represented Model: The way the application is represented to the user.

According to Davidson et al. [20], who researched this link between usability and mental models, the program will be perceived easier to use and easier to understand the closer the Represented Model resembles the Mental Model.

Several design methods are used to support and influence these mental models of the user: simplicity, familiarity, availability, flexibility, feedback, safety, and affordance are proposed by IBM [24]. By following these methods, the user's mental model will be better aligned with the represented model. According to [20], the application will then have higher usability.

Simplicity has been one of the key words throughout the development of the CHOOSE approach (the S stands for Simple). Additionally it came out as one of the main criteria during the requirements definition. As simplicity is the main guideline, in the next section this is the only design method that is further zoomed into. A design framework is furthermore also concerned with detailed design to make the application look beautiful. Although beauty is subjective, a lot of guidelines were taken into account, though are not further elaborated here and will be presented in a thesis.

Simplicity: Less Is More. When visiting a website it can sometimes feel like walking through Times Square: You see a myriad of different advertisement billboards each with catchy slogans like “The next big thing”, “Probably the best beer in the world”, “The real thing”. Many of these billboards are very flashy with vibrant colors and flashing lights, trying to get the passer-by its attention. Every brand competes with each other to make the billboard that pops out the most, trying to capture the so important passer-by glance.

However, people are impatient and they can only process a limited amount of information [24]. The more content you show, the smaller your chances will be of them to notice your most important content. Less really is more in this case.

Even small details like words, colors, buttons can add to the already heavy load a person has to process. Removing irrelevant options, slogans, and content decreases this load on users. Designing a user interface in a clever way can further diminish this load and enhance user experience [17].

Thompson et al. [25] did an experiment to find out whether users preferred features over usability or vice versa. They concluded that features sell a product better, but when users were able to test the product before their purchase they would buy the product with better usability over the product with more features. In software, the cost of adding extra features is close to nothing. Considering people appear to buy products based on features, this leads to features piled upon features. The problem is that with each extra feature that is added, the product becomes more difficult to use.

Iyengar and Lepper [26] set up multiple experiments to test whether people like more or less choice. All results obtained showed significant higher sales revenues when offering only a handful of options. They also found that people where more satisfied with what they bought when being offered fewer options. Because it offers a person a sense of control, people prefer to have a choice over no choice at all. However if that choice exceeds a handful of options, choice can get overwhelming.

4.2 Tool Presentation

During the requirements definition stage in the goal-directed design process, five criteria were derived for our tool (Section 4.1.3). Furthermore simplicity, familiarity, availability, flexibility, feedback, safety, and affordance were the design methods that were introduced in the design framework (Section 4.1.4). While presenting the tool, some criteria and design methods will be referred to where they are applicable.

One aspect of the CHOOSE approach is to build up a goal tree. To showcase the tool, an extract from a case study is presented. The case study was performed in an SME that sells tires and does some maintenance on cars. One of the goals of this company was to increase its customer base. Two possible scenarios were considered. The first scenario was opening a new shop, the second was to increase visibility through improved signing of the building and better online visibility. To showcase the tool, the goal 'online visibility' is added to the goal tree (Fig. 6).

When starting up the application, the user is presented with a playful start screen. At first glance the start screen is already radically different from traditional approaches. Firstly it has to entice the manager of working with the program when he/she has some spare time (Criterion 5). Another important criterion is that no outside help is needed to exercise EA (SMEs' resource constraint). At the bottom right a question mark is shown. Whenever in doubt about some concept, the manager can quickly get an explanation (Design method: safety). In our case we head over to the goals part of the application and start the wizard for adding a new goal. In step 1 the name of the goal and a description can be added. In the following screen, since 'online visibility' is one of the goals to achieve a general increase in visibility, the latter goal is selected as the upper goal. Next we want this goal to be assigned to the marketing expert. This is done by browsing through the actor tree and selecting our marketing expert. Next we need a process to operationalize this goal. Here 'manage social media' is selected to operationalize 'online visibility'. Finally 'Facebook' is selected to be the online platform of choice. Facebook will serve as input and output for our operation 'manage social media' and is thus also of concern for our goal 'online visibility'. Finally, in the last step, a small summary is shown before the goal can be saved. When we return to the 'goals' part of the application, we can now browse to the goal 'online visibility' (Fig. 7). In this view, the file explorer from Microsoft Windows is mimicked which should make it very intuitive for users to browse through the goals tree (Design method: familiarity). At the right hand side a focused view of all the connected elements is offered (Criterion 1). Note that very few buttons are offered, providing just enough features (Criterion 3). The main button here is the add button at the top right corner. This started the wizard that guided us through the procedure of adding our goal 'online visibility'. By guiding the user step by step, information is shown in chewable chunks, so it never becomes overwhelming for the user (Criterion 3). Every model can be searched through in the same way, offering a consistent user experience (Criterion 3).

(Prototype: https://www.dropbox.com/sh/03vyn790i1wggsv/G_uDPwJy00/CHOOSE)

