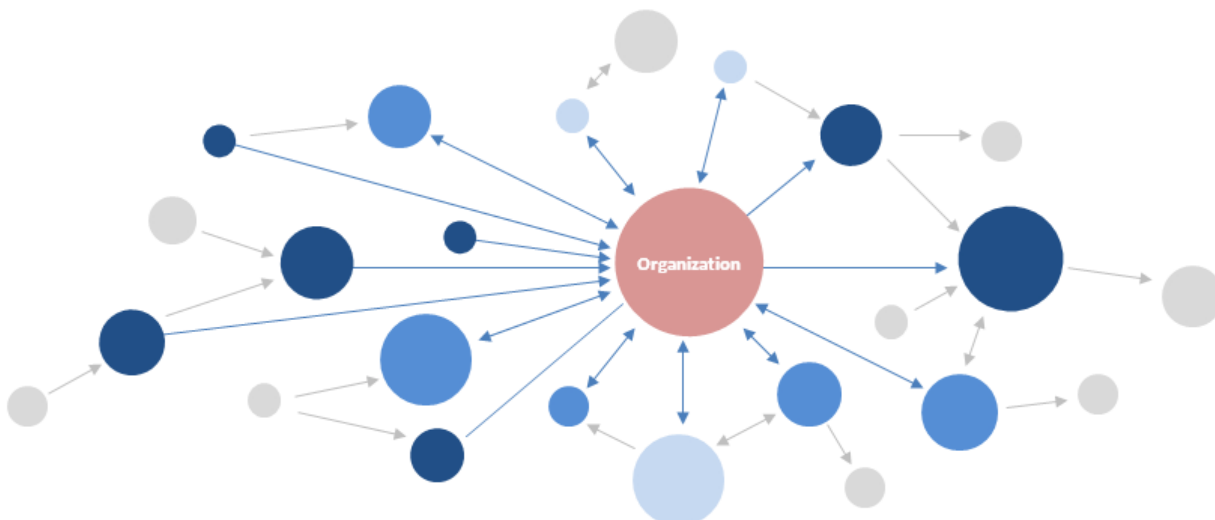
# Metamodelling for networked business model implementations

An application to the Industry 4.0 domain.

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# Metamodelling for networked business model implementations

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by

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# Foreword and Acknowledgements

In front of you lies the result of several months of hard work. When I started writing this master thesis, it was difficult to visualize the end result. However, after the months went by, I started to get a feeling for the research topic and thus the direction I had to take. I liked solving the several problems that I discovered during this research. For example, what to do with the biased opinions of the researchers? Finding a suitable solution (i.e. the metamodel integration), that also was perceived as valuable by various researchers, really was an interesting experience for me. Of course, there were also moments where I did not know what to do next. Nonetheless, eventually I always found a way to take the research further.

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At last, I would like to thank sincerely thank my mother, Marja, and my brother Machiel. I always could "talk your ears of your head" (i.e. Dutch saying) about my research. You really helped to clear my head several times. Next, to this, I would like to thank my friends, who were continuously interested in the status of my research.

Yours sincerely,

Martijn Cligge

# Summary

The main topic of this research, *metamodeling for networked business model implementations*, is introduced by briefly by describing the application domain of this study, the *Industry 4.0* domain. Until recently, innovation in the manufacturing industry was mainly driven by increasing efficiency in the manufacturing business processes. Technological capabilities used within organizational boundaries, like additive manufacturing, RFID tags and embedded systems, have led to significant improvements in process efficiency and product quality. Industry 4.0 introduces the use of Internet of Things (IoT) in manufacturing environments. IoT allows for the networking of physical objects, human actors, intelligent machines, and production activities. IoT allows for the creation of new business models of customized products and services. Due to the networked nature of IoT manufacturing organizations need collaborate with many new partners, such as Software and IT organizations, to realize these new business models. As a result, they become networked enterprises. Networked enterprises are organizations who collaboratively aim to create and implement a collective business model, by sharing values (in terms of products/services, resource and capabilities) and information and by interacting through inter-organizational business processes and supporting ICT. Due to large number of networked enterprises, creating and implementing new *networked* business models becomes a complex task. Therefore, insights into business model implementation (where with business model implementation is realized by business processes and ICT) aspects can help to facilitate the collaborations, interactions and relationships in such a way that the business model can be sustained at an operational level.

Business model literature has proposed several approaches to support ICT driven innovations (such as the introduciotn of IoT in the manufacturing industry) by describing how business value can be generated. While there exists a common agreement on that an effective and efficient business model is a valuable asset to organizations, current business models have several limitations. First, a limitation of current business models is that they often have informal representations and thus lack concrete metamodels. The informal representation makes structuring, visualizing and subsequently communicating the knowledge stored in business models difficult. Furthermore, the business model design often remains isolated from the business model implementation design, which is often expressed in formal languages like UML. This introduces a second limitation of business models, which is the neglected issue in business model literature on the technological implementation of the business model. While business models describe how an organization can create value, an enterprise architecture describes the connection between business processes and ICT. Where business models often lack a business model implementation perspective, enterprise architectures often lack a more economical business model perspective. As a result, questions such as "who benefits from the product?", and "who will pay for it?" are not included in the design of enterprise architectures, while they may have a huge impact on the design. Therefore, it is argued that aligning business models with enterprise architectures results in a harmonized package which describes the creation and implementation of the business model in a comprehensive and holistic manner.

Several researchers have proposed approaches to align business models with enterprise architectures. Nonetheless, these current approaches are often intra-organizational, facilitate merely a single-level of analysis (by either focusing on values, information or process interactions), are heavyweight by converting business model concepts to many detailed enterprise architecture concepts or use an informal approach by lacking concrete formal metamodels and modelling procedures. A result of these limitations is that complex network interactions are not perceived due to the intra-organizational perspective, the business model implementation cannot be described, analysed and visualized in a comprehensive manner due to the single-level of analysis (by either looking at values, information of processes) and the business model implementation design process becomes rather complex and thus time consuming, due to detailed conversion of business model concepts to the enterprise architecture concepts. Furthermore, the informal approach leads to different interpretations by the various stakeholders and difficulty in consistently exploiting the knowledge stored in business models while designing enterprise architectures using the business model-driven approach.

In total four knowledge gaps have been identified in literature on Industry 4.0, business models, enterprise architecture and business model - enterprise architecture alignment:

1. Current literature on the Industry 4.0 domain lacks a focus on business model implementation.

2. Current literature on business models has mainly proposed informal business model representations and lacks a focus on formal business model implementation design.
3. Current literature on enterprise architecture literature often lacks an economical business model perspective.
4. Current literature on business model – enterprise architecture alignment lacks a lightweight formal approach which can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

Based on these knowledge gaps, this study aims to develop an artefact which complies with the following requirements:
1. The artefact should include a formal representation of a business model with a focus on formal business model implementation design.
2. The artefact should extend enterprise architecture with an economic business model perspective.
3. The artefact should include a formal lightweight business model – enterprise architecture alignment approach that can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

The following research objective has been stated: *The objective of this research is to develop lightweight formal metamodels and a corresponding modelling procedure in UML that can support networked enterprises with a multi-level description, analysis and visualization of their technological business model implementation through enterprise architecture concepts.*

To fulfil this objective, the *Action Design Research* and the *design cycle* approaches are used to develop a set of formal lightweight metamodels and a corresponding modelling procedure in UML that allow for a multi-level description, visualization and analysis of networked business model implementations. The metamodels and modelling procedure will be applied to the Industry 4.0 domain to validate the approach and to obtain some first insights into business model implementation aspects for the Industry 4.0 domain. First, a desk study is performed to select a suitable business model, enterprise architecture and business model and enterprise architecture alignment approach. For the development of the artefact, the theoretical foundations of the VISOR business model framework, the VIP business model- enterprise architecture alignment framework and enterprise architecture modelling language ArchiMate will be used to elicit design requirements through theoretical analysis. These initial design requirements will be used to develop a set of initial design specifications. After that, researchers in the field of business model(ing) and enterprise architecture will be interviewed to evaluate the initial design requirements and design specifications on their consistency, coherency, completeness, validity and model levelling. Results from these evaluation interviews will be used to refine the initial design requirements and design specifications. Next, the refined design specifications will be applied to the application domain of this study, the Industry 4.0 domain, through a desk study and interviews with practitioners. By applying the metamodels and modelling procedure to the Industry 4.0 domain, some first insights into business model implementation aspects for the Industry 4.0 can be obtained. Furthermore, by using the metamodels and modelling procedure in the application to the Industry 4.0 domain, the practitioners should be able to evaluate the usefulness, ease of use and requirement fulfilment of the metamodels and modelling procedure. The results from these second-round evaluation interviews will be used to further refine the metamodels and modelling procedure.

Based on the collected and refined design requirements and evaluations with researchers and practitioners, two metamodels, two target metamodels (i.e. integrated metamodels) and a corresponding modelling procedure are developed. The following artefacts are developed:

- The VISOR metamodel. The VISOR metamodel is used to describe and visualize the business idea in a structured and formal manner. Highlights of the metamodel are the inclusion of essential concepts to define a networked business model with well-defined relationships between these concepts.
- The VIP metamodel. The VIP metamodel is a lightweight intermediate metamodel (between the VISOR business model and ArchiMate enterprise architecture metamodels) that can be used to bridge the gap between business models and the enterprise architectures. Highlights of the metamodel are the inclusion of essential concepts for

business model implementations and corresponding well defined relationships these concepts. The metamodel allows for a description, visualization and analysis on the level of values, information and processes.

- The VIP-VISOR target metamodel. The VISOR-VIP target metamodel can be used to transition from the concepts of the VISOR metamodel to the concepts of the VIP metamodel and extends the VISOR metamodel with a focus on formal business model design. Highlights of the metamodel are the well-defined formal integration relations between the VISOR metamodel concepts and the VIP metamodel concepts.
- The VIP-ArchiMate target metamodel. The VIP-ArchiMate target metamodel can be used to transition from the VIP concepts to ArchiMate concepts. As a result, the VIP metamodel instantiations can be modelled in enterprise architecture modelling language ArchiMate. Highlights of the metamodel are the well-defined formal concept mappings between the VIP metamodel concepts and the ArchiMate metamodel concepts.
- Next to that, a corresponding modelling procedure is developed which guides the networked enterprises through a step-by-step process in their business model creation and implementation process, with the use of the various metamodels.

In addition, the application of artefacts to the Industry 4.0 domain gives manufacturing organizations some first insights into business model implementation related aspects. Organizations who want to adopt and implement Industry 4.0 business models should focus on (1) hidden product design requirements and arrangements for equal profit and cost sharing (2) data interoperability issues and privacy issues when data is being processed (3) conflicting and heterogeneous business processes.

Important scientific contributions are the following:

- First this study contributes to business model literature with the development of the VISOR metamodel, which was initially expressed in natural language. The VISOR metamodel makes it easier to understand and visualize the relations between the business model concepts, which in turn should improve communication of the business idea.
  Second, the development of the VISOR-VIP target metamodel adds to the lack of a focus on formal business model implementation design in business model literature.
- Second, this study adds to literature on enterprise architecture by proposing the 'value activity' concept (which was perceived as a valuable contribution to ArchiMate by various researchers who are involved in the development of ArchiMate) and the two new relationships to the ArchiMate metamodels. The 'value activity' concept is a more economically business model oriented and abstract behaviour element as opposed to the more functionally oriented 'business process/function/interaction' concepts of ArchiMate. The first relationship should make modelling the interactions of processes with resources more precisely, while the second relationship allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value. These extensions should add a more abstract and business model oriented perspective to ArchiMate.
- Third, this study adds to literature on business model and enterprise architecture alignment. First, with the development of the VISOR-VIP and VIP-ArchiMate target metamodels, it is one of the first studies to integrate business model concepts and enterprise architecture through the application of formal metamodel integration techniques. The result of the formal integration of VISOR, VIP and ArchiMate concepts has resulted in a cross-domain modelling language, which could act a common grounding between business and IT oriented practitioners. This cross-domain modelling language allows various practitioners to holistically describe, visualize and analyse the business model, business process and ICT design which could reduce the number of misinterpretations. This in turn improves the decision-making processes and the planning of the business model' realization. Consequently, this results in a more consistent and unfragmented business model, business process and ICT design. Second, another contribution to literature on business model and enterprise architecture alignment is the development of the formal VIP metamodel, which can be used as lightweight intermediate to bridge the gap between more economical and abstract business model design and the more detailed and functional enterprise architecture design. The VIP metamodel is based on the theoretical foundations of VIP, which was initially an informal conceptual framework rather than a formal modelling approach. Third, by formally integrating the VIP concepts with ArchiMate concepts

in the VIP-ArchiMate target metamodel, this is also the first study that applies enterprise architecture thinking in VIP analyses.

Possible directions for further research are the following:

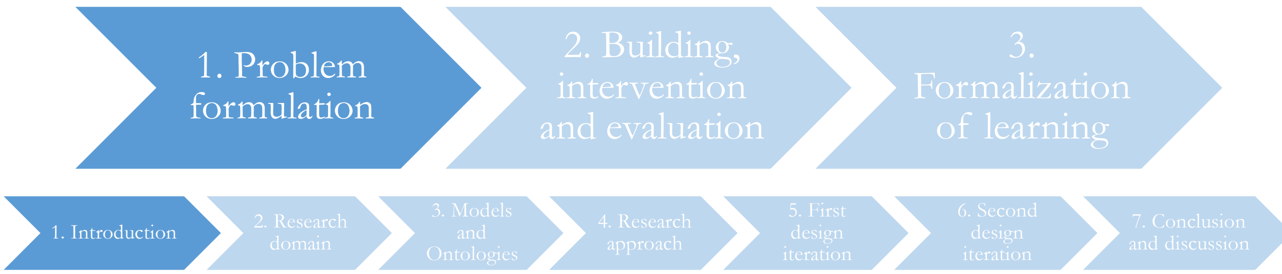
- A first research direction would be the inclusion of a detailed quantitative financial analysis in the modelling procedure and metamodels. In the work of Iacob et al. (2012), a detailed quantitative financial analysis can be used to determine the costs and possible revenues for a business model driven enterprise architectural change. This allows to determine whether the possible revenues exceed the costs of the architectural change, and if thus the business model design change is desired. Iacob et al. (2012) also related their approach to the TOGAF framework. In further research, it can be investigated how the modelling procedure and metamodels could be integrated with this widely accepted enterprise architecture framework.
- Since in this research they artefacts are merely applied on the general characteristics of the Industry 4.0 domain, another possible research direction is the application of the artefact in a *real-life* case study. Since the Industry 4.0 domain is merely the application domain of this study, other domains with networked characteristics, such as the Smart Hone domain can also be studied with the developed approach.

# Table of contents

# List of definitions

| Term | Definition |
|---|---|
| **Business model** | *Concept that supports (ICT driven) innovations by describing the general logic for creating business value* (J. Heikkilä, Tyrväinen, & Heikkilä, 2010; Osterwalder, 2004). |
| **Business model – business operations (enterprise architecture) alignment** | *"The extent to which a Business Model supports/enables and is supported/enabled by the underlying operational activities, processes and systems of the Business Model executor(s), as a single or networked enterprises."* (Solaimani, 2014, p. 58) |
| **Business model implementation** | *"The operationalization of the business model through business processes and ICT within and among organizations"* (Bask, Tinnilä, & Rajahonka, 2010; Bouwman, De Vos, & Haaker, 2008; Sam Solaimani & Bouwman, 2012). |
| **Enterprise architecture** | *"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, 2017, p.3) |
| **Feasibility of a business model** | *"The extent to which the business logic is sound to be operationalized"* (S. Solaimani, 2014) |
| **Industry 4.0** | *"A reform and re-organization of value chains to a networked coordination in the era of the 4th industrial revolution enabled by the Internet. More precisely, Industry 4.0 uses real-time individual customer requests and environment balances from all participants of the value chain to holistically integrate the production process towards realization of collaborative value."* |
| **Internet of Things (IoT)** | *"A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network"* (Xu, He et al., 2014, p.2233) |
| **Lightweight** | *"Methods whose adaptation costs is a small fraction of that of the overall requirements engineering process including training, application, and computational costs."* (Gervasi & Nusaibeh, 2001, p.114) |
| **Metamodel (i.e. ontology)** | *"A shared, descriptive, structural model, representing reality by a set of concepts, their interrelations, and constraints under the open-world assumptions*" (Aßmann, 2005, p. 256) |
| **Model** | *"Formal descriptions, representations, and specifications of things"* (Aßmann, 2005, p.253) |
| **Modelling procedure** | *The modelling procedure describes the steps applying the model- ling language to create results, i.e. models.* (Kühn et al., 2003, p.2) |
| **Networked enterprise** | *"Hardly non−substitutable linked companies that collaboratively aim at enabling or implementing the collective Business Model by means of offering service and product and/or sharing resources and capabilities."* (Solaimani, 2014, p. 61) |
| **Viability of a business model** | *"The long-term profitability and market adoption of a business model"* (S. Solaimani, 2014) |

# Chapter 1 Introduction




This chapter will introduce the research topic by describing the research problem, the current situation of the application domain, the knowledge gaps, and the resulting research questions. Furthermore, the scientific and practical contributions of this thesis will be described, and this chapter ends with the outline of the thesis.