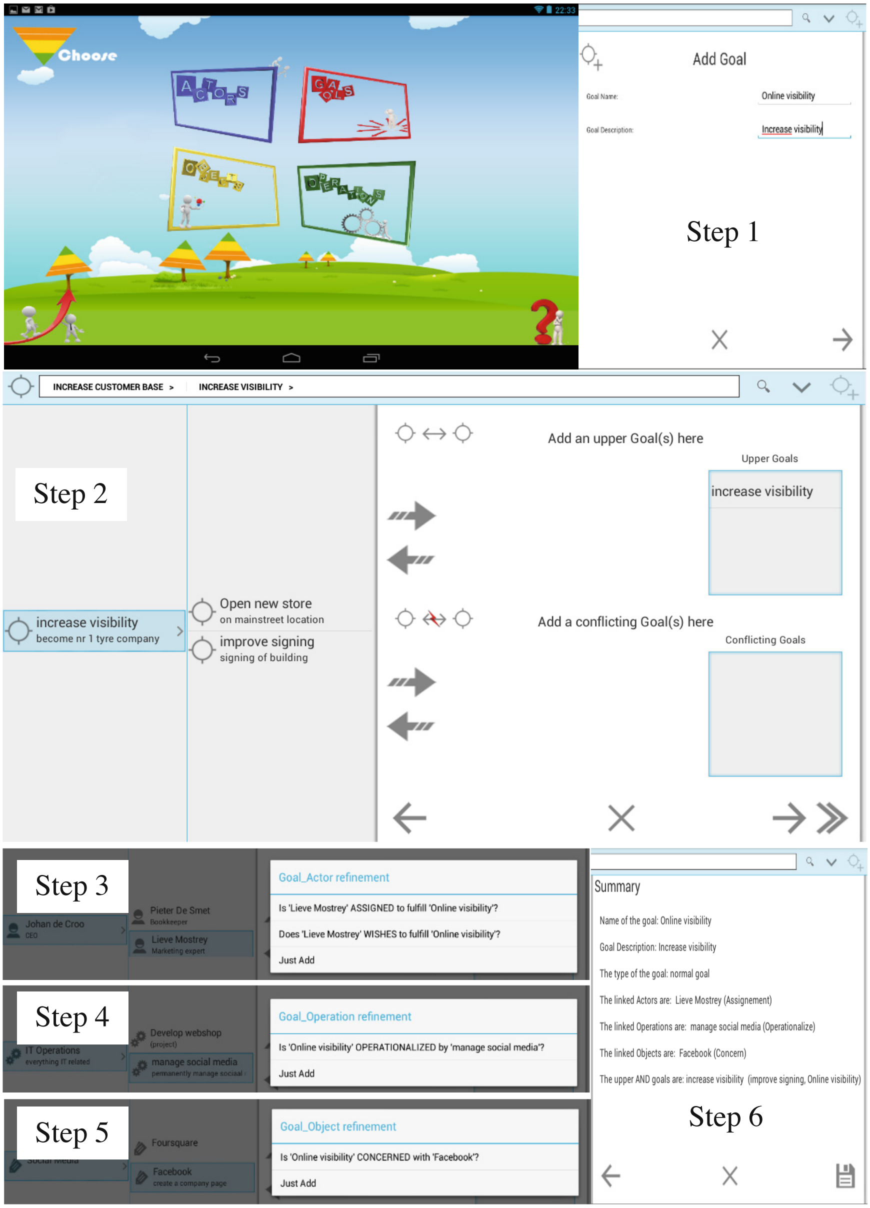

Fig. 6. Add goal 'online visibility'

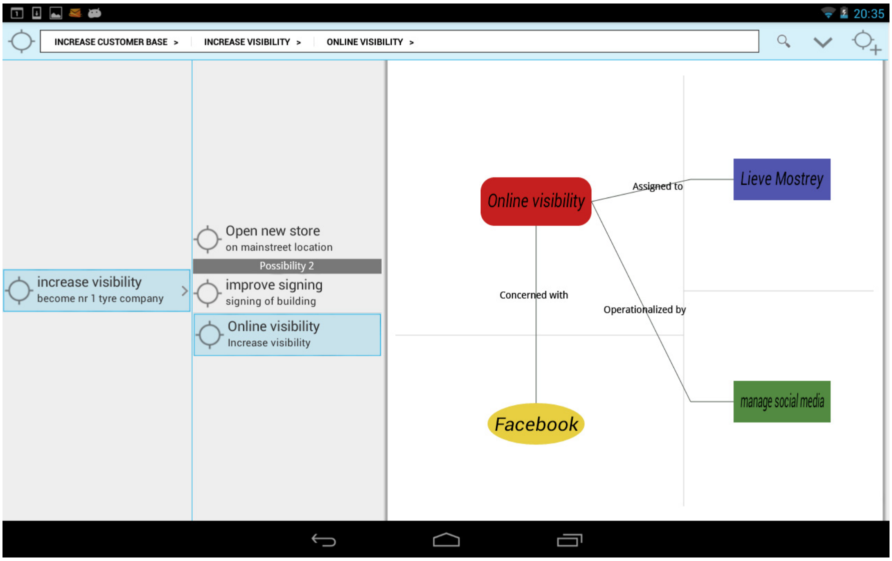

Fig. 7. Focused view 'online visibility'

5 Conclusion

EA approaches have been primarily developed for large companies, despite the importance of SMEs for economy. Tools furthermore have been developed to aid enterprise architects. In this paper, we investigated how tool support could be made usable for managers in SMEs. By using a goal-directed design approach in the tool development process, we came up with a radically different application. A tablet application has been proposed that is easy enough for managers and CEOs to use. First tests in SMEs have been very promising. They found it much easier to comprehend then traditional tools and were very enthusiastic about using a tablet. Further evaluation in practice will still be needed to evaluate the tool and the EA approach CHOOSE.

Although we focused on CEOs and managers working in SMEs, the goal-directed design approach could be expanded towards larger companies. Further research could find ways of better involving other stakeholders with easy to use applications. For example, employees could use a smartphone application to get an overview of their tasks and responsibilities, connected to the companies' goals. This could offer employees a sense of purpose.

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Appendix 2 Chapter 5

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An Android Tablet Tool for Enterprise Architecture Modeling in Small and Medium-Sized Enterprises

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Abstract. Enterprise architecture (EA) is used to improve the alignment of different facets of a company. The recognition for the need of EA in small and medium-sized enterprises (SMEs) has recently risen as a means to manage complexity and change [1]. Due to the specific problems and characteristics of SMEs, a different approach is necessary. CHOOSE was therefore developed as an EA approach focused on and adapted to the characteristics and needs of SMEs [2]. During case studies performed with CHOOSE, the need for software tool support became apparent. This paper describes a mobile software tool in support of the CHOOSE approach that should guide the CEO as enterprise architect throughout the entire EA process and facilitate the implementation, management, and maintenance of the resulting EA model. The generic development decisions make this software tool widely applicable for a multitude of models. Finally, evaluation in two Belgian SMEs is presented.

Keywords: Enterprise architecture, small and medium-sized enterprises, CHOOSE, Android tablet software tool.

1 Introduction

If you are about to build or rebuild a house, you will probably appeal to an architect to make sure the house fits your needs both structurally and functionally. The same can be said when starting, running or growing a business. An enterprise is a complex system of people, knowledge, fixed assets, projects, processes, and many more brought together to fulfill a common shared vision [3]. Enterprise architecture (EA) can help to guide this process and consists of principles, methods, and models to achieve its main objective, which is a coherent and consistent organizational design. Originally EA was focused on IT and its alignment with the business side. However, over the years the concept has grown into a much broader technique and is applied across the borders of IT and the alignment is therefore sometimes called enterprise coherence [4]. Although a lot of research is being done on EA, hardly anything is known about its use in the context of a small and medium-sized enterprise (SME) [5]. Some have pioneered in this field of study through the development of an EA approach adapted to the specific needs of this target group called CHOOSE (section

2.1) [2,6]. The application and implementation of EA in general and the CHOOSE approach in particular, has proven to be a complex and challenging task. Though these techniques could offer significant benefits to SMEs, hardly any SME uses EA and adoption is far below par [1,7]. Analysis of widely accepted adoption models like the technology acceptance model (TAM) [8] and the method evaluation model (MEM) [9] has shown that software tool support could significantly contribute to solving this paradox [2]. The research question of this paper is a design science [10] question: "How could such a software tool in support of the CHOOSE metamodel and method be developed?". This software tool guides the SME's CEO in his function as enterprise architect throughout the EA process and facilitates the implementation, management, and maintenance of the resulting EA. Evaluation by means of case studies in two Belgian SMEs provides the necessary proof of both the importance and efficacy of the software tool. This evaluation process was further used to provide valuable insights and measurements for the evaluation of the efficacy of the developed software tool.

In section two, a short introduction on EA and its applicability in SMEs is discussed after which the need for tool support in this area is illustrated. The third section elaborates on the development of the tool itself and explains the design and development choices. The fourth section elaborates on the evaluation of the software tool. Finally, the paper ends with a conclusion and future research directions.

2 Enterprise Architecture Software Tool Support

EA is employed to improve the alignment in companies. If we look at the term architecture it is clear that it is not without ambiguity [3]. A definition of architecture is given by IEEE Computer Society [11] and is described as "the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principle guiding its design and evolution". Multiple frameworks, models, and tools to create the structure of these components and their relationships exist. Examples of software tools currently in use include Rational System Architect [12], Aris [13], and QualiWare [14]. The drawback is that these tools are not disposing of analysis tools [15], nor are they supporting the CHOOSE metamodel, or are they adapted towards an SME target group.

2.1 CHOOSE for EA in SMEs

The current EA tools are primarily targeted at large enterprises. This focus is hard to justify since SMEs comprise up to 99.8% of all firms in the European Union while globally they account for 99% of business and 40% to 50% of the gross domestic product [16,17]. One of the major causes preventing the growth of SMEs is the lack of business skills [1]. Other than business skills, SMEs lack specialized IT knowledge and technical skills [18]. SMEs are constantly busy dealing with day-to-day business, leaving them little room for strategic issues [19]. Bernaert et al. [2] derived several requirements from these SME characteristics.

To manage the change and complexity in smaller enterprises, using EA could be a good solution [1,2]. In this light, the CHOOSE metamodel for EA (Fig. 1) is being developed based on the defined requirements for EA and SMEs [2]. CHOOSE is an acronym for “keep Control, by means of a Holistic Overview, based on Objectives and kept Simple, of your Enterprise”, incorporating these requirements in its name. The CHOOSE metamodel addresses the specificities and problems SMEs face by creating an overview of the business architecture layer of EA, including elements from the information systems and technology layer. Four dimensions are distinguished to create this overview. A strategic goal dimension (why), an active actor dimension (who), an operation dimension (how) and an object dimension (what). The creation of an EA model in CHOOSE involves creating specific entities of the four dimensions and modeling the relationships between them.

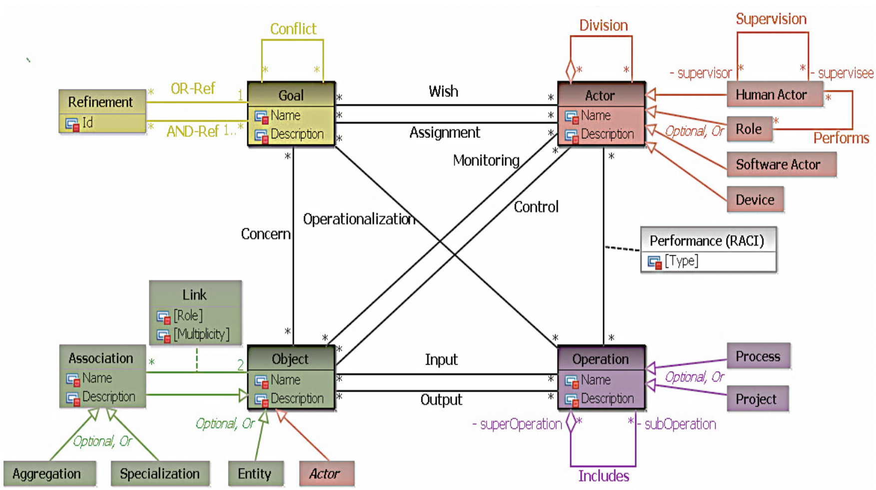

Fig. 1. CHOOSE metamodel [2]