## 1.1 Introduction

The emergence of Information and Communication Technologies (ICT) has offered organizations opportunities to differentiate themselves from competitors by providing innovative ICT driven product and service offerings and to improve their oppertational efficiency. The *business model* is a rather newly developed concept that supports ICT driven innovations by describing the general logic for creating business value (J. Heikkilä et al., 2010; Osterwalder, 2004). The business logic of an organization defines what value is offered to the end-customer (i.e. the value proposition), how this value is created through value creation activities and how this this value is captured through value capturing models (Zott, Amit, & Massa, 2011). While there exists a common acceptance that an effective and efficient business model is a valuable asset to organizations, current business models have several limitations. First, a limitation of current business models is that they often have informal representations. The informal representation makes structuring, visualizing and subsequently communicating the knowledge stored in business models difficult (Zott et al., 2011). Furthermore, due to the informal approach, the business model design often remains isolated from the business model implementation design, which is often expressed in formal languages like UML (Al-Debei & Avison, 2010; Pateli & Giaglis, 2004; Rasiwasia, 2012). This introduces a second limitation of business models, which is the neglected issue in business model literature on the technological implementation of the business model (Bouwman et al., 2008; El Sawy & Pereira, 2013; Osterwalder, Pigneur, & Tucci, 2005; S. Solaimani, 2014). Generally, the implementation of a business model is realized by business processes and ICT, such as Information systems (IS) within and amongst organizations (Bask et al., 2010; Bouwman et al., 2008; Sam Solaimani & Bouwman, 2012). A business model implementation defines *how* should *whom* do *what* to gain *which* value (J. Gordijn, Akkermans, & Vliet, 2000). With the emergence of ICT in business model innovation, an increased interaction between on the one hand the design of the business model and on the other hand the design of the ICT driven business model implementation is required to effectively deliver the products and services to the end-customer (Al-Debei & Avison, 2010; Bask et al., 2010). Not considering these perspectives leads to an incomplete understanding of the gap between the business model and the business model implementation, where business model design choices are not reflected in the design of the processes and supporting ICT (Bask, Tinnilä et al. 2010). Furthermore, severe set-backs are to be expected in the execution of the business model when implementation aspects are no considered. Even those business models that seems promising on paper, can fail when they are being technologically implemented (S. Solaimani, 2014). Therefore, it is argued that a business model cannot be viewed in isolation, but should be related to the business processes and supporting ICT perspectives that are required to realize the business model (Osterwalder 2004, Janssen and Gordijn 2005, Al-Debei and Avison 2010, Zott and Amit 2010).

Furthermore, ICT-driven product and service offerings are increasinlgy provided by collaborating organizations (Janssen & Gordijn, 2005; Osterwalder, 2004). Therefore, especially in ICT driven business model innovation, where organizations are collaboratively implementing business models through complex interactions and exchanges of (ICT) resources, capabilities and information and inter-organizational business processes, insights into business model implementation aspects are required to ensure the operational feasibility (refers to if the business logic is sound to be operationalized) and viability (refers to the long-term profitability and market adoption of a business model) of the business model (Janssen & Gordijn, 2005; Osterwalder, 2004; Sam Solaimani & Bouwman, 2012). Organizations who are collaboratively creating and implementing business models are defined as networked enterprises by Sam Solaimani and Bouwman (2012). The implementation of a networked and ICT driven business models is a challenging task, because the business processes of the networked enterprises are often conflicting and heterogeneous, the division of responsibility over different components of the value proposition is unclear and the ICT landscape is often fragmented (Erol, Schumacher, & Shin, 2016; Legner & Wende, 2007; Sam Solaimani & Bouwman, 2012). A business model's feasibility and viability is ensured when the business model is coherent, supporting and supported by the processes and ICT of the networked organizations (Solaimani 2014). Insights into business model implementation aspects can help to facilitate the collaborations, interactions and relationships in such a way that the business model can be sustained at an operational level.

Concluding, to ensure the feasibility and viability of the networked business model and to effectively deliver the products and services to the end-customer, business models, business processes and supporting ICT should be treated as a coherent package (Bask, Tinnilä et al. 2010). This thesis aims to address the gap of networked formal business model design and business model implementation by developing a formal approach that supports analysis of complex interactions between networked enterprises on various levels (i.e. business model, business processes and ICT). In the next section, the research problem will be discussed in more detail by describing the limitations of current academic literature on business model implementation.

## 1.2 Research problem

### *1.2.1 Problem exploration*

The introduction has underlined the relevance and need for insights into business model implementation aspects, particularly for *networked* ICT driven business model innovation. *Enterprise architecture* focuses on establishing a coherent view of an organization, by describing the business processes, applications, information and technological ICT infrastructure (Janssen & Gordijn, 2005; Lankhorst, 2017). Enterprise architecture thus facilitates analysis of the technological implementation of the business model. While business models often lacks a business model implementation perspective, enterprise architectures often lacks a business model perspective (Rahmati, 2013). As a result, questions such as "who benefits from the product?", and "who will pay for it?" are not included in the design of enterprise architectures, while they may have a huge impact on the design (Iacob et al., 2012). Furthermore, the business fit of the enterprise architecture design cannot be evaluated effectively (Iacob et al., 2012). Therefore, it is argued that aligning business models with enterprise architectures results in a harmonized package which describes the creation and implementation of the business model in a comprehensive and holistic manner. Consequently, it supports analysis on the on hand the feasibility and viability of a business model innovation and on the other hand the business fit of the enterprise architecture design (and thus help answering the aforementioned business model related questions) (Fritscher & Pigneur, 2011; Iacob et al., 2012; Janssen & Gordijn, 2005; S. Solaimani, 2014). The way business models and enterprise architecture correspond is described by Janssen and Gordijn (2005) as follows: *"Enterprise Architecture and business modelling methodologies meet in service offering and realization. In general, business models focus on the service value generated by a business, whereas enterprise architecture models show how a business realizes these services."* (Janssen and Gordijn 2005, p. 2). Aligning business models with enterprise architecture has numerous benefits since it -amongst others- supports the design and implementation activities of a new a business model, helps to identify key activities and resources that support new business models, improves the understanding of implications for the to-be architecture, improves the planning and assessments of projects and improves alignment between the value proposition and IT infrastructure (Fritscher & Pigneur, 2011; Iacob et al., 2012; Janssen & Gordijn, 2005; Petrikina, Drews, Zimmermann, & Schirmer, 2014).

While models and methods that help organizations to transform their business models to operational business processes and a supporting ICT architecture are still underdeveloped (J. Heikkilä et al., 2010; Petrikina et al., 2014), a few researchers have proposed approaches, such as Iacob et al. (2012), Fritscher and Pigneur (2011) or S. Solaimani (2014). Nonetheless, current approaches that align business models with enterprise architecture have several limitations. First, they often lack the network perspective and are focused on the alignment of organization-centric business models with intra-organizational business processes and ICT, instead of the implementation of a *networked* business model through inter-organizational business processes and ICT (S. Solaimani, 2014). The importance of insights into inter-organizational interactions is discussed in section 1.1. Hence, approaches are required that do facilitate networked business model and enterprise architecture alignment.

Second, instead of offering a comprehensive multi-level analysis, they often have a single-level of analysis by either focusing on value exchanges (such as exchanges of products or money), information/knowledge exchanges or interactions through business processes between networked enterprises (S. Solaimani, 2014). Especially in ICT driven business model innovation information plays an important role (Evans & Wurster, 1997; J. Gordijn, 2003). Therefore, it is crucial that the role of information and knowledge in business model implementation is underestimated (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). This limited level of analysis, by either focussing on values, information/knowledge or processes, limits the ability to analyse the feasibility and viability of the business model implementation for networked enterprises in a comprehensive manner. Therefore, a business model – enterprise architecture alignment approach is required that does facilitate this multi-level of analysis on the level of value, information and processes.

Third, most approaches are directly converting business model concepts to detailed enterprise architecture concepts, which results in a rather complex business model implementation design process. To bring an ICT driven business idea into execution, often only a limited amount of time is available (J. Gordijn, 2003). Rapidly increasing technological possibilities cause ideas to obsolete fast (J. Gordijn, 2003). Therefore, it is not possible to invest time and money to develop a detailed, complex description or 'blueprint' of the enterprise architecture, which often consists of many different concepts. As such, organizations often demand a quick, first execution of the business idea comprising of the essentials of the idea. Lightweight approaches are defined by Gervasi and Nuseibeh (2002) as whose adaptation costs is a small fraction of that of the overall design process, which includes training, application, and computational costs. Consequently, a *lightweight* business model – enterprise architecture alignment approach, consisting of a limited number of concepts and relations between these concepts, is required that does facilitate analysis, evaluation and visualization of the business model implementation on a relatively high-level of abstraction.

Fourth, current business model-enterprise architecture approaches are often using an informal notation and lack concrete metamodels. The absence of a formal integration and representation of business models with enterprise architectures poses difficulty in exploiting and structuring the knowledge stored in business models while designing Enterprise Architectures using the business model-driven approach. As a result, business models are still remaining isolated from the business process design and IT architecture design, since the business model descriptions is often represented informally (e.g. in natural language) as opposed to the formal representations of the business process and IT design (which are often described in UML) (Al-Debei & Avison, 2010; Heyl, 2014b; Pateli & Giaglis, 2004). Furthermore, informal representations often lead to different interpretations by the various stakeholder groups (J. Gordijn, 2003). Due to the increased number of stakeholders involved in ICT driven business model innovation, designing and implementing business models has become rather complex (Osterwalder, 2004). The complexity arises among the networked enterprises, which are often consisting of actors of different domains (such as suppliers, distributors, IT developers etc.) as well between the business oriented stakeholders and the IT oriented stakeholders within and among the networked enterprises. Stakeholders involved in ICT driven business model creation and implementation are stakeholders ranging from CxO's (e.g. Chief Executive Officer) to information technology stakeholders. These stakeholder groups have very different foci, which result in mixed-up and inefficient discussions between these stakeholders (J. Gordijn, 2003). In the research of Rasiwasia (2012) a typical scenario is illustrated, where a business analyst designs a business model, which holds sufficient knowledge about the business logic of an organization. However, IT requirement engineers and software architects experience difficulty to extract relevant knowledge from the business model to design the Information Systems due to the informal approach. Due to the difficulty to transfer the business knowledge into ICT design much of the business knowledge remains underutilized. A result of this is fragmentation and inconsistency of knowledge in one the one hand the business model design and on the other hand the technological business model implantation design. Conversely, business analysts experience a difficulty in communicating and controlling system design changes as the business model changes over time. Therefore, metamodels that aim to represent the business model and business model implementation conceptualizations in a structured, uniform, formal and understandable way can help to reduce the level of complexity and ambiguity by highlighting important issues and pointing out relationships between them and to increase the common understanding by the various stakeholders (J. Gordijn, 2003; Osterwalder, 2004; Rasiwasia, 2012). In this way, a consistent and unfragmented exploitation of business knowledge when designing enterprise architectures (and vice versa) can be ensured.

Metamodels consist of structural models, which are presenting a certain reality by a shared conceptualization, consisting of concepts and their formal relations (Aßmann, Zschaler, & Wagner, 2005). *Shared* refers the notion that the metamodel should capture consensual knowledge that is accepted by a group (such as the business model for business analysts). With *formal* relations between the metamodel concepts, it is possible to conclude implications that follow from the fact that two concepts are connected with a relationship. So, the formal relationships of metamodels can help to define the implications of business model designs choices on enterprise architecture design and vice versa. The corresponding *modelling procedure* describes the step-by-step process of applying the metamodel to create results i.e. model instantiations (Kühn et al., 2003; Zivkovic & Kühn, 2007). Furthermore, metamodel integration techniques address the semantic heterogeneity of different metamodels. With semantic heterogeneity referred to the heterogeneity of shared conceptualizations. For instance, the Business Model Ontology of Osterwalder (2004) and the metamodel of enterprise architecture modelling language

ArchiMate (Lankhorst, 2017) differ in semantic heterogeneity, since the former aims to conceptualize the business logic, whereas the latter conceptualizes enterprise architectures. Various approaches are presented in literature which aim to facilitate metamodel integration in a formal manner, such as the model integration method of Zivkovic and Kühn (2007) or Kühn et al. (2003). The benefits of integrating metamodels *formally* is better support for the assembly of cross-domain specific modelling languages (Zivkovic & Kühn, 2007). In addition, since various domains have a common or shared formal modelling language (i.e. the integrated metamodel, containing model concepts of various domains, such as software application concepts and business process concepts) considerable time and cost savings, increased quality, an enhanced acceptance in model development and more effective exchange of domain specific knowledge can be achieved (Bauknecht, Tjoa, & Quirchmayr, 2003).

Concluding, to support the analysis, evaluation and visualization of the networked (addressing limitation one) business model's feasibility and viability, a multi-level analysis (addressing limitation two), lightweight (addressing limitation three) formal (addressing limitation four) business model – enterprise architecture approach, consisting of concrete metamodels and a corresponding modelling procedure, is required. For the development of such an approach, this thesis focuses on a specific application domain, the Industry 4.0 domain. The next section describes what the Industry 4.0 domain is and why it is an interesting area for studying business model implementations.

### *1.2.2 Application domain*

Most of the technological developments that increased production efficiency in the manufacturing industry were traditionally accomplished inside of the boundaries of a manufacturing organization. For example, by including additive manufacturing and robotics at the manufacturing technology level and RFID and embedded systems at the supporting information technology level (Schumacher, Erol, & Sihn, 2016). More recently, academics and practitioners envision significant efficiency gains through digital integration and intelligentization outside the traditional boundaries of an organization. Via horizontal networking, that incorporates everything from ordering to delivery, and vertical networking, from the office floor through all the layers of automation in a factory, these efficiency gains can be realized (Chung, Yam, & Chan, 2004; Kagermann et al., 2013; Schumacher et al., 2016; Wang, Wan, Li, & Zhang, 2016). Internet of Things (IoT) is a type of ICT that helps to address the requirements of horizontal and vertical networking (Kagermann et al., 2013; Schumacher et al., 2016). IoT enables the digital networking over the Internet of physical objects, human actors, intelligent machines, and production activities over different industrial domains (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Oesterreich & Teuteberg, 2016; Schumacher et al., 2016). IoT is subsumed by the visionary Industry 4.0 concept, which is an initiative of the German government to increase efficiency in the German Manufacturing Industry through the application of IoT technologies. According to a research of Bauer, Schlund, Marrenbach, and Ganschar (2014), Industry 4.0 could lead to an increase in productivity of 30% for the chemical industry, 20% for the automotive industry and 30% for the mechanical industry in Germany until 2025.

Industry 4.0 is not merely introduced by the German government to increase efficiency. It should also address the competitive market situation which the manufacturing industry is facing; customers are demanding more highly customized products and services and shorter product life cycles (Rennung, Luminosu, & Draghici, 2016a; Weyer, Schmitt, Ohmer, & Gorecky, 2015). With IoT, "Things" (such as the earlier mentioned physical objects, like products) are equipped with sensors, actuators and Internet capabilities that allows the "Things" to communicate, sense and interact with the external environment. Sensors of the IoT devices generate huge volumes of real-time data that becomes globally available through the horizontal networking via Internet capabilities (Kagermann, 2015). A result of the global availability of the real-time sensor data is the emergence of new business models which fulfil the demand of customers of highly customized products and services (Burmeiser, Luettgens, & Piller, 2015; Wang, Wan, Li, et al., 2016). IoT sensor data enables sophisticated analysis and flexible decentralized control of the industrial production environment, which subsequently allows for the creation of customized mass-produced products and value-added services (Burmeiser et al., 2015; Kagermann, 2015; Wang, Wan, Li, et al., 2016). An example of a new business model that is possible due to IoT are predictive maintenance services, which can be offered by analysing IoT sensor data to gain knowledge on how the physical condition of the product. A consequence of the networked nature of IoT is that a shift is required from traditional single-organization business models (that are realized inside of an organization), to networked business models where organizations collaboratively work together realize a business model outside of their organizational borders (Kress, Pflaum, & Löwen, 2016; Leminen, Westerlund, Rajahonka, & Siuruainen, 2012; Livari, Ahokangas, Komi, Tihinen, & Valtanen, 2016; S. Solaimani, 2014).

Despite the technological advancements such as IoT, Industry 4.0 still has to become a reality. In a study of Rose, Lukic, Milon, and Cappuzzo (2016) was found that adoption of Industry 4.0 amongst 380 surveyed US manufactures is low. In another study on Industry 4.0 of Erol et al. (2016) was discovered that manufacturing organizations have problems grasping the overall idea of Industry 4.0, relating Industry 4.0 to their business operations and defining plans and projects to transform their business according to Industry 4.0. They are unsure how the new technologies will impact their business model and business operations and what the possibilities are that the new IoT technologies could offer them (CGI, 2016; Erol et al., 2016; Schumacher et al., 2016). Industry 4.0 literature mainly has a technology perspective, while the business perspective is underdeveloped, which makes it more difficult to get the required insights to commercialize Industry 4.0. (Glas & Kleemann, 2016). S. Solaimani (2014) argues that to realize large-scale commercialization of an innovation, not only technological aspects need to be considered. Therefore, a focus on business model implementation aspects, by taking into account strategies, business model related aspects as well as organizational, financial and operational issues, such as business processes, is consequently necessary. S. Solaimani, Bouwman, and Itälä (2013b) argues that having an operationally feasible and viable business model is a perquisite for large-scale commercialization of an innovation.