2.2 Need for Software Tool Support

Despite the customized EA approach offered by CHOOSE with its intrinsic qualities aligned with the characteristics of SMEs, it is also very important to take the adoption of the approach into account. Techniques that are technically superior or fully customized to the needs of the user will not yield the expected benefits as long as the techniques are not effectively used in practice. To help optimize, facilitate, and speed up the adoption process, Bernaert et al. [2] investigated different adoption models and proposed the MEM [9] to evaluate the CHOOSE approach. MEM supplements the widely used TAM [8] to be better applicable for the evaluation of methods. MEM provides a model that helps discern external factors and their impact on the attitude, evaluation, and behavior of practitioners towards the adoption of IS methods, such as EA. Central determinants in this model are perceived ease of use and perceived usefulness. The conviction of the end-users that the information technology will help them better perform their job relates to the perceived usefulness. Perceived ease of use alternatively deals with the amount of effort and time needed to learn how to work with it. Both aspects influence the attitude towards the method and subsequently the behavioral intention to use. Crucial for the adoption is that the increase in performance is perceived as being of higher influence to adoption than the effort necessary to learn the developed technology and work with it [8,9]. Fig. 2 gives an overview of MEM and its main components. The biggest difference with TAM is the introduction of actual efficacy coming from Rescher [20]. This difference is subtle but nevertheless very important. It implies that when explaining human behavior, the subjective reality is often much more decisive than the objective reality and therefore perceived efficacy mediates the impact of actual efficacy on adoption in practice [2].

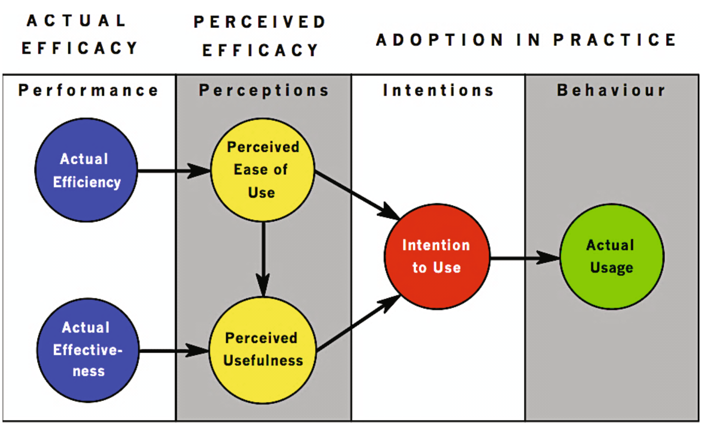

Fig. 2. The Method Evaluation Model

The development of a software tool supporting the application and implementation of CHOOSE could significantly contribute to the actual efficacy, leading to a higher adoption and added value through an increase in the subjective perception of this efficacy. Hence, measuring the perceived usefulness and perceived ease of use of the software tool during the evaluation process (section 4), will provide valuable insights with respect to the ability of this tool to increase adoption of CHOOSE, which reflects the notion of rational selection [20], which states that, generally, those methods or tools will be adopted that outperform others in achieving intended objectives.

Next to the contribution of a tool to the adoption of an approach, research concerning the implementation and use of EA in practice stresses the complexity and need for guidance by means of tool support. In general, there are three main areas where critical problems arise in the process of EA: modeling, managing, and maintaining EAs [21]. An important driver of problems in these areas is the inherent complexity of the EA process [22]. An enormous amount of information has to be transformed using the semantics and syntax of the modeling language. A tool can offer the much needed support and guidance for the development, storage, and analysis of an EA [22]. This drawback emphasizes the importance of an integrated tool for building, analyzing, and communicating the EA to all stakeholders. Other advantages of tool support include [3]:

- A tool can help to standardize the semantics and syntax used during the development of the EA within a company.
- The use of a tool contributes to the construction of correct and consistent architecture artifacts by guiding the development process and through the application of mistake proofing techniques. Tools can impose rules to make sure the desired practices and guidelines are followed.
- Tools facilitate the comparison of alternatives by providing impact of change and quantitative analysis features.
- Software tools can use computational power for the analysis of the architecture.

Although the aforementioned research confirms the importance of tool support, these findings cannot simply be extrapolated to the environment of SMEs and the importance of tool support for the implementation of the CHOOSE approach. However, case studies performed by Bernaert and Callaert (upcoming paper) confirm this need for tool support. During these case studies, the CHOOSE technique was applied in six Belgian SMEs by means of simple post-its on a whiteboard. The CEOs were convinced of the added value of having access to a software tool supporting this EA process. Fig. 3 shows a small fraction of the resulting EA model and pinpoints the importance of a tool for the development, storage, and analysis of the EA artifacts, since the use of post-its created an unmanageable EA model. The post-its should not be readable due to confidentiality issues.

Fig. 3. Partial EA artifact of a Belgian SME

2.3 Software Tool Requirements

On the one hand, the lack of business and IT skills in SMEs causes the need for user-friendly intuitive ways to model the EA in order for the SMEs to have an overview of the company and to enable growth [1]. On the other hand, we see that in our current society, a new organizational form called the mobile enterprise is rapidly emerging [23]. Defining a mobile enterprise is difficult. In a narrow way, specific mobile solutions are used for specific problems in the organization. In a broad way, mobile solutions can be part of the strategy and are diffused throughout the entire company [23]. The combination of this particular need and the trend of increasing mobility creates a need for mobile applications to model the EA. This can help with the process of becoming a mobile enterprise and can leverage other information technology support systems. The use of the CHOOSE metamodel for such a tool is further supported by the proposition that a software tool should be based on a metamodel and be capable of representing EA information in customizable graphical and textual forms [24]. Further, a lot of companies still use Microsoft Office (29% of respondents) (e.g., Word, Excel, PowerPoint) or Visio (33% of respondents) to model their EA [25]. Export to and import from these Office tools could offer benefits.

Based on these insights, it is safe to say that the development of a software tool adjusted to the specific needs of SMEs, based on CHOOSE and incorporating these requirements could substantially improve the added value of EA for SMEs.

3 Software Tool Development

It was decided to let the software tool resemble as close as possible the use of post-its on a whiteboard to copy the case study process. The graphic processing power of Android tablets was chosen to enable this graphical drawing behavior and adhere to the increasing trend of the mobile enterprise. In the following paragraphs, a generic solution for the development of a software tool for making CHOOSE models is proposed. It is generic in the sense that any framework composed of entity types and relations between them is a possible candidate to be developed in the same way. First, the CHOOSE metamodel is mapped onto a graph data structure and the database model is developed. After this, a possible software design is proposed. During each step, the specificities of developing for the Android platform are explained.

3.1 Representation

The CHOOSE metamodel (Fig. 1) consists of four different types of entities and various possible relationships between them. This structure can be unambiguously represented by a directed graph, where entities correspond to vertices and relationships to edges. Both the vertices and the edges require a type attribute for the graph to be a correct representation of the EA. Furthermore, vertices have a name and a description. In its most basic form, the CHOOSE metamodel can be represented by the relational database model in Fig. 4 top.

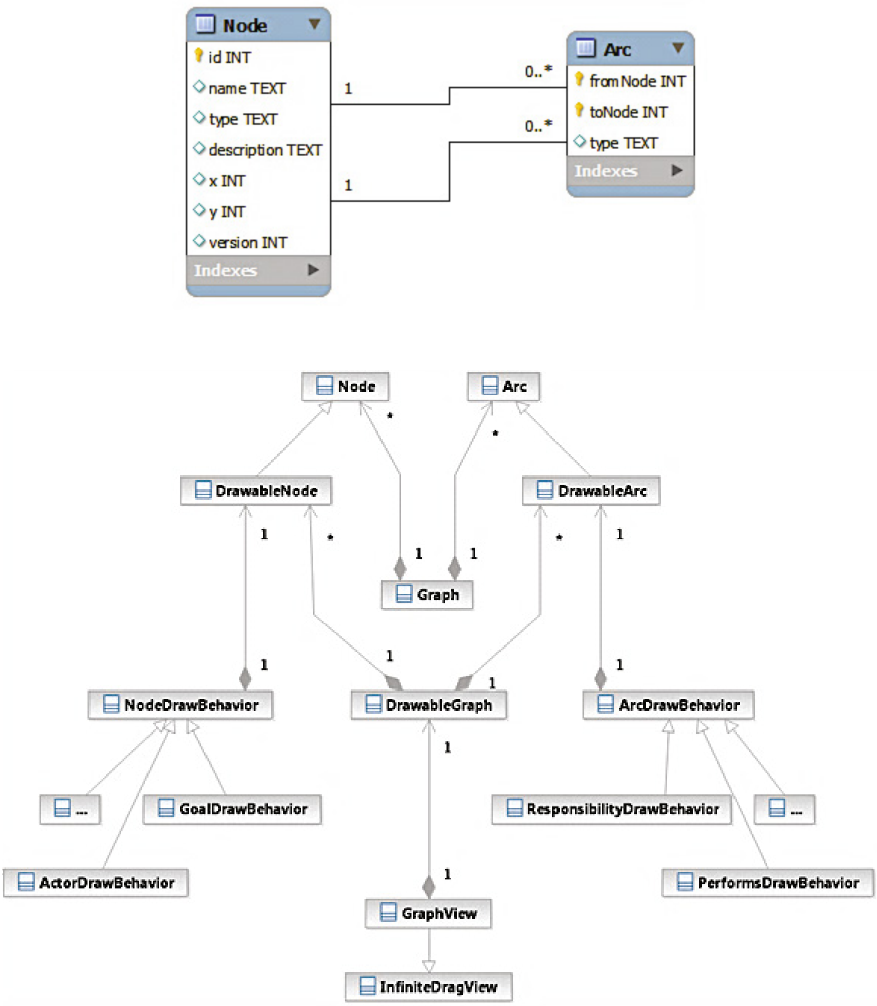

Fig. 4. Database model for a graph data structure (top) & Class diagram of the tool (bottom)

The Android framework offers an abstraction of data in the form of a content provider, which separates the user of the content provider from the backend of the storage. A content provider provides a way to add and manipulate data and is accessible from every application on the Android device. In that way, companies can create their EA in the modeling application and use this database in other applications specifically designed for the company. This could further increase the perceived usefulness of the CHOOSE approach. In this case, the SQLite database management system natively present in the Android framework is used.

3.2 Software Design

The given design allows for maintainability and extendibility of the metamodel as well as the software and is illustrated in Fig. 4 bottom. The basis is formed by the InfiniteDragView class, which allows for an infinitely scrollable field to be shown to the user. The use of this field is extended by the GraphView class, allowing for a graph structure to be shown. The graph data structure is achieved by using a Graph class, consisting of collections Node and Arc objects (Attributes are hidden) [26]. These objects are extended so they have drawing properties in order to visualize them. In that way, the GraphView class uses a DrawableGraph as input.

For the implementation of the drawing of the Nodes and Arcs, the strategy pattern is used [27]. A DrawableNode and a DrawableArc have a DrawBehavior object. All DrawBehavior classes implement the clickable interface. The specific draw behavior is added at runtime. When the GraphView calls the draw methods on the DrawableNode and DrawableArc objects, the DrawBehavior determines how a Node or Arc should be drawn. This depends on the type of Node or Arc but also on the state of this Node or Arc. It can be focused, disabled, pressed or normal. These states are chosen according to the Android design guidelines [28].

3.3 Use of the Tool

The tool is designed to be used on Android tablets but can run on every device running Android 4.0 or higher. It consists of three main panels that can be accessed through a tab interface. In the edit panel, users can create and edit their architecture. The view panel serves for users to adjust the visualization of the architecture. The analyze panel delivers useful output using the earlier created architecture. The view and analyze panels are software tool benefits that were not possible when only post-its and a whiteboard were used. These three panels are further explained with an example of a Belgian SME selling car tires [6]. In this example the tire company has to make sure customers leave safely with the proper tire pressure.

Edit

The users are welcomed in the edit tab, in which the architecture can be created and edited. In this screen, users can add, delete, and change entities and relationships of the architecture. To create a new entity, users need to press on an empty point on the plane. This plane is scrollable by swiping a finger across the screen and zooming is done by making a pinching gesture, both according to Android design guidelines [28]. Users are then subsequently asked which type of entity they want to add, which name it needs to have, and an optional description can be given. This process is done in multiple dialogs, which makes the action to complete more intuitive and clear to the user [29]. The entity is then placed where the user originally pressed. An important object in this SME is obviously a tire. The process of creating a tire object is illustrated in Fig. 5. In the last screenshot four more related objects have been created.