Concluding, the industry 4.0 domain is an interesting area to explore how the gap between business models and business model implementation can be addressed since (1) Industry 4.0 has a networked perspective and (2) there is a lack of a business model implementation perspective in current Industry 4.0 literature.

### *1.2.3 Problem statement*

Based on the introduction and the problem exploration sections it can be concluded that on the one hand, business model literature generally does not address how a business model can be technologically implemented though a formal business model implementation design. Due to this limited scope, it is difficult to define how the business model operational feasibility and viability could be ensured, especially in environments where networked enterprises are collaboratively realizing a business model. In addition, due to the informal representation, business models remain even further isolated of the remaining business model implementation design, which is often represented in formal modelling languages. On the other hand, enterprise architecture often lacks a more abstract and economical business model perspective. Therefore, the business model related aspects (with questions such as: "who benefits from the product?") are not considered in the design are not considered in the architecture design and the fit with the business cannot be evaluated effectively.

Aligning business models with enterprise architectures could help to obtain insights in aspects of the business model implementation and to include a business model perspective in enterprise architectures. However, current approaches that align business models with enterprise architectures are often intra-organizational, facilitate merely a single-level of analysis, are heavyweight by converting business model concepts to many detailed enterprise architecture concepts or use an informal approach by lacking concrete formal metamodels and modelling procedures. A result of these limitations is that complex network interactions are not perceived due to the intra-organizational perspective, the business model implementation cannot be described, analysed and visualized in a comprehensive manner due to the single-level of analysis and the business model implementation design process becomes rather complex and thus time consuming, due to detailed conversion of business model concepts to the enterprise architecture concepts. Furthermore, the informal approach leads to different interpretations by the various stakeholders and difficulty in consistently exploiting the knowledge stored in business models while designing enterprise architectures using the business model-driven approach. Together, these limitations hinder the analysis of the feasibility and viability of the networked business model.

Therefore, the following main research problem for this study can be defined as follows: *lightweight formal metamodels and modelling procedures that can support networked enterprises with a multi-level analysis, description and visualization of their business model implementation through enterprise architecture concepts are currently lacking in academic literature.*

#### *1.2.4 Knowledge gaps*

Based on the problem exploration section, the application domain section and the problem statement the following knowledge gaps can be defined:

1. Current literature on the Industry 4.0 domain lacks a focus on business model implementation.
2. Current literature on business models has mainly proposed informal business model representations and lacks a focus on formal business model implementation design.
3. Current literature on enterprise architecture literature often lacks an economical business model perspective.
4. Current literature on business model – enterprise architecture alignment lacks a lightweight formal approach which can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

#### *1.2.5 Research objective*

Based on the problem statement and the knowledge gaps, this study aims to develop an artefact which should comply with the following requirements:

1. The artefact should include a formal representation of a business model with a focus on formal business model implementation design.
2. The artefact should extend enterprise architecture with an economic business model perspective.
3. The artefact should include a formal lightweight business model – enterprise architecture alignment approach that can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

Following these requirements, the main research objective of the master thesis is defined as follows:

*The objective of this research is to develop lightweight formal metamodels and a corresponding modelling procedure in UML that can support networked enterprises with a multi-level description, analysis and visualization of their technological business model implementation through enterprise architecture concepts.*

The metamodels and modelling procedure will be represented in UML since this is a widely accepted formal ICT modelling language. After the metamodels and modelling procedure have been developed, they will be applied to the Industry 4.0 domain. The Industry 4.0 domain is merely the application domain of this study. Please note that other domains with networked characteristics can be studied as well with this approach. This application will demonstrate how the metamodels and modelling procedure can be used in practice. Furthermore, it will give insights into business model implementation aspects for the Industry 4.0 domain.

### 1.3 Research questions

To structure the thesis report of this research, the following main research is defined:
*What are the design specifications of lightweight metamodels and a corresponding modelling procedure that facilitate a multi-level description, analysis and visualization of the technological implementation of a networked business model through enterprise architecture concepts?*

Sub-questions will be used to structure the thesis report and to answer the main research question.

1. What are the defining technological and business characteristics of the Industry 4.0 domain and what are the challenges in the industry 4.0 domain?
2. What are the basic concepts of metamodels, business models, enterprise architectures and business model – enterprise alignment approaches and what are the limitations of current approaches?
3. A. What are the initial design requirements and design specifications of the metamodels and modelling procedure, incorporating both business model and enterprise architecture concepts?
   B. How do researchers evaluate these initial design requirements and design specifications?
4. A. What is the result of an application of the metamodels and the modelling procedure to the Industry 4.0 domain?
   B. How do practitioners evaluate the refined design requirements and design specifications?

## 1.4 Contribution

The kind of research problem and research objective can be defined as a practice-oriented study. Since the objective of this research is to develop metamodels and modelling procedure, it can also be classified as design-oriented research (Verschuren & Doorewaard, 2010). According to Johannesson and Perjons (2014), design-oriented research needs to deliver artefacts, which could be in the form of a construct, model, method and instantiation. The artefact for this particular study could be classified as a combination of a model (i.e. the metamodel) and a method (i.e. the modelling procedure which uses the metamodel). According to Johannesson and Perjons (2014), the development of the artefact should be desired due to problems experienced in practice. Instead of being merely relevant for single actor, the design has to be generalizable and contributing to the knowledge for global practice. In their Action Design Research approach Sein et al. (2011) confirm this, by stating that the to be developed artefact and design should be practice-inspired, while the artefact itself should be theory ingrained. Therefore, this research has both scientific and practical relevance. The scientific relevance and practical relevance will both be described in the following sections.

### *1.4.1 Scientific relevance*

This study has several scientific contributions. First of all, this study contributes to business model literature by developing a formal representation in UML of a networked business model. Currently, most business model literature proposes informal business model representations (Zott et al., 2011). The Business Model Ontology (Osterwalder, 2004) and the e3 value model (J. Gordijn et al., 2000) are two of the few (semi-)formal business model representations. The formal representation can make the relation between the business model and the enterprise (IT) architecture clearer, so alignment issues between a business model and enterprise architecture can be studied in a more consistent manner. Furthermore, it becomes easier to understand and visualize the relations between the various business model concepts, which in turn should improve communication of the business idea. A second contribution to business model literature can be found in the inclusion of an information, business process and enterprise architecture perspective. Most literature on business model(ling) mainly focuses on value related aspects, such as the e3 value model of J. Gordijn et al. (2000) or the value network analysis of Allee (2008), while the information, business process and enterprise architecture perspective is neglected. The inclusion of these perspective should make studying business model implementations more comprehensive and holistic for researchers in the field of business models and enterprise architectures. A third contribution to business model literature is the development of a formal approach for business model implementation, where current business model literature lacks a focus on formal business model implementation design.

Second, this study adds to literature on enterprise architecture by proposing formal metamodels consisting of enterprise architecture concepts and business model concepts. This should add a more abstract and business model oriented perspective to existing enterprise architecture approaches. As such, researchers in the field of enterprise architecture could evaluate the business fit of enterprise architecture more precisely.

Third, this study adds to literature on business model and enterprise architecture alignment since, first, it is one of the first studies to integrate business model concepts and enterprise architecture concepts through a set of formal target metamodels (i.e. integrated metamodels). Current literature mainly relates business model and enterprise architecture concepts in an informal conceptual manner, such as the approach of Rahmati (2013), and neglects to establish these relations via formal metamodels and metamodel integration techniques. The study of de Kinderen, Gaaloul, and Proper (2014) is the only study in the field of business model – enterprise architecture alignment that has applied formal metamodel integration techniques yet. Similar to the benefits of a formal representation of the business model, a formal integration of business model concepts with enterprise architecture can support studies on alignment issues that hinder the feasibility and viability of the business model in a more consistent, holistic and unfragmented manner through the well-defined relationships between the business model and enterprise architecture concepts. Another contribution to literature on business model and enterprise architecture is the development of a lightweight formal intermediate metamodel to bridge the gap between business model design and enterprise architecture design. As stated in the problem exploration section, current approaches often convert the more abstract business model concepts directly to many detailed functional enterprise architecture concepts, while a lightweight intermediate metamodel is missing. This lightweight intermediate metamodel can be used by researchers to study issues that arise with when networked enterprises aim to realize a networked business model, by focusing on the essential concepts that play a role in business model and enterprise architecture alignment without diving into various side issues and non-relevant details. In addition, literature on business model and enterprise architecture alignment often has a single-organization perspective, so this study also adds to the scarce amount of scientific literature on *networked* business model and enterprise architecture alignment/integration.

Fourth, the amount of literature on business model implementation in the Industry 4.0 domain is almost non-existent (while there exist for example studies on business model implementation for eHealth (S. Solaimani, Bouwman, & Itälä, 2013a), this is non-existent for the Industry 4.0 domain), by addressing business model implementation related aspects such as organizational, financial and operating related issues.

### *1.4.2 Practical relevance*

This study also has several practical contributions. First of all, the lightweight formal representation of business model concepts and the formal integration of business model concepts with enterprise architecture concepts aims to improve communication between business oriented stakeholders, such as CxO's and IT oriented stakeholders. One the one hand, by representing or visualizing business model related concepts in UML, IT oriented stakeholders can retract business knowledge from the business model while design the enterprise (IT) infrastructure more effectively. On the other hand, business oriented stakeholders can communicate business model design (changes) to IT oriented stakeholders more effectively. The result of the formal integration of business model concepts with enterprise architecture concepts results in a cross-domain modelling language (Zivkovic & Kühn, 2007), which aims to create an holistic view on the business model, business process and ICT design and could act a common grounding between the business and IT oriented stakeholders. Consequently, the number of misinterpretations should be reduced which improves the decision-making processes and the planning of the business model' realization. Eventually, this results in a more consistent and unfragmented business model, business process and ICT design.

Second, the development of a lightweight intermediate metamodel (between on the one hand the more abstract and economically oriented business model and on the other hand the more detailed and functionally oriented enterprise architecture) should make the description, analysis and visualization of the business model implementation less time consuming and easier to understand for business oriented stakeholders. By keeping the metamodels and modelling procedure *lightweight*, business oriented stakeholders can still understand them, since business oriented stakeholders often do not understand very formal *heavyweight* models well (J. Gordijn, 2003). Also, lightweight approaches are often used in the realm of very formal heavyweight approaches, so in later stages of the design process, these could be further formalized by IT oriented stakeholders (J. Gordijn, 2003). Also, by including information and process related aspects in the approach, networked enterprises should be able to analyse and subsequently optimize the business model implementation in a more comprehensive and harmonized manner, instead of merely analysing and optimizing value, information or process related aspects of the business model implementation.

Third, as stated before, inter-organizational business processes are often fragmented, the division of responsibility over different components of the value proposition is unclear and the ICT landscape is often fragmented. By taking a *networked* perspective, insights into inter-organizational business processes and interactions on the level of values, information and processes can be obtained. These insights can subsequently be used by practitioners to determine where issues occur when the various processes and ICT resources interact with each other.

Lastly, the application of the metamodels and modelling procedure to the Industry 4.0 domain could give manufacturing organizations insights into business model implementation related aspects. The applied metamodels and modelling procedure could help them to realize for example what partners are of importance to realize the networked business model, what technologies are of importance and what business processes of various actors need to be connected to each other to ensure the feasibility and viability of the networked Industry 4.0 business model.

## 1.5 Research strategy

According to Johannesson and Perjons (2014), a research strategy offers high-level guidance, while a research method can be seen as a technique or tool for performing a specific task. There exist various research strategies which could be used for this research. For this research, the design process of Verschuren and Hartog (2005) and two design cycles of the Action Design Research methodology from Sein et al. (2011) are used (see figure 3)). The designing cycle of Verschuren and Hartog (2005) consists of six separate phases. The designing cycle starts with the first hunch, where the goal which the artefact should realize will be defined. This is driven by a first 'hunch' and 'initiative' for constructing a new material or immaterial artefact. In the second stage, design requirements will be defined which will should be fulfilled within the frame of the design goal. These requirements could be either functional requirements (i.e. functions which the artefact should fulfil or enable once it is realized), or non-functional requirements, such as user requirements (i.e. the requirements of the designed artefact according to the requirements and desires of the future user or contextual requirements (i.e. political, economic, juridical and/or social prerequisites or constraints)). In the third step, more specifically the specification step, the structural specification of the artefact will be defined. The structure of the artefact is derived from the previously determined design requirements. In the fourth step, more specifically the prototype step, the structural specification is being transferred into a prototype that comprises the complete design and can be used for empirical evaluations. In the fifth step, more specifically the implementation step, the prototype is transferred into a real-life context. In the last step, the artefact is evaluated.

Even though the stages of the designing cycle are presented as a linear process, they are part of an iterative process. This implies that the designer continuously moves back and forth between the several design steps. Regularly, a number of iterations both within one stage and across stages is necessary to obtain a final or definitive design or artefact that is well balanced and comes up to all our expectations. The designing cycle of Verschuren and Hartog (2005) describes *what* the different steps of the design process are to build the artefact. *How* this iterative process could be organized is part of the Action Design Research (ADR) of Sein et al. (2011). An advantage of using the ADR approach is that the design requirements and the specified artefact are continuously evaluated and refined in the iterative process, with extensive interaction with researchers as well as practitioners (or end-users). ADR consists of four different phases. The first stage covers the *problem formulation*, while the second stage is about the *Building, Intervention and Evaluation* (BIE) of the artefact. The third stage, the *reflection and learning* stage is continuously executed during the problem formulation and BIE stage, to refine the artefact. The last stage consists of reflections and outcomes in *formalization of learning* stage. For this research, the ADR will structure how the research is conducted, whereas the *designing cycle* of Verschuren and Hartog (2005) will be used in the BIE cycles of ADR to iteratively design, evaluate and refine the metamodels and modelling procedure, based on several discussions with researchers and practitioners.

ADR differentiates between IT-Dominant BIE design cycles and Organization-Dominant design cycles. Since this thesis aims to design formal metamodels and modelling procedure which defines the *technological* implementation of a business model, the IT-Dominant BIE cycle seems most suitable for this research. The IT-Dominant BIE cycle starts with an initial specification of the artefact and set of design requirements which is discussed and evaluated with researchers in the first BIE design cycle. This will lead to a set of refined design requirements and a refined design specification of the artefact. After that, the refined design requirements and design specification are discussed and evaluated with practitioners. According to the ADR method, in later stages, the artefact is refined several other times based in further discussions with practitioners, researchers and end-users. In these later stages, the designer takes the artefact into a wider organizational context, which allows for a comprehensive intervention that involves evaluating the artefact in a use setting. This process of different design stages with researchers, practitioners and end-users will be repeated until the specification of the artefact is as 'accurate' as desired. For this research, only the first two design cycles will be executed (i.e. the researcher and practitioners design cycles) due to limited time constraints. This research merely aims to provide a first attempt to the design such metamodels and a modelling procedure. The setting of the scope also implies that the artefact is also not applied in a real use (e.g. case study) context due to time constraints, but rather applied on a high level to the Industry 4.0 domain in the practitioner design cycle. The relation between the *designing cycle* (Verschuren & Hartog, 2005) and the ADR stages (Sein et al., 2011) is visualized in figure 1.2.

In the two BIE cycles, the *design requirements*, *design specification* and *design evaluation* steps of the designing cycle of Verschuren and Hartog (2005) will be used. Note that the *prototype design* step of the design cycle of Verschuren and Hartog (2005) is incorporated in the *design specification* step due to scope and time constraints. An initial set of design requirements with an initial specified artefact (both derived from the problem statement, design goal (or research objective) and through theoretical analysis on literature on business models and networked business model-enterprise architecture alignment (Johannesson & Perjons, 2014)) will be discussed with and evaluated by researchers. A completed BIE stage with the researchers will lead to a refined set of design requirements and a refined design specification. The refined metamodels and modelling procedure will subsequently be applied (i.e. implemented) to the Industry 4.0 domain. The refined design requirements, refined design specification and the implementation of the metamodels and modelling procedure will be input for the next BIE cycle, which will be conducted with practitioners. This stage will result in a refinement of the implementation of the artefact, as well as a further refinement of the metamodels and the modelling procedure. Please note that the implementation step of Verschuren and Hartog (2005) only is executed in the second design cycle with the practitioners. This is due the fact that 1) this research has a limited amount of available time and 2) the researchers are merely used in this research for their theoretical knowledge on business models and enterprise architecture (so not for their knowledge on the Industry 4.0 domain), while the practitioners are used for their practical perspective as well as their knowledge on Industry 4.0. Finally, the outcomes of both BIE design cycles will be formalized in the last ADR stage, the *formalization of learning* stage. This will include a final set of refined design requirements, refined design specification and adherence to the ADR design principles (which will be discussed later). Sein et al. (2011) proposed the design phase called *Reflection and Learning*. It is argued that this phase is incorporated into the entire design process, in which the results are evaluated sequentially and consequently. Therefore, no separate reflection and learning stage is included in the research strategy.