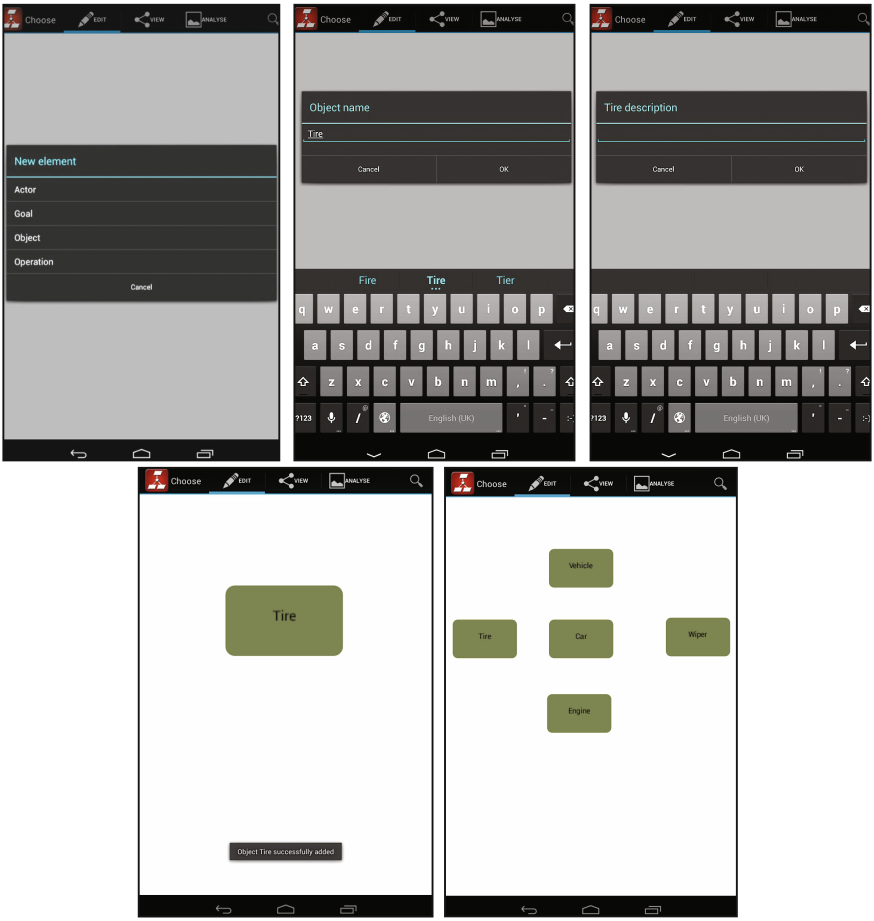

Fig. 5. Creation of entities

Changing the properties of an entity can be done by pressing on it in the edit panel, after which a dialog appears. In this dialog it is possible to change the name of the entity as well as the description. It also offers one of the two ways to create a relationship between different entities. Typing in the “Create relationship with” textbox lets the search function look for matching entities, which are then suggested. This function adds value if compared with post-its on a whiteboard. If different relationship types are possible, a dialog will ask which type it is. A second way in which a relationship can be created is by long pressing on an entity. The user hears a sound and the device will vibrate, which means it is now possible to draw a relationship between two entities. This is a fast way to model small parts of the EA.

In the car tire center example, there exists a composition relationship between the car and the engine and also between the car and the wiper. A specialization relationship exists between the car and the vehicle entity and there is also an aggregation relationship between the car and the tire. The change dialog and the creation of the relationships are shown in Fig. 6. The relationship between car and wiper is purposely created in the wrong direction and can be reversed or deleted by pressing on this relationship as shown in the last screenshot of Fig. 6.