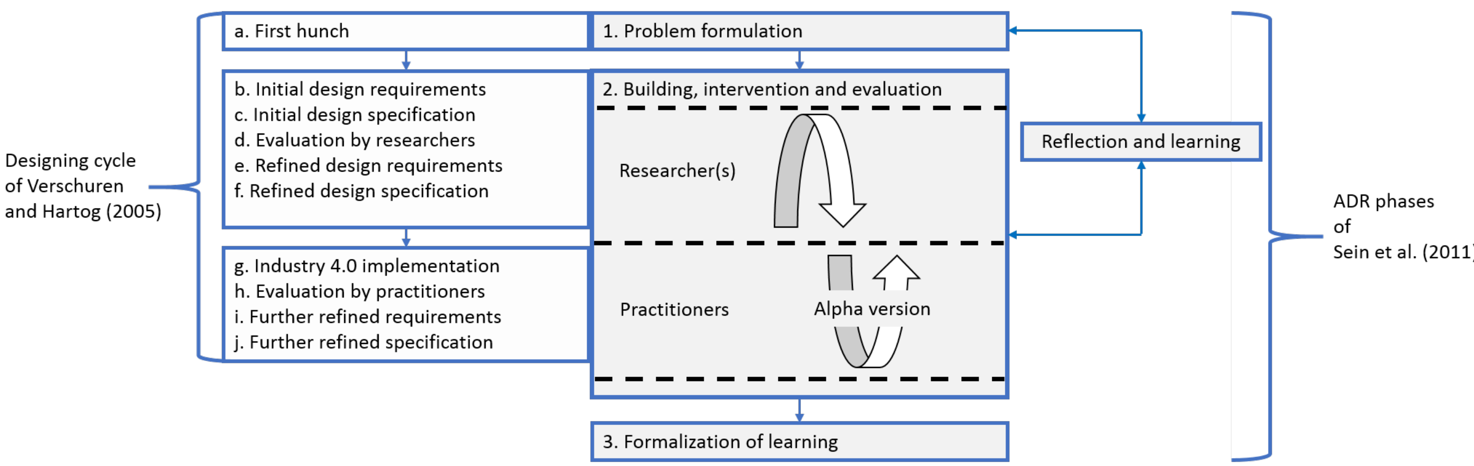



Figure 1.2 The research approach of this research with the relation between the designing cycle of Verschuren and Hartog (2005) and the ADR approach with the IT-Dominant BIE of Sein, Henfridsson, Purao, Rossi, and Lindgren (2011) (Adapted from (Sein et al., 2011) and (Verschuren & Hartog, 2005)).

Sein et al. (2011) has formulated seven design principles which should be adhered during the design process. For the *problem formulation* stage, two design principles are formulated. The first principle emphasizes viewing problems as knowledge creation opportunities. As a result, the research is problem inspired. Principle two emphasizes that the artefact should be embedded in theory. For the *BIE* stage, three design principles are formulated by Sein et al. (2011). The third principles, reciprocal shaping, emphasizes that the artefact should be influenced mutually by the IT artefact and the organizational context. The fourth principle emphasizes refers to mutually influential roles, meaning that every project participant (researchers and practitioners) should learn from each other. The fifth principles emphasize that evaluation should be interwoven with the design process. For the *reflection and learning* stage, the design principle emphasizes three types of reflections (1) intervention results (2) the learning from the terms of theories selected and (2) the evaluation of adherence to design principles. Lastly, in the *formalization of learning* stage, the seventh design principle emphasizes that the learning should be abstracted to a class of field of problems.

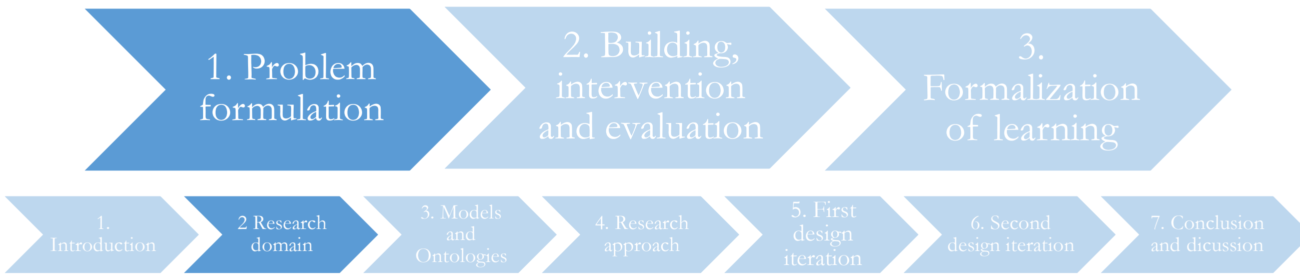
## 1.6 Thesis outline

In table 1.1, the outline of this thesis is displayed which is based on the research approach as displayed in figure 1.2.

Table 1.1 Outline of the thesis

| **ADR Research phase of (Sein et al., 2011)** | **Design iteration** | **Design step of designing cycle of (Verschuren & Hartog, 2005)** | **Chapter** | **Research question** | **Deliverable** |
|---|---|---|---|---|---|
| **1. Problem formulation** | - | a. First hunch | 1. Introduction | - | -Problem statement<br>-Knowledge gaps<br>-Research objective<br>-Research questions |
| | | | 2. Application domain | Sub research question 1 | -Technological and business characteristics Industry 4.0 domain<br>-Challenges Industry 4.0 domain |
| | | | 3. Models and Ontologies | Sub research question 2 | -Background on metamodels, business models, enterprise architecture models and business model – enterprise architecture approaches<br>-Selected models which form the theoretical foundations for the elicitation of design requirements.<br>-Limitations business models, enterprise architecture and business model – enterprise architecture approaches |
| | | - | 4. Research approach | - | - |
| **2. Build, intervention and evaluation** | Design iteration 1 with researchers | b. Design requirements | 5. First design iteration | Sub research question 3 | -Initial design requirements based on literature |
| | | c. Design specification | | | -Initial design specification |
| | | d. Evaluation | | | -Evaluation on initial design requirements and design specification with researchers |
| | | e. Design requirements | | | -Refined design requirements based on evaluation with researchers. |
| | | f. Design specification | | | -Refined design specification based on evaluation with researchers. |
| | Design iteration 2 with practitioners | g. Implementation | 6. Second design iteration | Sub research question 4 | -Implementation of artefact in the Industry 4.0 domain |
| | | h. Evaluation | | Sub research question 5 | -Evaluation on refined design requirements and design specifications by practitioners |
| | | i. Design requirements | | | -Further refined design requirements based on evaluation with practitioners. |
| | | j. Design specification | | | -Further refined design specification based on evaluation with practitioners. |
| **3. Formalization of learning** | - | - | 7. Conclusion and discussion | - | -Adherence to ADR design principles<br>-Minimum viable artefact |

# Chapter 2 Application domain




In this chapter, an answer is given to research question one: *What are the defining technological and business characteristics of the Industry 4.0 domain and what are the challenges in the industry 4.0 domain?* The main objective of this research question is twofold: (1) to get a basic understanding of the business and technological characteristics of the domain, which subsequently will be used to, first, find business model, enterprise architecture and business model – enterprise architecture approaches that suit the domain and, second, in the application of the artefacts to the domain. (2) To explore domain specific challenges that need further research.

This chapter is structured as follows: first, the approach of the literature review will be explained. Second, the term Industry 4.0 will be defined. Third, technological developments that enable the Industry 4.0 are described. Fourth, non-technological business-related characteristics of the domain will be described that go beyond the enabling technologies. Fifth, challenges that hinder a large-scale realization of Industry 4.0 will be explored will be defined as knowledge gaps. Finally, this section concludes by answering the research question.

## 2.1 Approach to literature review

A literature review will be used to analyse the business and technological characteristics, as well as the challenges of the Industry 4.0 domain. A literature review aims to draw a distinction on what already has been done, and what needs to be done (Hart, 1998). S. Solaimani (2014) argues that in order to move away from exploration towards an exploitation of an innovation, research needs to be based on a coherent body of knowledge that covers technological, organizational, economic and business (entrepreneurial) issues, both from a strategic and an operational level. In line with the argument of S. Solaimani (2014), the literature review on the application domain of this study aims to provide an overview of technological as well as business related aspects of the Industry 4.0 domain. These business and technological related aspects could subsequently be used as context for the development of the artefacts, as well as for the application of the metamodel and modelling procedure to the Industry 4.0 domain. Next to this, this literature review aims to provide a brief overview of the studied areas that are frequently investigated, as well as issues that challenge a realization of the Industry 4.0 innovation and thus needs further attention from researchers. To come up with a technological as well as a business-related perspective, the following keywords were used: *Industry 4.0, Internet of Things, Cyber-Physical Systems, Business models, ecosystem* and *value*. These keywords include both a technological perspective (such as the keyword *Internet of Things*), as well as a business perspective (such as the keyword *value*).

In order to enhance the reliability and representativeness of the literature, a series of most appreciated databases by the TU Delft was used (see Table 2.1). To come up with a set of relevant articles, a selection criterion is established, which is specifically: the article should include some business as well as a technological description of the Industry 4.0 domain. Abstracts and titles were checked on compliance with this selection criterion. Articles that were solely focused on Industry 4.0 technologies were not included, since the scope of the first research question is to describe Industry 4.0 from a technological as well as a business perspective. Furthermore, only the 50 first search results were checked of databases that had a high number of results. After the first initial selection based on the titles and abstracts was retrieved, the text of articles was scanned. This resulted in a final set of 50 articles. The reference list of the papers was used to find additional studies relevant to this thesis (i.e. articles which elaborated on business and technological aspects of the Industry 4.0 domain).

Table 2.1 Used academic databases and search results.

| Science database | Number of articles found | Number of useful articles |
|---|---|---|
| **Science Direct** | 217 | 12 |
| **Scopus** | 33 | 5 |
| **IEEE Xplore Digital Library** | 3360 | 5 |
| **Google Scholar** | 1760 | 28 |

## 2.2 How can the concept "Industry 4.0" be defined?

Industry 4.0 is a term that is popularized in Germany and is used to label the fourth industrial revolution (Burmeiser et al., 2015). Technology leaps have caused several paradigms shifts in the industry, which has led to three preceding industrial revolutions. The first industrial revolution was in the field of mechanization, the second industrial revolution was in the field of electrification and the third industrial was in the field of computerisation, while the fourth is in the field of digitalization and the internet (Lasi et al., 2014; Wan & Keliang Zhou, 2015). The term Industry 4.0 was first introduced by the Industrie (German translation of the term "Industry") 4.0 working group in 2011 and is one of the key initiatives of the German government high-tech strategy of 2020 (Hermann, Pentek, & Otto, 2016). In the final report of the working group, *Recommendations for implementing the strategic initiative INDUSTRIE 4.0,* is stated that the fourth revolution is triggered by: *"the introduction of the Internet of Things and Services into the manufacturing environment"* (Kagermann, Wahlster et al., 2013, p.5). The German government initiated Industry 4.0 due to changing market conditions. In the past, industrial production started with the transformation from craft production to mass production. (Brettel, Friederichsen, Keller, & Rosenberg, 2014). A saturated market for mass production forced manufacturing companies towards product differentiation and shorter product life cycles. In addition, a relocation of production towards low wage countries affected the mass production of standardized products too, since this requires high-wage countries to focus on resolving the tension between economies of scale and scope. With Industry 4.0, the German government aims to address these aforementioned challenges; Bauer, Schlund et al. (2014) state that Industry 4.0 could lead to an increase in productivity of 30% for the chemical industry, 20% for the automotive industry and 30% for the mechanical industry in Germany until 2025. Some authors state that Industry 4.0 can be considered a real revolution, while others doubt if it might be an imposed hype (Drath & Horch, 2014). Despite these doubts, most authors believe that Industry 4.0 will fundamentally change supply chains, business models and business operations (such as (Bauer, Hämmerle, Schlund, & Vocke, 2015; Brettel et al., 2014; Burmeiser et al., 2015; Lier, 2014; Schmidt et al., 2015)).

Table 2.2 Definition of Industry 4.0 found in literature

| Author | Definition |
|---|---|
| **(Platform I4.0, 2015)** | Industry 4.0 is a reform and re-organization of value chains to a networked coordination in the era of the 4th industrial revolution. More precise, Industry 4.0 uses real-time individual customer requests and environment balances ("Big Data") from all participant institutions of the value chain to holistically integrate the production process. |
| **(Bauer et al., 2015)** | Industry 4.0 promotes computerization and networking of industrial business processes – particularly those in the manufacturing arena. |
| **(Sendler, 2013)** | Industry 4.0 is the linking of products and services with one another and with their respective environment through the internet and other network services that enables the development of new products of services so that many functions of products work autonomously – without human intervention. |
| **(Feldmann, 2015)** | Industry 4.0 realizes an optimized collaborative value (smarter services and processes) by a smart cooperation of new and enhanced competences and capabilities in a supply network on basis of new technologies, in particular information and communication technologies. |
| **(Schmidt et al., 2015)** | Industry 4.0 shall be defined as the embedding of smart products into digital and physical processes. Digital and physical processes interact with each other and cross geographical and organizational borders. |
| **(Brettel et al., 2014)** | The upcoming industrial revolution will be triggered by the Internet, which allows communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks. |

There is no popular and widely-used definition of the term Industry 4.0 in literature yet (see table 2.2 for all the different definitions). However, Table 2.2 does show that there are some important concepts that are used in all definitions. These include, for example, the Internet, Big data, Cyber-Physical Systems (CPS), digital/physical processes, networking and cooperation. This shows that Industry 4.0 is not merely a technological transformation, but also affects the way manufacturing organizations conduct business. For this thesis will be mainly referred to Industry 4.0 with a combination of the definition of the Industrie 4.0 working group (since this working was the first to introduce the term and the technological and non-technological aspects of Industry 4.0 are included in the definition) combined with concepts found other studies. For this thesis, Industry 4.0 will be defined as:

*A reform and re-organization of value chains to a networked coordination in the era of the 4th industrial revolution enabled by the Internet. More precisely, Industry 4.0 uses real-time individual customer requests and environment balances from all participants of the value chain to holistically integrate the production process towards realization of collaborative value.*

## 2.3 Technology developments that enable the Industry 4.0

### *2.3.1 Internet of Things and Cyber-Physical Systems*

Because technology is generally considered to be the trigger or enabler for an industrial revolution, in this section key technologies that enable the fourth revolution will be discussed. To describe each of these technologies, Figure 2.1 will be used as guidance. Technological developments that enable the Industry 4.0 all have in common that they facilitate the networking of physical objects, human actors, intelligent machines, and production activities (Lasi et al., 2014; Oesterreich & Teuteberg, 2016; Schumacher et al., 2016). Internet of Things (IoT) and Cyber-Physical Systems (CPS) are two of the most cited technological developments in literature and are the main facilitators for the networking of the aforementioned concepts (Schumacher et al., 2016). According to Xu, He, and Li (2014), a widely accepted definition of IoT is: *"a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network"* (Xu, He et al., 2014, p.2233). The market of IoT is growing rapidly; according to research of Gartner (2014), 6.4 billion things will be connected in 2016, and in 2020 20.8 billion things will be connected. Xu et al. (2014) state that the integration of sensors, big data analytics, actuators, and Internet communication technologies serve as the foundation of IoT. The authors state that these technologies allow for a wide variety of objects and devices to communicate and cooperate with one another over the cloud networks. The main concepts of IoT include (1) data sensing through IoT sensors (2) analysis of the sensor data through big data analytics (3) actuation by using the actuators, and (4) data sharing by using the (cloud) Internet communication technologies (Ghanbari et al., 2017). IoT enables physical objects to become active participants in business processes, where they can communicate about their status, surrounding environment, production processes and maintenance schedules. This allows to flexible control of the industrial production environment (Kagermann 2015). In the context of Industry 4.0, the "things" in IoT consists of CPS, which are described by Bagheri, Yang, Kao, and Lee (2015) as *"the systems in which natural and human-made systems (physical space) are tightly integrated with computation, communication and control systems (cyber space*)" (Bagheri, Yang et al. 2015, p. 1622). A CPS can *"independently exchange*

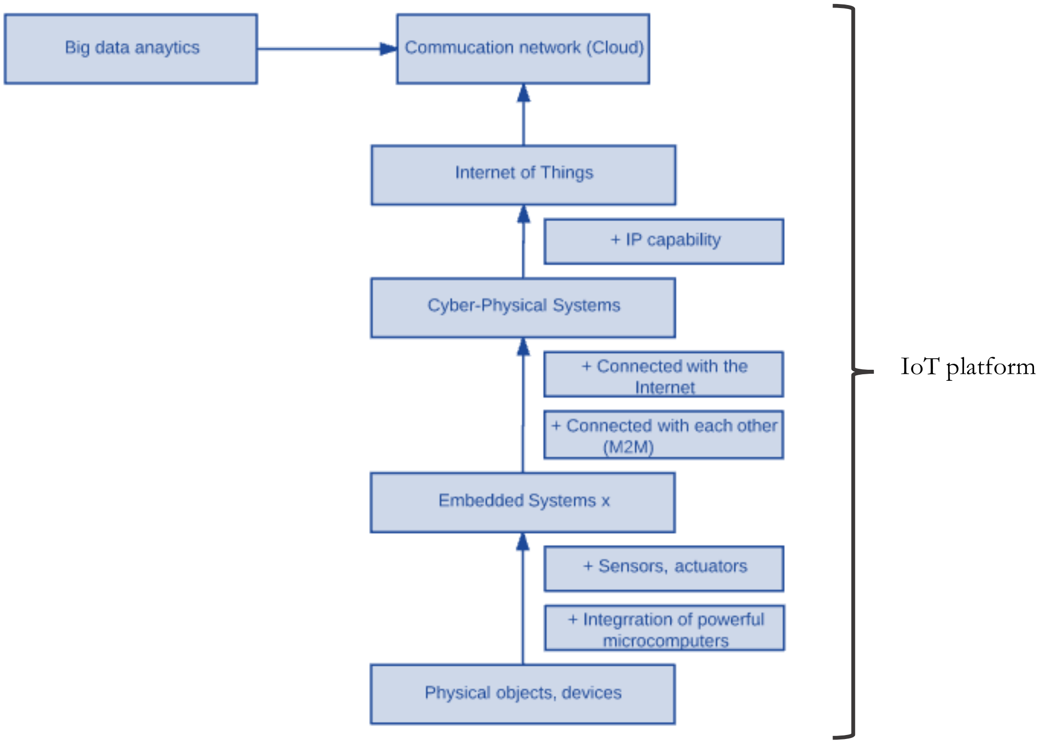



Figure 2.1 Converging technological developments (adapted from (Glas & Kleemann, 2016; Kagermann, 2015))

*information, trigger actions and manage their own performance"* (ICA, 2015). Acatech (2011) defines CPS as systems that:

- directly record physical data using sensors and affect physical processes using actuators;
- evaluate and save recorded data, and actively or reactively interact both with the physical and digital world;
- are connected with one another in global networks via digital communication facilities;
- use globally available data and services (Acatech, 2011).

A simple scenario for the development of a CPS application is given in the article of Jazdi (2014). The author describes an industrial coffee machine which was extended to a CPS by connecting it to other industrial coffee machines over the cloud. A web portal and Android app were created for the operation of the CPS. The web portal and app make it possible for the user to exchange data with the industrial coffee machine. By transforming the industrial coffee machine into a CPS, it is possible to remotely determine which component is defective or which ingredient has been used up. Also, products can be customized remotely; the temperature and the strength of the coffee can be automatically customized to the needs and preferences of the coffee drinker.

Next, CPS are in turn embedded systems that are equipped with network components (see Figure 2.1) (Kagermann, 2015). Embedded systems are physical objects with sensors, actuators and intelligent microcontrollers. Embedded systems have been around for a long time, however, embedded systems that are connected to each other, leading to CPS Machine to

Machine communication is a new phenomenon (ICA, 2015). The combination of physical objects, sensors, actuators and cloud networks is generally defined as Internet-of-Things platforms (Kagermann et al., 2013; Turber, vom Brocke, Gassmann, & Fleisch, 2014). IoT platforms will be discussed in the following sections in more detail.

There is some discrepancy between the use of terms of IoT and CPS in literature. Some authors only mention CPS a key enabler for the Industry 4.0, while others mention IoT as key enabler (such as (Shrouf, Ordieres, & Miragliotta, 2014). Jazdi (2014) states that CPS which are connected to the Internet can be defined as IoT. However, as can be seen in figure 2.1, Kagermann (2015) states that an embedded system which is connected to the Internet becomes a CPS. The difference might be found in the statement of Glas and Kleemann (2016), who state that unlike CPS, IoT allows for the interconnection of *heterogeneous* devices from various manufacturers with diverse functionalities. This can be realized due to the IP capabilities of these devices (Kagermann, 2015). This is consistent with the description of Xu et al. (2014), who state that IoT enables a *wide variety* of devices and objects to be connected. Jesse (2016) describes that IoT is much more inclusive than simple Machine to Machine communication of CPS; *everything is connected to everything else* (Jesse, 2016, p. 275). Hence, it is assumed that CPS mainly consists mainly Machine to Machines communication of over the Internet, while IoT takes this a step further and concerns the communication of a wide variety of heterogeneous devices and objects with different functionalities. For this thesis, with Industry 4.0 technologies will be mainly referred to IoT since IoT covers all of the characteristics of the "underlying" embedded systems and CPS.

#### *2.3.2 Sub-conclusion section 2.3*

To conclude, IoT allows the connection of physical objects (such as products), human actors, intelligent machines, and production activities due to their IP capabilities. These "things" can sense their environment through sensors, communicate with each other over the internet (e.g. a cloud network), change their physical environment via actuators, and use big data analytics capabilities to do this all in an autonomous and self-organizing manner.

## 2.4 Beyond the enabling technologies

### *2.4.1 Horizontal and vertical networking*

The technologies described in the previous section are the technologies that define the technological capabilities for Industry 4.0. Until recently, innovation in the manufacturing industry was mainly driven by increasing efficiency in the isolated manufacturing business processes. Technological capabilities used within organizational boundaries, like additive manufacturing, RFID tags and embedded systems, have led to significant improvements in process efficiency and product quality. IoT facilitates digital networking of virtual and physical objects, human actors, intelligent machines, production lines and processes inside and *outside* the boundaries of manufacturing organizations (Schumacher et al., 2016). As a result, efficiency gains can also be realized outside of the organizational boundaries. This can be best explained with the value creation process of IoT, which is displayed in figure 2.2. The inner loop refers to physical objects equipped with sensors and actuators which are used to improve their "own" efficiency. In this loop, data is sensed and analysed locally to generate a certain action to realize efficiency. The outer loop corresponds to the *connected* device information loop, which allows the IoT device to exchange data outside of the traditional organizational boundaries (Ghanbari et al., 2017). Academics and practitioners envision significant efficiency gains through this exchange of data outside of the organizational boundaries. This is realized through digital integration and intelligentization via horizontal (with value networks that incorporate everything from ordering to delivery, see figure 2.3) and vertical networking (through all layers of automation in a factory) (Chung et al., 2004; Kagermann et al., 2013; Schumacher et al., 2016; Wang, Wan, Li, et al., 2016). With vertical and horizontal networking enabled by IoT, the traditional value chain changes into a value network (Ghanbari et al., 2017). A value network is defined by Allee (2008) as "*a web of relationships that generates economic value and other benefits through complex dynamic exchanges between two or more individuals,*

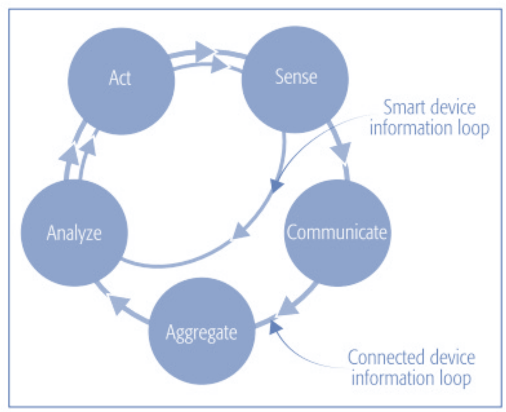



Figure 2.2 Value creation with IoT (retrieved from (Ghanbari, Laya, Alonso-Zarate, & Markendahl, 2017))

*groups or organizations. Any organization or group of organizations engaged in both tangible and intangible exchanges can be viewed as a value network, whether private industry, government or public sector*" (Allee, 20098, p.3). In a value network, the relation between organizations include flows of tangible assets (e.g. products, services and profit) and intangible assets (e.g. knowledge or data) (Allee, 2008; El Sawy & Pereira, 2013). Business ecosystems have a broader scope then value networks and look even further beyond the traditional value chains. A business ecosystem is a group of interconnected and interdependent organizations that cooperate and compete with each other in a dynamic manner that changes over time (Moore, 1996; Peltoniemi & Vuori, 2004). Digital business ecosystems are ecosystems that evolve around a certain digital technology such as IoT (El Sawy & Pereira, 2013) Wang, Wan, Li, et al. (2016) states for a successful implementation of Industry 4.0 one organization should both compete and cooperate with many other organizations in the digital business ecosystem. The authors require that data (such as the sensor data of the IoT devices that needs to be available to each organization (El Kadiri et al., 2016)), information, finance and material should fluently flow between the organizations.

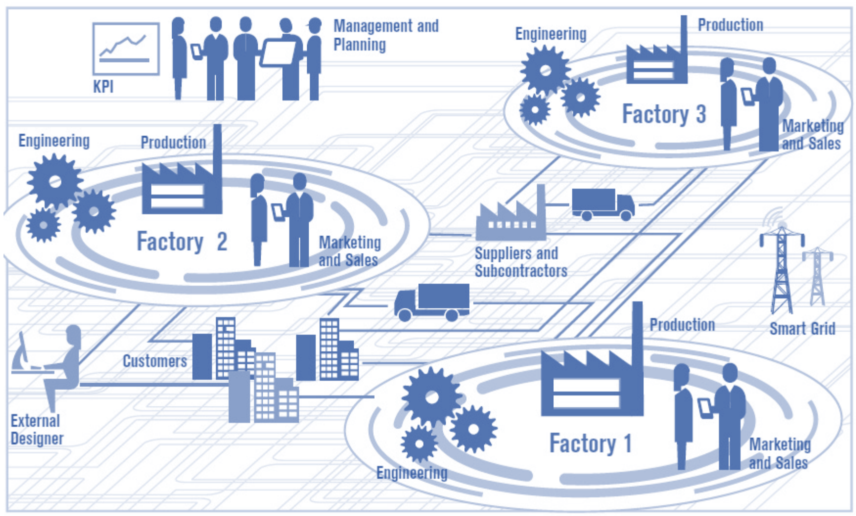


Figure 2.3 Horizontal Industry 4.0 value network (Retrieved from (Kagermann, Wahlster, & Helbig, 2013)).

Networking helps to meet the competitive market conditions of customized products and shorter-time-to market since networks can cope with increasing complexity. Networking refers to any set of recurring ties (e.g. resource, friendship, information ties) between a set of nodes (e.g. individuals, groups, organizations, information systems etc.) (Fombrun, 1982). For example, when organizations are networked with IoT, the manufacturing business processes could become (geographically) distributed (Brettel et al., 2014). This allows manufacturing organizations to flexibly alter products and enable rapid product innovation locally (Schmidt et al., 2015; Wan & Keliang Zhou, 2015). The traditional linear process of making, selling, buying and using products or services becomes distributed among the different actors in the network (Bankvall, Dubois, & Lind, 2017).

Concluding, manufacturing organizations have to work beyond traditional organizational boundaries in horizontal and vertical networks to increase efficiency further and to deal with their complex environment, such as the increasing heterogeneous customer demand. IoT meet the requirements of digital integration and intelligentization through vertical and horizontal networking. The networked nature of IoT results not only in a network of physical objects and devices, such as industrial production machines, but also in a network of organizations. Therefore, new cross-domain cooperation between multiple organizations in digital business ecosystems are emerging. As a consequence, new value propositions emerge which are based on the possibilities of sharing and exchanging of IoT data and information (Lier, 2014). These will be discussed in the following section.

#### *2.4.2 Emergence of new value propositions*

Before the introduction of IoT, data was already collected during production. However, this data stayed inside the production systems and even had to be deleted after some time because of the limited storage capacity. With the introduction of IoT, data could be collected in real-time and be globally available (Schmidt et al., 2015). Furthermore, IoT allows the transmission of data to be error free (as opposed to analog signals which were vulnerable to transmission errors), replicated indefinitely and very inexpensive (Lakhani & Iansiti, 2014). This unlimited, accurate and low cost global availability of data and information allows for the realization of new value propositions for highly customized services and products, coordinated product-service combinations and value-added services (Burmeiser et al., 2015; Lakhani & Iansiti, 2014; Lier, 2014; Wang, Wan, Li, et al., 2016). The *value proposition* describes the drivers of customer value as well as the unique features of the organization's offering (Burmeiser et al., 2015). It addresses why a particular customer segment would value an organization's product and services and be willing to pay a price for them (El Sawy & Pereira, 2013). Each of the new value propositions realized through IoT for the manufacturing industry will be discussed briefly.

a) ***Value-added services***

Traditionally, manufacturing organizations sold mainly tangible products. Now, due to the digitalization manufacturers can expand new intangible services, which is often referred to the servitization of the manufacturing industry (Rymaszewska, Helo, & Gunasekaran, 2017). Servitization allows for the creation of opportunities for additional profit generation. Digital servitization could be defined as providing digital services embedded in physical products (Ju, Kim, & Ahn, 2016). Three distinctive aspects of digital servitization are mentioned in the article of Ju et al. (2016); they have relatively low marginal costs, they partly substitute traditional products and are usually an accompaniment to the product offering (Wang, Wan, Zhang, Li, & Zhang, 2016). Burmeiser et al. (2015) state that in the past manufacturing organizations avoided to offer additional services. With the introduction of the IoT in the manufacturing industry, services present a potential to better connect to the customer by monitoring the product usage by the customer and offer additional services that meet their usage behaviour (for example with the aforementioned predictive maintenance services). Examples of offered services are maintenance services. With maintenance services, manufacturers of IoT industrial machines could use IoT sensor data to monitor the machine's condition and subsequently provide preventive and predictive maintenance. This helps to minimize product downtime and decrease additional costs. Especially in the manufacturing arena, high reliability of the machines is essential. Breakdowns of industrial production machines are expensive, since it leads to downtime. This will result in a loss of earnings and expensive repair work (Herterich, Uebernickel, & Brenner, 2015). Other examples of new services that are now possible because of IoT include optimization of machine operations (where historic operational data could be used to optimize operations to reduce operational costs) or software services (where software of the machines is easily updated over the cloud).

b) ***Highly customized smart products***

According to Rymaszewska et al. (2017), IoT creates an opportunity for manufacturing organizations to gain insights into how customers are using their products through the IoT sensor data. Therefore, it will be easier to differentiate and tailor products to the individual demands of the customer, and thus results in organizations being closer with their customers (Burmeiser et al., 2015; Rymaszewska et al., 2017). The decentralized manufacturing process allows manufacturing organizations to further differentiate and customize their products according to the insights required from the IoT sensor data

### *2.4.3 Co-creation, co-conversion and co-capture of value*

To offer a value proposition, an organization needs to perform certain value creation activities. If an organization does not operate in a network, ways to create (value creation refers to activities executed to realize a value proposition (Zott et al., 2011)) and capture (value capturing refers to underlying cost structures and revenue formula (Zott et al., 2011)) value take place inside of the boundaries of the organization. When organizations operate in an IoT network, creation and capture of value shifts mostly to co-creation and co-capture of value. Organizations in a network collaborate together in the value creation activities and value capturing, not only to complement each other, but because to be able to offer a value proposition for their customers that otherwise would not be possible (S. Solaimani, 2014). El Sawy and Pereira (2013) add that next to value co-creation and value co-capturing also value co-conversion or value-in use is of importance in the complex digital business ecosystems. Traditionally, the role of a manufacturing organization is to add standardized value to raw materials, or to deliver value to customers. However, when moving away from the traditional model of manufacturers making standardized products, this conceptualization of value no longer fits (El Sawy & Pereira, 2013). As explained before, with Industry 4.0, the products and services are customized. Then, instead of assuming is delivered in standard quantities, it is more useful to consider value as an experience through use and perceived by each customer (El Sawy & Pereira, 2013). While it seems like organizations are providing activities (services) or products, they are actually exchanging applications and capabilities, skills and knowledge. Customers and organizations then become partners to create value, where organizations first deliver potentially-value propositions, and customers assemble and utilize these propositions in context to realize the value. So, the value conversion is a subsequent step after value creation. With the introduction of co-creation, co-capture and co-conversion of value, an organization becomes dependent on resources and capabilities of other organizations. Generally, networked organizations exchange interact, dynamically collaborate and evolve around a specific core, which corresponds to shared and common assets. Often these are in the form of digital platforms. In the next section these will be discussed.

#### *2.4.4 Digital platforms in Industry 4.0*

Platforms can be view from a computer science perspective. From this perspective, with platforms is referred to standards or IT architectures that allow modular substitution of complementary assets (El Sawy & Pereira, 2013; Ghanbari et al., 2017). A platform describes a technological architecture that allows compatible complements to use it and is centred around a central technology (El Sawy & Pereira, 2013). From a business or economic perspective, platforms create value by serving as a facilitator for interaction between organizations (Tiwana, 2015). Organizations in the digital business ecosystem provide the products and services through these digital platforms with standard new architectures and interfaces through their customers. Digital platforms define the "playing field" upon which organizations collaborate, value is accumulated and customer access and discover a value proposition (El Sawy & Pereira, 2013). An example of a well-known platform of this is the based software-based platform of Apple's Iphone operating system (iOS), where different organizations are developing apps on through which they deliver services through their customers. For Industry 4.0, physical objects (such as products or industrial machines) that are equipped with IoT sensors act as a platform (Kagermann, 2015). IoT platforms will be adapted towards supporting the collaborative business processes (Kagermann et al., 2013). An example of such a platform are the industrial production machines which are equipped with IoT sensors. The industrial machines act as a platform through which predictive maintenance services are offered to the customer of the machine. Different organizations, such as IT developers, IoT sensor developers, big data analysts and the manufacturers of the industrial production machines, interact, collaborate and evolve around the industrial production machine in order to deliver the predictive maintenance service to the customer.

#### *2.4.5 Sub-conclusion section 2.4*

IoT enables horizontal and vertical networking in the manufacturing industry which leads to efficiency gains outside of the organizational boundaries. Through IoT, value is co-created, co-captured and co-converted in collaboration with the end-customer and organizations in the business ecosystem. IoT platforms facilitate the interactions between the end-customer and the organizations. A result of this is the creation of new value propositions of value added services and customized products.