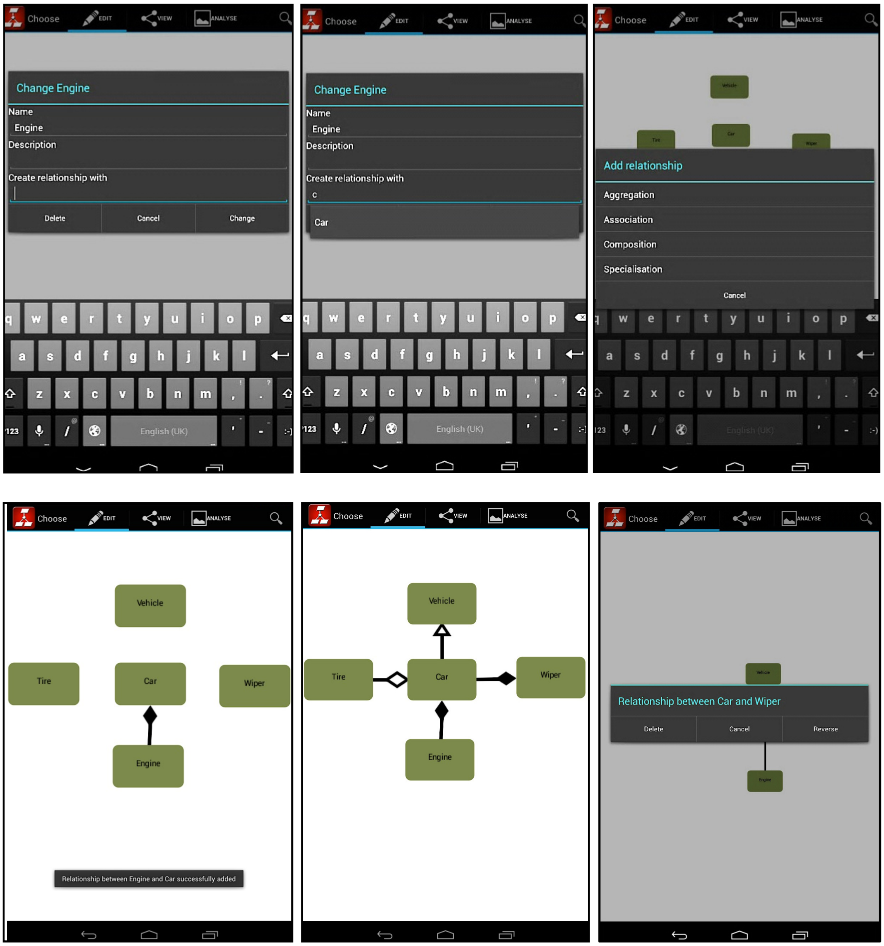

Fig. 6. Changing entities and creating relationships

During the creation, the user can let the application draw the architecture. At the moment, this happens using a force-directed algorithm around the center coordinates of the plane [30]. In its most rudimentary form, all vertex objects in the graph are modeled as point charges that are all exerting a repelling force on each other. The arcs are modeled as springs with a certain length. Letting the system react by computing the exerted forces and moving the vertices leads to a state with at least a local minimum in kinetic energy and an equilibrium in the whole system. The benefit of this algorithm is the flexibility. It allows for users to place certain vertices on fixed positions and additional positioning rules can easily be enforced. The downside is the fact that the global optimum is not guaranteed. For both small and large architectures, this creates an aesthetically pleasing structure. It must be noted that for larger architectures there is the possibility of a loss of overview on the user's side since entities will be relocated. The possibility to fixate certain vertices can help to prevent this. The process and result for a more complex graph is shown in Fig. 7.

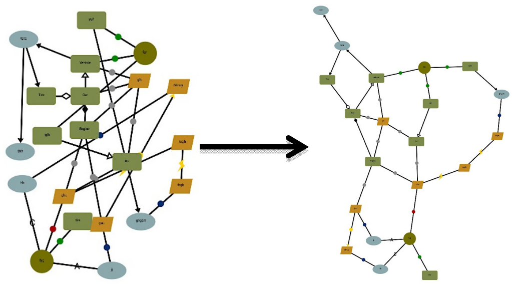

Fig. 7. Automatic drawing of the architecture

View

During the first case study it was clear that the overview is lost very quickly even with the automatic positioning due to the non-planarity of the generated graphs representing the architecture. This problem is tackled by letting users select and isolate entities on which they can work separately in the edit tab. In this way, the user will never have to deal with large unmaintainable structures. It is in this situation that the method to add relationships by typing and searching the related element is the most useful as a lot of entities will not be reachable on the screen. In the tire company example, a few more entities are added such as a safety goal, a customer actor, a process of driving a car, and others. We will isolate the objects to work on them independently (Fig. 8).

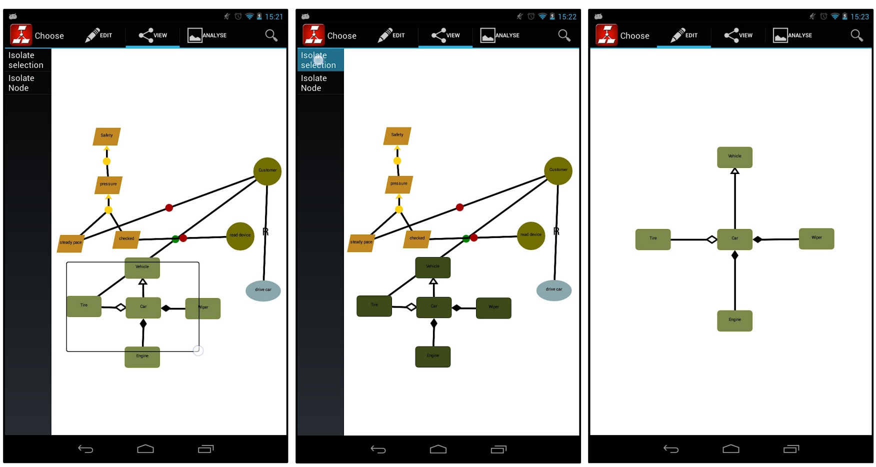

Fig. 8. Isolation of parts of the architecture and changing the visualization

The view panel also allows for multiple viewpoints to be selected, which isolate specific parts of the EA [11]. The goal viewpoint isolates all goals, allowing the generation of a goal tree. The operation viewpoint isolates all processes and projects while the operation flow viewpoint also adds the objects to show possible streams of objects throughout the operations. The other viewpoints are similar (Fig. 9).

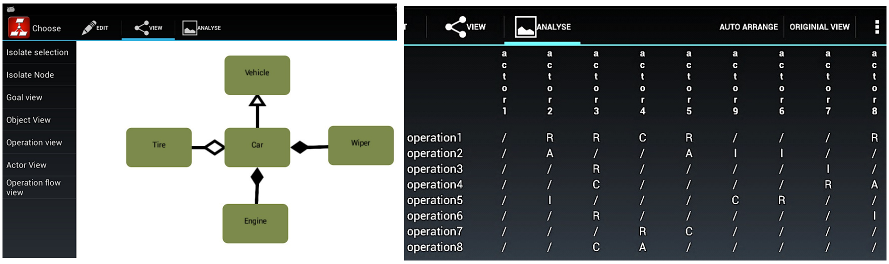

Fig. 9. The view panel (left) & RACI chart (right)

Analyze

The analyze tab is designed to create output for the user. First, it allows the user to generate a RACI chart with export functionality to Excel using the RACI relationships modeled between actors and operations. Second, reports are generated to point out suspicious loops or other problems. Third, it is also the start of an as-is/to-be analysis. Once clicked, users can edit their architecture while the tool keeps track of the changes. This feature is already implemented in the code and saves the changes in the database. The output, as well as indicating that the user is working on the as-is/to-be analysis, however still have to be implemented.

4 Case Studies

Case studies were performed in two Belgian SMEs to evaluate the software tool according to the perceived ease of use (PEU) and perceived usefulness (PU) dimensions of MEM. It was decided to have interviews instead of questionnaires to get the most possible feedback and recommendations on both dimensions of MEM.

4.1 First Case Study

During a first case study at a Belgian chocolate factory, the application was tested by adding elements and relationships during the interviewing process. It was clear that after the creation of just a dozen entities, the overview is lost easily. Very soon, when modeling at an average speed, the architecture becomes a web of entities between which the relationships and the complete structure are no longer clear. This was the incentive for the creation of separate viewpoints so that users could work on parts of the architecture (PEU). The results of the adaptations allowed for faster entry of the architecture (PEU) and let the user make an abstraction of parts of the architecture that are already modeled (PU). The CEO's recommendations were also the incentive for the as-is/to-be analysis (PU) and the RACI chart (PU), which were implemented.

4.2 Second Case Study

The second case study was performed at a Belgian vendor of window glass. The SME's CEO used the application without any further explanation and the case study led to several useful conclusions. First, although the application is made according to the Android design guidelines, it was not completely intuitive what actions the user can trigger. A tutorial when the application is started for the first time is therefore necessary (PEU). Second, for users to independently create their business architecture, it is necessary that they have an insight in how the CHOOSE model works. This is especially true for users who are not familiar with EA modeling. When the application is started for the first time, a second tutorial explaining the CHOOSE model would be very useful (PEU). A wizard based on the step-by-step guidelines of the CHOOSE method could guide the user in developing a CHOOSE model from scratch (PEU). Third, once the SME's CEO knew how the program works, the business architecture was created without much effort (PEU). The creation of entities and relationships went fast (PEU) and the CEO could fully use his mental ability to create the architecture instead of focusing on how the software works. From this perspective, the implementation of the visual approach was a success.

4.3 Case Study Conclusions

Moody's MEM [9] is proposed by Bernaert et al. [2] to assess the intention to use of CHOOSE, which is positively correlated to the actual usage. The CEOs were asked how the tool could improve their perceived ease of use and perceived usefulness, which are both positively correlated to the intention to use.

Related to the perceived ease of use, the tool was better than using only post-its on a whiteboard, but could be improved by incorporating guidance for the user, like the earlier mentioned tutorials and wizards. The search functionality and viewpoints were already implemented to increase the perceived ease of use.

The perceived usefulness was the part where most of the added value could be delivered by the software tool. This confirms the research of Moody [9] and Davis [8]. The RACI chart with export functionality, as-is/to-be analysis, and some additional viewpoints were already implemented and perceived as increasing the usefulness. Other functionalities could increase the perceived usefulness even more. As a first example, a querying functionality with export to Excel could enable different analyses and viewpoints. A CEO could for example get a list of all employees who are responsible for less than three operations. A second example of a useful functionality is automatically checking the SME's CHOOSE model based on the defined CHOOSE hard and soft constraints. This could deliver interesting insights for the CEO. For instance, an operation (process or project) which is not linked to any goal could then pinpoint a forgotten link in the CHOOSE model that could be added, or could discover operations that are not contributing to any of the company's goals.

Although some additional functionalities could be added, the feedback during the case studies revealed that during the creation of the SME's CHOOSE model, the perceived usefulness was already increased. The CHOOSE metamodel, and thus the software tool whose data model is based on this metamodel, explicitly links goals with each other in a goal tree and also links these goals to operations. This enables explicit traceability from highest-level goals all the way down to operations, which was perceived as very valuable for the SMEs' CEOs. It also triggered critically thinking about the structure of the SME.

5 Conclusion and Further Research

This research has investigated the need for a software tool in support of the implementation of EA in the environment of SMEs as pioneered by the CHOOSE approach from Bernaert et al. [2]. Both literature review and case studies have confirmed this need and the paper presents a software tool in support of this need.

An overview of the main features of the software tool was given and an initial evaluation by means of two case studies has confirmed the potential of the software tool in increasing the adoption of CHOOSE and providing the much needed guidance and support.

The software tool addresses the specific issues SMEs face (time, IT skills, and financial constraints) by being simple, intuitive, and user-friendly. By designing only parts of the EA model at once, users are capable of keeping an overview. Together with the overview users have of their company, the analysis functionalities provide them with useful information and strategic insights. Further, the generic architecture allows for other software tools using metamodels to be developed in the same way as the software tool described in this paper [31].

The case study evaluation in two SMEs revealed more insight in how the software tool helps CHOOSE in increasing its perceived ease of use and perceived usefulness. The case study evaluation was primarily used to get as much insight and as many future research directions as possible by interviewing the CEOs when they were using the software tool. Future evaluation of this software tool in accordance to other software tools or no software tool (e.g., to identify problems arising from a lack of EA modeling experience instead of arising from the tool) could be performed by means of a questionnaire based on the perceived usefulness and perceived ease of use dimensions of MEM through the adapted six-item scales of TAM [8]. This would make the evaluation more rigorous and could dig deeper into the shortcomings of the tool's prototype, like extra features enhancing the overview (e.g., drill down capabilities and extra search functionalities) or possible user-defined customizations to the metamodel (e.g., user-defined properties).

Some recommendations from the CEOs were already implemented and the software tool increased the added value of CHOOSE. Nevertheless, the software tool is still under development and the case studies have identified multiple improvement paths to be tackled. Further research with respect to additional valuable functionalities is required and continuous fine-tuning will contribute to the overall added value of the software tool in support of CHOOSE.

In this stage, only an Android version of the application exists. The architecture is made in such a way that it can be transferred easily across platforms so that it is available for most of them. A more appropriate future solution could be the development of a web application using HTML 5 in combination with the jQuery JavaScript library. These technologies have the potential to create an application accessible from every device running a browser. It also would make the transfer between different platforms [32,33] easier as users can access their architecture everywhere and it could then also support multi-user use with one common database server. Other areas of improvement include the architecture of the software and the analysis part of the business architecture. The graph structure allows for mathematical analyses generating useful information using straightforward graph algorithms.

The tool will soon be available in the Android Play store. In the meantime the tool can be installed using the following link, leading to the installation file:

https://www.dropbox.com/s/716ecd87jo3n167/BusinessModeller.apk

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