### 2.5 Challenges in the industry 4.0 domain

#### *2.5.1 Lack of business model implementation perspective*

There exist numerous studies on the Industry 4.0 with a technology perspective, such as the studies of Jazdi (2014), Shrouf et al. (2014) or Zezulka, Marcon, Vesely, and Sajdl (2016). There do exist studies on the non-technological perspective, such as research on Industry 4.0 business models of Burmeiser et al. (2015), the research of industrial services and network business models of Bankvall et al. (2017) or the impact of Industry 4.0 on current business models from Arnold, Kiel, and Voigt (2016). However, in an extensive review on the definition of Industry 4.0 of Glas and Kleemann (2016) is found that most literature analyses Industry 4.0 from a technological perspective and neglects to have a non-technological business perspective, while this perspective is of importance since despite the technological advancements as described in this section Industry 4.0 still has to become reality. In a study of Rose et al. (2016) was found that adoption of Industry 4.0 amongst 380 surveyed US manufactures is low. In another study of Erol et al. (2016) was found that many organizations have difficulty to grasp the idea of Industry 4.0, they have a lack of understanding for the concrete relevance and benefit of Industry 4.0. According to the study, they struggle to identify strategic fields of action, programmes and projects to move towards Industry 4.0. Furthermore, they are unsure how the new technologies will impact their business model and business operations (CGI, 2016). S. Solaimani (2014) argues that to realize large-scale commercialization of an innovation, not only technological aspects need to be considered. A focus on business model implementation aspects, taking into account strategies, business model related aspects as well as organizational, financial and operating issues is consequently necessary. It is essential to determine how a viable and feasible business model can be formulated, and how the collaborations, interactions and relationships can be facilitated in such a way that it can be sustained at an operational level as well. S. Solaimani et al. (2013b) argues that having an operationally feasible and viable business model is a perquisite for large-scale commercialization. As a result, the alignment between the high level networked business model and the operational activities becomes a vital issue. In the context of Industry 4.0 exist several studies on the effect of Industry 4.0 on business models. However, literature on the execution and implementation of a business model is limited for the Industry 4.0 domain. It is argued that shifting the merely technological perspective of current literature on the Industry 4.0 domain to a business model implementation perspective can provide the insights into how the Industry 4.0 could be commercialized and how business models and business operations are related. In line with argument of S. Solaimani et al. (2013a), this master thesis aims make a first attempt to obtain insights into business model implementation aspects for the Industry 4.0 domain, with the application of a business model-enterprise architecture alignment metamodel model and modelling procedure.

#### *2.5.2. Sub conclusion section 2.5*

Although the technological developments and new value propositions in the Industry 4.0 domain seem promising, it still has to become a reality. For a large-scale commercialization of an innovation, a focus on business model implementation aspects, taking into account strategies, business model related aspects as well as organizational, financial and operating issues can help to commercialized Industry 4.0. However, most Industry 4.0 literature mainly has a technological focus, while a focus on business model implementation aspects is lacking. This leads to the following knowledge gap:

*KG 1: Current literature on the Industry 4.0 domain lacks a focus on business model implementation aspects.*

In the next chapter, a business model, an enterprise architecture model as well as a business model – enterprise architecture approach will be selected as foundation for the development of the metamodels and modelling procedure. In table 2.3 the characteristics of the Industry 4.0 are used to select business model and business model enterprise architecture models to develop the metamodels. The following criteria are derived from the Industry 4.0 characteristics:

Table 2.3 Selection criteria for business model selection

| **Criterion** | **Description.** |
|---|---|
| **C1** | The business model should have a networked character, which should allow for a description of a network of organizations that collaboratively realize a value proposition through co-creation, co-capture and co-conversion of value. |
| **C2** | The business model should be focused on and able to express digital platforms/technologies. |

## 2.6 Chapter conclusion

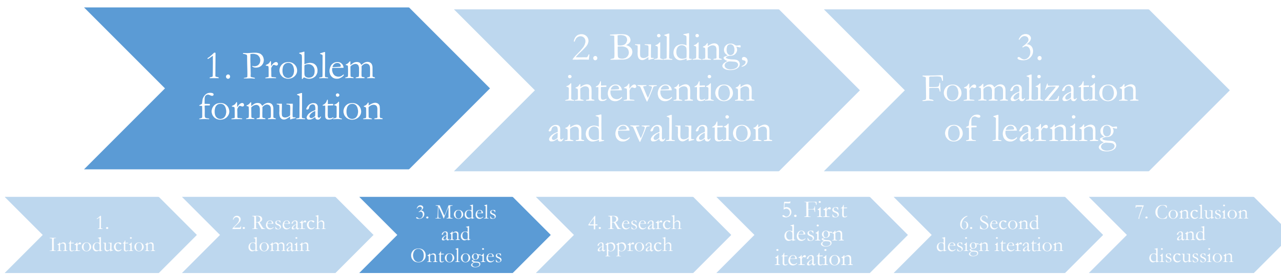
This chapter provided an answer to the following research question one: *What are the defining technological and business characteristics of the Industry 4.0 domain and what are the challenges in the industry 4.0 domain?* A final set of Industry 4.0 characteristics is defined for this thesis. First, from a technological perspective, Industry 4.0 is enabled by the digitalization of the manufacturing industry through IoT, which allows for the creation of more flexible and efficient networked manufacturing business processes. Second, from a business perspective, the introduction of IoT has led to the formation of horizontal and vertical networks where organizations in the digital business ecosystems evolve and interact around digital platforms. As a result, new value propositions emerge for highly customized or differentiated products and value-added services (combinations). Furthermore, value creation and capture shifts to complex co-creation and co-capture of value. Also, value-conversion emerges between different actors after the value is created.

The technological and non-technological developments seem promising. However, Industry 4.0 still has to become a reality. A focus on business model implementation aspects can help to commercialize Industry 4.0. Most research on Industry 4.0 has a technological perspective, while non-technological business perspective is underdeveloped, especially the business model implementation perspective. The following knowledge gap has been identify based on this limitation:

*KG 1: Current literature on the Industry 4.0 domain lacks a focus on business model implementation aspects.*

This thesis aims to develop formal metamodels and a modelling procedure which can be used by organizations to analyse and describe the implementation of a networked business model. To make a first attempt to obtain insights into Industry 4.0 business model implementation aspects, the metamodels and modelling procedure will be applied to Industry 4.0 domain.

# Chapter 3 Models and ontologies




In this chapter, an answer is given to the following research question: *What are the basic concepts of meta-models, business models, enterprise architecture and business model – enterprise architecture alignment approaches and what are the limitations of these approaches?* In this chapter, suitable models are selected to develop the artefact, the research problem on which this research focuses is explored further and its importance is justified. Therefore, the main objective of this research question is twofold (1) to select suitable business models, enterprise architecture models and business model enterprise architecture approaches and (2) to explore limitations of these current business models, enterprise architecture models and business model - enterprise architecture alignment approaches that need further research, given the focus on networked business model – enterprise architecture alignment in ICT driven business model innovation (such as the application domain of this study). The selected models will form the foundation for the theoretical analysis, where design requirements will be elicited from these models. The limitations of current approaches will be used to formulate knowledge gaps. As such, although the researcher is aware of the numerous business model and enterprise architecture approaches, this chapter does not aim to provide an in-depth review of business model and enterprise architecture literature.

This chapter is structured as follows. Since the research aims to design metamodels with a corresponding modelling procedure, first a brief background on (meta)model concepts is given. Second, a general background of business models and enterprise architectural models is provided and limitations of current models are explored. Also, a specific business model and enterprise architecture model will be selected in this section which will be used to develop the metamodels. Second, a literature review on approaches that facilitate business model - enterprise architecture alignment will be discussed. Limitations of current approaches will be explored and an approach that seems most suitable for networked business model and enterprise alignment will be selected as well. Concluding, this chapter should result in a set of selected models which will later be used to elicit design requirements through theoretical analysis, as well as a set of knowledge gaps that need further research.

## 3.1 Definitions of models, ontologies and metamodels

### *3.1.1 Relation between metamodels, models and ontologies*

In this section, the fundamental terms '(meta-) model', 'ontology' and modelling procedure are discussed. Models are formal descriptions, representations, and specifications of things (Aßmann et al., 2005). With formal is referred to a formal specification of a conceptualization, which means that there is at least one formal relation defined between terms in the conceptualization. With formal relation is meant that it is expressed in a formal modelling language (such as UML) and that it is possible to conclude implications that follow from the fact that two concepts are connected with the relation. According to Pidd. (2000), formal models are a representation of reality. While models represent reality authentically they may be abstract, leaving out irrelevant details. Models can describe a structure or a behaviour. An UML class diagram is an example of a structural model, where the model describes static concepts of a reality and their interrelation (Aßmann et al.; Rumbaugh, Jacobson, & Booch, 2005). A behaviour model also specifies the behaviour certain concepts. The Semantic Web has propagated another notion of model- *ontologies*. One of the most cited definitions of ontologies is proposed in the work of Gruber (1993), who defines them as a *"formal explicitly specifications of a shared conceptualization"* (Gruber, 1993, p. 201). In this definition, with conceptualization if referred to an abstract model of some phenomenon in the world. With explicit is meant that the type of concepts used are explicitly defined. Lastly, shared refers the notion that the ontology should capture consensual knowledge that is accepted by a group or certain field of interest (for example the logic of a business in the business model ontology of (Osterwalder, 2004)). Another definition is provided by Aßmann et al. (2005), who states that an ontology is a type of a *model*, which *"is a shared, descriptive* (i.e. they describe certain concepts of reality), *structural model, representing reality by a set of concepts, their interrelations, and constraints under the open-world assumptions*" (Aßmann, 2005, p. 256) which focuses on the description and conceptualization of things. A model can be defined as an ontology when it meets the conceptualization, explicit and shared knowledge criteria. Models which are representing and specifying models can be defined as metamodels. A metamodel is a prescriptive model of a modelling language, where the modelling language contains the concepts with which the model can be described (Kühn et al., 2003; Seidewitz, 2003). Metamodels are closely related to ontologies, since a metamodel is also an explicit model of the concepts within a domain of interest. A valid metamodel can be thus considered as an ontology (Kühn et al., 2003). Since metamodels prescribe valid instantiations of model, it enables control over the structure and validity of model instantiations. Consequently, if there is agreed upon one metamodel, the same structure is imposed on instantiations of these models, which allows for an easy exchange of the models.

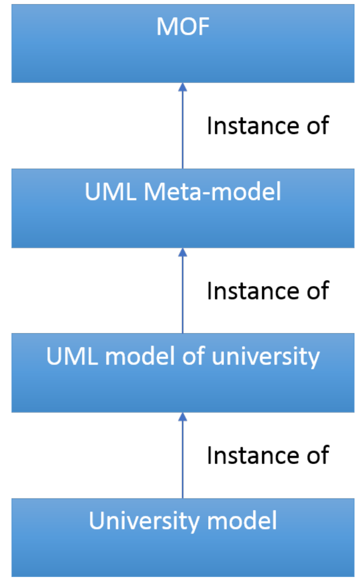



Figure 3.1 Relations between model instantiations (Adapted from (Rasiwasia, 2012) and (Kühn, Bayer, Junginger, & Karagiannis, 2003))

Lastly, there also exists meta-metamodels, such as the Meta-Object Facility (MOF) of UML. These represent and specify metamodels. In other words, they describe what the valid ingredients of a metamodel are, which are often (Flatscher, 2002): (1) Classes (concepts) (2) Attributes of classes, contained in the classes and (3) Binary relations between the classes. The *modelling procedure* describes the step-by-step process of applying the modelling language (i.e. metamodel) to create results i.e. models (Kühn et al., 2003; Zivkovic & Kühn, 2007). The relation between reality, models, metamodels and meta-metamodels is visualized in figure 3.1. In the example in figure 3.1, the university has various classrooms, courses, teachers and students (i.e. reality). These could be described by a UML class model. How the UML class model should be defined is prescribed by the UML class metamodel. Lastly, the way the UML class metamodel is defined is prescribed by the MOF (OMG, 2017). Furthermore, the process of how to define the UML model of the University is prescribed by the modelling procedure.

### *3.1.2 Metamodel integration*

(Meta)Models support the communication between people by focusing on the essentials of a particular problem or domain. There exist numerous (meta)models to describe different problems, such as business models which are used to describe the logic of a business, balanced scorecard models which are used to define the strategy of an organization, organizational structure models which are used to describe the working environment, or architecture models and application landscape models which describe the information systems and IT infrastructure (Zivkovic & Kühn, 2007). In practice, these different models are used interchangeably. Different types of models often need to be assembled to project specific modelling solutions. In other words, different modelling languages have to be integrated (Kühn & Karagiannis, 2005). The use of different metamodels is often challenging due to the semantic heterogeneity of the modelling languages. Metamodel integration techniques address the semantic heterogeneity of different metamodels. Various approaches are presented in literature which aim to facilitate metamodel integration in a formal manner, such as the metamodel integration method of Zivkovic and Kühn (2007) or Kühn et al. (2003). One of the benefits of integrating various metamodels is better support for the assembly of cross-domain specific modelling languages (Zivkovic & Kühn, 2007). Furthermore, since various domains have a common or shared formal modelling language (i.e. the integrated metamodel, containing model concepts of various source metamodels, such as software application concepts and business process concepts) considerable time and cost savings, increased quality, an enhanced acceptance in model development and more effective exchange of domain specific knowledge can be achieved (Bauknecht et al., 2003).

### *3.1.3 Sub-conclusion section 3.1*

In this section a general background on (meta)models, ontologies, modelling procedures and metamodel integration was provided. It was discussed that models are specification of reality, while metamodels are models which describe the concepts of a modelling language. Ontologies are models which are an explicit, shared and formal specification of a conceptualization. A valid metamodel can be defined as ontology. Integrating different metamodels via formal metamodel integration has numerous benefits, such as better support for cross-domain modelling languages, an effective exchange of the knowledge that is captured in the different models as well as enhanced acceptance by the users of the integrated metamodel. Models which are relevant for this study are more specifically business models and enterprise architecture models, and the relation between these two models. These models will be discussed in the following section.

## 3.2 Business and enterprise architecture models

### *3.2.1 Business models: definitions and perspectives*

In the previous chapter was described that Industry 4.0 opens up new business opportunities for manufacturing organizations by the integration of customers and partners from the digital business ecosystem (Kagermann, 2015; Rennung, Luminosu, & Draghici, 2016b). To utilize these opportunities, Industry 4.0 requires substantial changes to the business logic (i.e. the way in which an organization collaborates on a strategic and operational level in brining products and services to the market) of an organization. According to Osterwalder et al. (2005) a *business model* is a model which is used to express the business logic of an organization. Livari et al. (2016), Vermesan, R., Gluhak, Boesenberg, and Hoeer (2016), Arnold et al. (2016), Zott et al. (2011) and Westerlund, Leminen, and Rajahonka (2014) state that despite the importance of business models for defining the business logic, there does not exist a common or unified view on what a business model is. This can be seen by the various definitions of business model which can be found in literature (Zott et al., 2011). In the literature review of Zott et al. (2011) was discovered that previous business model literature has viewed business models as a statement, a description, a representation, an architecture, a tool, a template, a method, a pattern or a framework. However, according to Zott et al. (2011), what is common between the different views on business models is that they tend to describe the value proposition, value creation activities and value capturing of an organization. The position of the business model in relation to the business strategy, and IT is considered by Osterwalder and Pigneur (2002) to be between the business strategy, business processes and underlying ICT of an organization (see figure 3.2).

There exists a common acceptance that an effective and efficient business model is a valuable asset to organizations. Yet, most organizations still experience difficulty to understand their business model (Lindgren & Aagaard, 2014). According to Livari, Ahokangas et al. (2016), this a result of the many organization-centric business model conceptualizations. Most research on business models has a single organization perspective (such as the business model canvas of Osterwalder et al. (2005)). Therefore, most business model research lacks the consideration of network-embeddedness by only focusing on the value proposition and corresponding value creation activities and value capturing within the boundaries of an organization (Bankvall et al., 2017; Freytag & Clarke, 2012; Livari et al., 2016; Zott et al., 2011). Single-level organization business models are less suited for network environments since they tend to explain how one organization can deliver value to its customers and partners, by establishing relationships with other organizations within the internal business logic of an organization, instead of the external business logic of the network (Livari et al., 2016). This will lead to misassumptions on the value network (El Sawy & Pereira, 2013). Single-organization business models assume that the current value created through the network would continue unchanged and not change dynamically, and are therefore less suitable to network or ecosystem environments (El Sawy & Pereira, 2013). In contrast, a networked business model considers the organizations and their business models as interdependent. Instead of putting the value creation operations of an organization at the centre-stage, adding suppliers and other important actors as secondary issues, and then trying to insert new products and services into this network, a networked business model starts with the network value proposition and configures the network in delivering it (Livari et al., 2016).

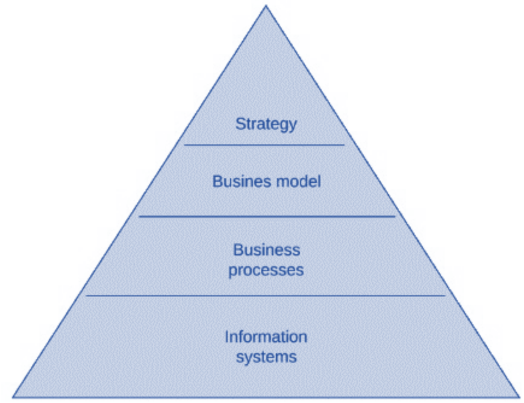



Figure 3.2 The position of a business model within an organization (adapted from Osterwalder and Pigneur (2002))

An example of a widely accepted organization-centric business model is the business model canvas of (Osterwalder, 2004). Examples of business models that are developed to be used in an ecosystem or network environment are the VDML of OMG (2012), VISOR business model framework of El Sawy and Pereira (2013), the Business Model Cube of Lindgren and Rasmussen (2013), the e3 value model of J. Gordijn et al. (2000) and the STOF model of Bouwman et al. (2008). Although the researcher is aware of the numerous business models that exist in literature, it not in the scope of the research to discuss and review them all in detail, since (part of) the objective of this chapter is merely to select a suitable business model for the development of the metamodels and modelling procedure. An analysis on the commonly used business models has led to the decision to select the VISOR framework (El Sawy & Pereira, 2013) as main foundation to develop the metamodels. This is based on comparison of the selection criteria in the previous chapter in table 3.1. Next to these criteria, the VISOR business model also has practical and academic relevance and the business model is developed based on an extensive literature review on other business model (frameworks) so the model is embedded and conceptualized in literature as well. In the next section, a detailed description of the VISOR business model framework is provided.

Table 3.1 Business model selection based on selection criteria

| **Criterion/ Business model** | **STOF (Bouwman et al., 2008)** | **VISOR (El Sawy & Pereira, 2013)** | **BMC (Osterwalder, 2004)** | **e3 value model (J. Gordijn et al., 2000)** | **Business model cube (Lindgren & Rasmussen, 2013)** |
|---|---|---|---|---|---|
| **C1** | Yes, the STOF model takes the value network which delivers the service and products into account. Furthermore, the business model takes the value in use into account. | Yes, the VISOR model is especially designed to organize a network of organizations around a joint value proposition. Furthermore, the business model takes the conversion of value (value-in use) into account. | No, the business model canvas has more of an inside-out analysis, by starting with the internal business logic of a single organization. Furthermore, the business model does not take the conversion of value (value-in use) into account. | Yes, e3 value is designed around the exchange of values in a value network to realize value propositions. However, the business model does not take the conversion of value (value-in use) into account. | Yes, the business model cube does the network of organizations which aim to realize a joint value proposition into account. However, the business model does not take the conversion of value (value in use) into account. |

| | | | | | |
|---|---|---|---|---|---|
| **C2** | Partly, although STOF has a platform concept, the model is more designed towards mobile services. | Yes, VISOR is especially developed for organizations who operate around digital platforms and digital services in a technology-enabled and digitally interconnected environment. | No, the BMC has a resource concept which could be used to define the digital platform, however, the business model is not explicitly focused on digital platforms. | No, the e3 value model is suitable to model exchanges of values, but does not include explicit concepts to model digital platforms, such as IoT platforms. | No, the business model cube does not have specific components or concepts which could be used to express digital platforms. |

#### *3.2.2 VISOR business model framework*

El Sawy and Pereira (2013) developed the VISOR business model framework to help organizations to better navigate through the digital business world by helping to understand the dynamic environment of digital business ecosystems and corresponding digital platforms. According to the authors, the emergence of networked digital organizations and digital platforms created a need for business models which should help them design more effective business models. El Sawy and Pereira (2013) define five categories which cover the dimensions of a digital service or product: The Value proposition, the Interface, the Digital service platforms, the Organizing model, and the Revenue model. First, the value proposition defines why a particular customer segment would value an organization's product and services and is willing to pay a price for them. Second, the interface refers to the way which customers experience success of delivery through the interface of a service. Third, the digital service platform shapes, enables and supports the business processes and relationships required for a digital product or service to be delivered to the customer. Fourth, the organizing model describes how the network of organizations will organize business processes, resources, value chains and partner relationships to effectively and efficiently deliver products and services. Lastly, the revenue model defines the way to make money through the offered products and services. It defines how money is collected, and how each partner profits. In the next section, two major limitations of business models will be discussed.

#### *3.2.3 Limitations of single-organization-and networked business models*

One limitation of both single-organization and networked business models is that they are often described in an informal manner such as by using natural language, and thus lack concrete metamodels. The previous discussed VISOR framework also has an informal representation in natural language. According to Zott et al. (2011), structuring, visualizing and subsequently communicating the knowledge in business models becomes difficult due to the informal approach, lack of concrete metamodels and well defined relationships between the concepts of business models. Another disadvantage of the informal approach is that the business model design often remains isolated from the business model implementation design, which are often expressed in formal languages like UML (Rumbaugh et al., 2005). Therefore, business models are not integrated with other aspects of the business design, such as the design of the business processes and IS (Al-Debei & Avison, 2010; Pateli & Giaglis, 2004; Rasiwasia, 2012). This limitation introduces another limitation of business models, which is the neglected issue in business model literature on the technological implementation of the business model (Bouwman et al., 2008; El Sawy & Pereira, 2013; Osterwalder et al., 2005; S. Solaimani, 2014) (where with business model implementation is referred to the translation of the business model into an operational design, which includes the business processes and underlying IT (Brews & Tucci, 2003)). This neglected implementation perspective leads to a limited understanding of the gap between the business model design and formal design of the business model implementation (Bask et al., 2010). Furthermore, severe set-backs are to be expected in the execution of the business model when the implementation aspects are no considered. Even those business models that seems promising on paper, can fail when they are being technologically implemented (S. Solaimani, 2014). *Enterprise architecture* models offer insights of the implications of business model design (changes) on the design of the business processes and underlying ICT (Iacob et al., 2012; Janssen & Gordijn, 2005). Therefore, enterprise architecture and the relation with business models will be explained in the next section.

### *3.2.4 Enterprise Architecture: definitions and perspectives*

While business models are focused on the value proposition, value creation and value capturing of an organization, enterprise architecture describes the connection between business processes and ICT (see two layers of the bottom of the triangle of figure 3.1). A business model describes *what* an organization should do to create value, while *how* this could be done requires an in-depth understanding of the business processes and underlying ICT. The relation between business models and enterprise architecture is described by Janssen and Gordijn (2005) as follows: *"Enterprise Architecture and business modelling methodologies meet in service offering and realization. In general, business models focus on the service value generated by a business, whereas enterprise architecture models show how a business realizes these services."* (Burren, Janssen et al., 2005, p. 2). Enterprise architecture studies the organizational structure, business processes, ICT and infrastructure (Lankhorst, 2017). The most important aspect of an enterprise architecture is that it provides a holistic view of the organization (Lankhorst, 2017; Op 't Land, Proper, Waage, Cloo, & Steghuis, 2009). Enterprise Architecture is defined by Lankhorst (2017) 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, 2017, p.3). According to de Kinderen et al. (2014), Enterprise Architecture is generally considered to provide a mechanism for cohesive steering instrument when organizations undergo a transformation process. It provides organizations the ability to analyse the current state of the organization, identify and describe alternative future states by acting as some kind of "compass" or "atlas". Furthermore, it guards the cohesion and alignment between the different aspects of the organization such as the ICT and business processes.

### *3.2.5 ArchiMate*

There exist numerous approaches or models in the enterprise architecture community, such as the Zachman framework (Zachman, 1987), ArchiMate (Jonkers et al., 2006), ARIS or the Open Group Architecture Framework (TOGAF) (The Open Group, 2017). Although the researcher is aware of the existence of these various enterprise architecture models and frameworks, these are not discussed in detail since it is not in the scope of this research. For the development of business model – enterprise architecture alignment approach, concepts of the open standard and modelling language ArchiMate will be used for the following reasons: (1) ArchiMate has an integrated approach for modelling all aspects of an organization (2) The use of ArchiMate is advocated by its representativeness and wide acceptance in the academic and practitioner communities (Iacob et al., 2012). ArchiMate is an open and independent description language for Enterprise Architecture, supported by different tool vendors and consulting firms. It is developed in a joint research between companies and knowledge institutions (Jonkers et al., 2003). The ArchiMate core framework (as displayed in figure 3.3) provides architects a graphical modelling language with concepts to describe, analyse and visualize an architectural model with its relationships among business domains in an unambiguous way. ArchiMate is developed around the principles of service-oriented architectures. Therefore, ArchiMate views the organization as a layered set of systems, where layers are supported by other layers via services (e.g. the application layer provides application services to the business layer (Jonkers et al., 2004)). The relationships and model concepts are defined by various metamodels, such as the business layer metamodel. In these metamodels, the active structure elements (such as an actor) performs certain behaviour (such as reading) on a passive structure element (such as a book).

| | Passive structure | Behavior | Active structure | Motivation |
|---|---|---|---|---|
| Strategy | resources | courses of action, capabilities | resources | stakeholders, drivers, goals, principles and requirements |
| Business | business objects | business services, functions and processes | business actors and roles | |
| Application | data objects | application services, functions and processes | application components and interfaces | |
| Technology | artifacts | technology services, functions and processes | devices, system software, communication networks | |
| Physical | material | | facilities, equipment, distribution networks | |
| Implementation & migration | deliverables | work packages | plateaus | |

Figure 3.3 ArchiMate 3.0 core framework

### *3.2.6 Limitations of enterprise architecture approaches*

A limitation of enterprise architecture is that they often lack a more economical business model perspective (Rahmati, 2013). While business models are often more abstract and economically oriented, enterprise architectures are often more detailed and functionally oriented. Therefore, the questions such as "who will benefit from the product or service" or "who will pay for it" remain unanswered (Iacob et al., 2012). Also, it becomes more difficult to evaluate the business fit of the enterprise architecture. Based on the missing technological business model implementation perspective of business models, and the missing business model perspective of enterprise architectures approaches, it is argued that the enterprise architecture should be aligned with the business models. Aligning business models with enterprise architectures results in a harmonized package which describes the creation and implementation of the business model in a comprehensive and holistic manner. As a result, it supports on the one hand the analysis on the feasibility and viability of a business model innovation and on the other hand the business fit of the enterprise architecture design. A few studies have related business models to enterprise architecture, which will be discussed in the following sections.

### *3.2.7 Sub-conclusion section 3.2*

Business models are used to express the business logic of an organization or a network of organizations. Two limitations of business models are that they are often represented or visualized in an informal manner and that they neglect a perspective of formal business model implementation design. This lead to the formulation of the following knowledge gap:

*KG 2: Current literature on business models has mainly proposed informal business model representations and lacks a focus on formal business model implementation design.*

Enterprise architecture can be used to define the technological implementation of a business model. However, current enterprise architecture models still lack a more economical business model perspective, such as the value proposition. As a result, it becomes more difficult to evaluate the business fit of the enterprise architecture and to answer important questions such as, "who will benefit from the product or service" or "who will pay for it"? This leads to the formulation of the following knowledge gap:

*KG 3: Current literature on enterprise architecture literature often lacks an economical business model perspective.*

Based on these knowledge gaps, in this research, a f*ormal* integration of the theoretical foundations of VISOR and ArchiMate will be proposed to address these issues. Since this study focuses specifically on formal ICT driven *networked* business model implementations, the characteristics of the implementation of a business model by networked enterprises will be described in the following section. After that, a literature review on current approaches that relate business models with enterprise architecture models will be presented.

## 3.3 Business model implementations for networked enterprises

The term networked enterprise is defined by S. Solaimani (2014) as follows: *"hardly/non‐substitutable linked companies that collaboratively aim at enabling or implementing the collective Business Model by means of offering service and product and/or sharing resources and capabilities."* (Solaimani, 2014, p. 61). Networked enterprises collaboratively implement a networked business model, in which all actors are involved through exchanges of (ICT) resources, capabilities, information, knowledge, inter-organizational business processes (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). Networked enterprises are (inter)dependent on its partners to realize the joint value proposition (M. Heikkilä, 2010; S. Solaimani, 2014). This is where the motivation to join the network comes from; the attainment of goals that are unachievable by the organizations independently (M. Heikkilä, 2010). The advantage of the heterogeneous character of networked enterprises is that it allows to respond to the heterogeneous customer demand (i.e. the demand for differentiated and customized products) (Chung et al., 2004). However, a result of this heterogeneity is that the realization of the business model implementation becomes challenging because the business processes of the networked enterprises are often conflicting and heterogeneous, the division of responsibility over different components of the value proposition is unclear and the ICT landscape is often fragmented (Chung et al., 2004; Erol et al., 2016; Legner & Wende, 2007; Sam Solaimani & Bouwman, 2012). Consequently, it becomes difficult to ensure effective delivery of the service or product to the end-customer (M. Heikkilä, 2010; Legner & Wende, 2007; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012)

When the business model is coherent, supporting and supported by the processes and ICT within and among the networked enterprises involved, the business model's feasibility and viability is ensured (Solaimani 2014). Insights in the complex interactions on various levels (i.e. values (such as products/services, resources and capabilities), data, information, knowledge and processes) between the actors are essential to ensure the feasibility and viability of the business model. These insights can help to facilitate the collaborations, interactions and relationships in such a way that the business model can be sustained at an operational level. Therefore, especially in *networked* ICT driven business model innovation insights into business model implementation aspects are required to ensure the operational feasibility and viability of the business model (Janssen & Gordijn, 2005; Osterwalder, 2004; Sam Solaimani & Bouwman, 2012). With the characteristics of networked enterprises in mind, current approaches that aim to align business models with enterprise architectures will be reviewed in the next section.

## 3.4 Business model – Enterprise architecture alignment approaches

This second literature review aims, first, to provide an overview of the current approaches that align business models with enterprise architecture and, second, to explorer limitations of these approaches. Limitations of the approaches are based on (1) whether they have a networked perspective (based on the overall focus on *networked* business models of this thesis), (2) whether they support multi-level of analysis of values (in terms of products/services and valuable resources and capabilities), business processes and information (based on section 3.3 on networked enterprises), (3) whether they are lightweight or heavyweight (based on context of ICT driven business model innovation, which is often characterized by a limited amount of available time (J. Gordijn, 2003)) and (4) the formality of the approach (based on the discussions and benefits of a formal approach in section 3.1.2).

### *3.4.1 Literature review approach*

The following keywords were used for this literature review: "value modelling" OR "business model" OR "Value" AND "enterprise architecture" AND "Alignment". The same approach as in section 2.1.1 was used for this literature review. First, an initial search was conducted at the scientific databases as displayed in Table 3.2. After that, an initial set of articles was selected through reading the title and abstract. An article was selected based on if the article (1) contained a description of enterprise architecture *and* business model concepts and (2) of the article proposed an alignment approach/technique. Articles focused on other fields of alignment, such as Business-IT alignment were not selected, since this research primarily focuses on alignment of business models and enterprise architectures. Since Google Scholar provided a large number of results that could than not be handled in the limited available time, only take the top 50 results into account. After which the text of articles was scanned, a final set of 11 articles was retrieved. Normally, it is desired to only review peer reviewed articles, however, since the amount of research on this topic is still on its infancy (J. Heikkilä et al., 2010) also some master theses were included in the final set to able to review a bigger set of literature. In the following section, the results of the literature review will be discussed.

Table 3.2 Used academic databases and search results.

| Science database | Number of articles found | Number of useful articles |
|---|---|---|
| **Science Direct** | 9 | 0 |
| **Scopus** | 5 | 0 |
| **IEEE Xplore Digital Library** | 24 | 1 |
| **Google Scholar** | 4190 | 10 |

### *3.4.2 Results*

Most research states that by aligning business models with enterprise architecture, the gap between the design of the business model and the implementation of a business model can be addressed by providing insights into business model implementational aspects (Iacob et al., 2012; S. Solaimani, 2014). Literature provides multiple benefits of aligning business models with enterprise architecture: it helps to identify key activities and resources that support a new business model, it help emphasizing underutilized assets, improves the understanding of implications on the new architecture, helps to determine the rationale for the architectural change and it delivers the information strategic planning process towards architectural change and business model implementation (Fritscher & Pigneur, 2011; Iacob et al., 2012; Janssen & Gordijn, 2005; Petrikina et al., 2014). Although there does not exist a commonly used definition of business model – enterprise architecture alignment, S. Solaimani (2014) provides a novel definition for business model – business operations (refers to the business processes and underlying ICT) alignment: *"the extent to which a Business Model supports/enables and is supported/enabled by the underlying operational activities, processes and systems of the Business Model executor(s), as a single or networked enterprises."* (Solaimani, 2014, p. 58). Petrikina et al. (2014) and J. Heikkilä et al. (2010) state that the subject of business model – enterprise architecture is not widely investigated subject yet. The relatively low number of search results confirms this statement.

The study of Janssen and Gordijn (2005) was one of the first studies in the field of business model – enterprise architecture alignment. In the approach of Janssen and Gordijn (2005), ArchiMate is used for the enterprise architectural component, while for the business model component the e3 value model of J. Gordijn et al. (2000) is used. The authors proposed an informal conceptual correspondence between the concepts of the e3 value model and the concepts of the business layer metamodel of the ArchiMate. J. Heikkilä et al. (2010) proposed an approach where business model concepts are related through operating models. The authors used the C-SOFT business model and analysed the business model implementation through a resource based viewpoint with elements from enterprise architecture. Fritscher and Pigneur (2011) used a different approach. The authors proposed a model construct that is similar to an enterprise architecture model, however, business model concepts are added to the enterprise architecture model. The enterprise architecture modelling language ArchiMate of Lankhorst (2017) is used, as well as the Business Model Canvas of Osterwalder et al. (2005). The more abstract concepts of the Business Model Canvas are related through concepts of IT services to the more detailed and functional ArchiMate concepts. According to the authors, this should help to strategically align the business vision with enterprise architecture design considerations. In the work of Iacob et al. (2012), numerous concepts of ArchiMate are conceptually and informally mapped to the concepts of the Business Model Canvas (Osterwalder et al., 2005). In addition to the approach of Fritscher and Pigneur (2011), Iacob et al. (2012) proposed an alignment method, which includes a financial component, that guides a migration from an as-is to a to-be architecture. Gaaloul and Proper (2012) proposed a similar approach as the approach of Janssen and Gordijn (2005). The authors defined an informal conceptual correspondence between concepts of the e3 value model and concepts of the business layer of the ArchiMate metamodel. The authors state that it possible to map concepts of the e3 value model to the ArchiMate metamodel. However, in contrast to Janssen and Gordijn (2005), the authors discover some mapping limitations. Gaaloul and Proper (2012) state that there is still a significant difference in the semantics of the e3 value model and the ArchiMate metamodel. According to the authors, the semantics of the concepts of the e3 value model differ from semantics of the concepts of ArchiMate, where some concepts of the e3 value model (more specifically the 'value activity' and 'value object' concepts) have a more networked and economical focus as compared to the more functional and intra-organizational concept of the ArchiMate metamodel.

In the approach of de Kinderen et al. (2014), again the combination of the e3 value model and ArchiMate is used. This study was the first study that related concepts of business model with enterprise architecture via formal metamodel integration techniques, by integrating the e3 value model through concepts of the DEMO methodology into the business layer metamodel of ArchiMate. Sam Solaimani and Bouwman (2012) and S. Solaimani (2014) proposed the conceptual VIP (i.e. Values, Information and Processes) framework, which aims to relate business model concepts to generic enterprise architecture concepts. The VIP framework is especially developed for networked business model implementations and acts as an intermediate between the more abstract business model and the more detailed and operational business processes and IT. In the work of Rahmati (2013), the VIP framework is used as intermediate to relate business model concepts to enterprise architecture concepts. The author proposed several informal conceptual correspondences between concepts of the VISOR model, concepts of the VIP framework and numerous concepts of the ArchiMate metamodels. Petrikina et al. (2014) proposed an informal approach which takes general concepts of various business models and enterprise architecture frameworks, which resulted in an approach that does not use a specific business models or enterprise architectures. This should make the approach less tool dependent. More recently, Ding

(2015) has integrated the Value Metamodelling Language VDML (OMG, 2015) into the business layer metamodel of ArchiMate. Also in the study of Roelens (2015) VDML is used. In this approach, concepts of VDML are related to generic concepts of business architectures. There exist multiple other approaches to align business models to business processes modelling techniques (such as by aligning the e3 value model to business process modelling language BPMN). However, these are not discussed in detail since the objective of this master thesis is to align business models with *enterprise architectures*. See table 3.3 for an overview and evaluation of all the reviewed approaches.

Table 3.3 Overview and evaluation of current business model – enterprise architecture approaches

| **Author and year/Evaluation criteria** | **Business model** | **Enterprise Architecture** | **Network focus** | **Multi-level analysis** | **Lightweight** | **Formal approach** |
|---|---|---|---|---|---|---|
| **(Janssen & Gordijn, 2005)** | e3 value Model | ArchiMate | X | | | |
| **(J. Heikkilä et al., 2010)** | C-SOFT | Generic enterprise architecture concepts | X | | | |
| **(Fritscher & Pigneur, 2011)** | Business Model Canvas | ArchiMate | | | | |
| **(Iacob et al., 2012)** | Business Model Canvas | ArchiMate | | | | |
| **(Gaaloul & Proper, 2012)** | e3 value Model | ArchiMate | X | | | |
| **(de Kinderen et al., 2014)** | e3 value Model | ArchiMate | X | | | X |
| **(Rahmati, 2013)** | VISOR | ArchiMate | X | X | | |
| **(Petrikina et al., 2014)** | Generic business model concepts | Generic enterprise architecture concepts | | | X | |
| **(S. Solaimani, 2014)** | Generic business model concepts | Not addressed specifically | X | X | X | |
| **(Ding, 2015)** | VDML | ArchiMate | | | | X |
| **(Roelens, 2015)** | VDML | Generic business architecture concepts | X | | | X |

### *3.4.3 Limitations existing approaches*

In this section, limitations of the previous discussed approaches are discussed.

1. Most approaches often lack a network perspective by transforming one specific business model to a specific intra-organizational enterprise architecture model (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). Examples are the approaches of Iacob et al. (2012) or Fritscher and Pigneur (2011), who both transform the intra-organizational Business Model Canvas of Osterwalder et al. (2005) into a single organization enterprise architecture. Petrikina et al. (2014) also maps intra-organizational business model concepts to enterprise architecture concepts. Because of this single organization perspective, an analysis, description or visualization of the complex and dynamic inter-organizational interactions of networked enterprises (as discussed in section 3.3) is not supported. Therefore, insights into these interactions cannot be obtained, and thus it becomes more challenging ensure the operational feasibility and viability of the networked business model. Therefore, networked approaches are required that do facilitate networked business model and enterprise architecture alignment.

2. Most approaches facilitate a single level-of-analysis by merely focusing on the exchange of either values (such as products, services or money), exchanges of information/knowledge or interactions of business processes. With the current approaches, no facility is provided to analyse critical elements of interactions on the level of values, information and processes. Nonetheless, it is necessary to have insights in the complex interactions on the level of values, information and business processes to ensure the feasibility and viability of the business model, so a multi-level-of-analysis, taking into account values, information and processes is required (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). By not supporting multi-level analysis, only part of the business model implementation (i.e. either value, information or process related implementational aspects) can be optimized. Especially for the Industry 4.0 domain and other ICT driven

innovation, information and knowledge are key for the realization of a business model and thus have also strategic value. Consequently, the role of information should not be underestimated (Evans & Wurster, 1997; J. Gordijn, 2003; Osterwalder, 2004). In the approach of Ding (2015), Value Delivery Metamodel (VDML) (OMG, 2015) is integrated with concept of the business layer of ArchiMate (Lankhorst, 2017). This is similar in the approaches of Janssen and Gordijn (2005),Fritscher and Pigneur (2011), Iacob et al. (2012), and de Kinderen, Gaaloul et al. (2012) who all mostly maps concept of the business layer of ArchiMate to the Businessmodel, whereas information concepts are ignored in the concept mapping. Roelens (2015) uses the Value Delivery Modelling Language as well and neglects the exchanges of information objects and business processes of the networked enterprises. As such, it is argued that a business model – enterprise architecture alignment approach is required that does facilitate this multi-level of analysis on the level of value, information and processes.

3. Most approaches are converting business models concept to numerous or many and detailed enterprise architecture concepts (directly), such as the approaches of Iacob et al. (2012), Ding (2015) or Rahmati (2013). To bring an ICT driven business idea into execution, often only a limited amount of time is available (J. Gordijn, 2003). Rapidly increasing technological possibilities cause ideas to obsolete fast (J. Gordijn, 2003). Therefore, it is not possible to invest time and money to develop a detailed description or 'blueprint' of the enterprise architecture, consisting of many different concepts and their interrelations. As such, organizations often demand a quick, first execution of the business idea comprising of the essentials of the idea or a first step towards business model implementation. Approaches whose adaptation costs is a small fraction of that of the overall design process costs (which includes training, application, and computational costs) are defined by Gervasi and Nuseibeh (2002) as *lightweight* approaches. Lightweight approaches include only a limited number of model concepts and a limited number of viewpoints (J. Gordijn, 2003). Therefore, it is argued that a *lightweight* business model – enterprise architecture alignment approach (consisting of a limited number of concepts and relations between these concepts(J. Gordijn, 2003)), that facilitates analysis, evaluation and visualization of the business model implementation is required.

4. Almost all approaches that relate business model concepts to enterprise architecture, such as the approach of Janssen and Gordijn (2005) Fritscher and Pigneur (2011), S. Solaimani (2014) or Rahmati (2013), have an informal conceptual representation, where no well-defined formal relationship methodology to define the relations between business model concepts and enterprise architecture concepts. The scarce amount of formal approaches that do exist, such as the approach of the Envision metamodel of Janssen, Steen, Haaker, and Bouwman (2015) or de Kinderen et al. (2014), are relating the business model concepts and enterprise architecture concepts on a very high-level, for example by integrating one UML class, defined as "enterprise architecture", to a formal representation comprising of different classes of the business model canvas (Osterwalder, 2004). By relating the concepts on such a high level, it is still not clear how specific concepts of enterprise architecture, such as information, data or business processes could formally be integrated into networked business models. This is also acknowledged by Heyl (2014b) who states, after an extensive literature review on business models, enterprise architecture models and frameworks and BPM approaches, that a business and process ontology, based on a semantic metamodel is lacking in current literature. He states *"A research work to develop a proposal of Business and Process Architecture Ontology, based on a semantic metamodel could close this gap, is still open. It would be a significant contribution to the professional community to provide a systematic procedure that could enable the use of structured practices that would always lead to deliverables and similar results, independent of the people implementing them"* (Heyl, 2016, p. 11). The absence of a formal integration and representation of business models and enterprise architecture approaches poses difficulty in exploiting the knowledge stored in business models while designing Enterprise Architectures using the business model-driven approach. Consequently, it becomes more difficult to interpret the relation between the business model and enterprise architecture concepts. By taking an informal approach, business models are still isolated from the business process design and IT architecture design, which are often defined in formal modelling language like UML (Al-Debei & Avison, 2010; Heyl, 2014b; Pateli & Giaglis, 2004). Another consequence of the informal representation is the different interpretations by the various stakeholder groups (J. Gordijn, 2003). The inherent ambiguity of informal notations limits the ability to understand the business model-architecture design and the relation of the business model with the enterprise architecture. Since ICT driven business model innovations are often realized by a large number of stakeholders, designing and implementing business models has become a rather complex task (Osterwalder, 2004). This complexity arises among and within the

networked enterprises, as well between the business oriented stakeholders and the IT oriented stakeholders. Due to the different foci of these stakeholder groups discussions between these stakeholders become inefficient and confusing (J. Gordijn, 2003). Consequently, it becomes challenging to transfer the knowledge stored in business model into ICT design. A result of this is fragmentation and inconsistency of knowledge in one the one hand the business model design and on the other hand the technological business model implantation design. Therefore, it is argued that concrete metamodels that represent business and IT conceptualizations in a structured, uniform, formal and understandable way can help to reduce the level of complexity and ambiguity by highlighting important issues and pointing out relationships between them and to increase the common understanding by the various stakeholders (J. Gordijn, 2003; Osterwalder, 2004; Rasiwasia, 2012). Furthermore, formal metamodel integration techniques can be used to develop cross-domain specific modelling languages, including business model concepts and enterprise architecture concepts (Zivkovic & Kühn, 2007). In this way, a consistent and unregimented exploitation of business knowledge when designing enterprise architectures (and vice versa) can be ensured.

The VIP business model – enterprise architecture framework of Solaimani (2014) iand Solaimani and Bouwman (2012) is the only approach that meets most of the evaluation criteria by having a network-centric perspective, facilitating multi-level analysis by taking the exchanges of values, information and processes into account. Furthermore, the framework is rather lightweight approach to bridge the gap between business models and enterprise architecture by including only a limited number of concepts. However, the framework is represented by an incomprehensive informal notation without concrete metamodels and without the support of tooling to analyse the business model implementation. VIP is rather a conceptual *framework* or theoretical lens expressed in natural language that helps researchers focus on important aspects of networked business implementations, instead of a formal *modelling language*, consisting of concrete metamodels and a modelling procedure, that can be used the analyse, describe and visualize a networked business model implementation. Furthermore, the framework does not include a business model component, such as the Business Model Canvas and a concrete enterprise architecture component, such as ArchiMate. In his study, S. Solaimani (2014) acknowledges the limitation of the informal approach; using the VIP framework in multiple case studies was found that all participants were of the opinion that a uniform visualization method is strongly needed. The participants emphasized that a comprehensive VIP visualization would have helped them to oversee the complex inter-organizational interactions, from which subsequently critical and problematic processes could be extracted. Nonetheless, since the VIP framework addresses most of the current limitations of business model and enterprise architecture approaches, the theoretical foundations of the VIP framework will be used to develop the metamodels and modelling procedure. To address limitation four, formal metamodels and a modelling procedure will be developed, to address the gap as defined by Heyl (2014b). In the next section, the theoretical foundations of the VIP framework will be briefly discussed.

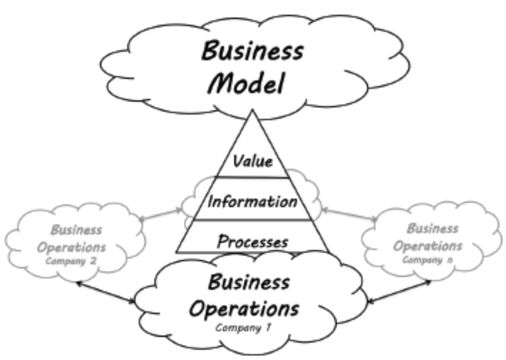


Figure 3.4 VIP framework within networked enterprises (Retrieved from (Sam Solaimani & Bouwman, 2012))

#### *3.4.4 VIP framework*

The position of the VIP framework in ration to the networked business model and the business operations (i.e. processes and ICT) is displayed in figure 3.4 and the framework itself is displayed in figure 3.5. The columns of the table address the four core concepts of networked enterprise collaborations:

1. The business network or ecosystem consisting of the stakeholders and their relationships where objects of value are exchanged.
2. The exchange of resources and capabilities, which includes value, data, information, knowledge objects and business processes.
3. Multiple types of relations and interactions designed to co-create and share values, information and business processes.
4. The interdependencies between the collaborating organizations.

The sustainability of the ecosystem is dependent on the orchestrated positive outcomes for all involved actors on all levels and with regard to all concepts.

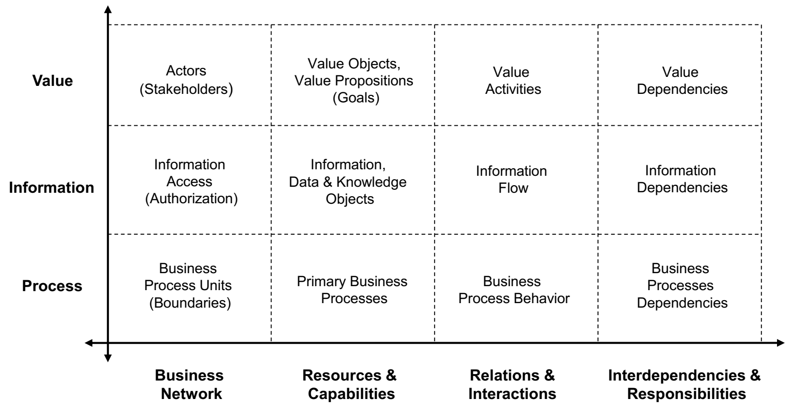



Figure 3.5 VIP Framework (Adapted from (Sam Solaimani & Bouwman, 2012))

### *3.4.5 Sub conclusion section 3.3 and 3.4*

Networked enterprises are collaboratively designing and implementing a networked business model through exchanges and interactions on the level of values (in terms of products/services and resources and capabilities), information/knowledge and business processes. To facilitate analysis of the feasibility and viability of a business model implementation, it is therefore essential to take this multi-level interaction into account. Current approaches that facilitate business model implementation through aligning business models with enterprise architectures often do not take this multi-level interaction into account. Furthermore, they often have an organization-centric focus, are heavyweight by including many model concepts and have informal representations. This leads to the following knowledge gap, which forms the main knowledge gap addressed in this research:

*K4: Current literature on business model –enterprise architecture alignment lacks a lightweight formal approach which can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.*

The VIP framework does facilitate multi-level analysis, has a networked focus and is rather lightweight approach to bridge the gap between business models and enterprise architectures. However, similar to most business model – enterprise architecture alignment approaches, it has an informal notation and thus lacks concrete metamodels and a modelling procedure. VIP is rather a conceptual framework or theoretical lens instead of a formal modelling language that can be used to describe, analyse and visualize a networked business model implementation.

## 3.5 Chapter conclusion

This chapter provided an answer to the following research question: *What are the basic concepts of metamodels, business models, enterprise architectures and business model – enterprise alignment approaches and what are the limitations of current approaches?* Models are a formal specification of reality, while metamodels and ontologies are models which are an explicit, shared and formal specification of a conceptualization. Business models are models that aim to express the business logic of an organization, while enterprise architecture generally defines the implementation of the business model through a description of business processes, information and ICT. A limitation of business models is that they often neglect to address formal ICT driven implementation aspects and are often presented in a formal representation. A limitation of enterprise architecture models is that they often miss more economical oriented business model components. A few researchers have proposed approaches to align business models with enterprise architectures. However, current approaches are often intra-organizational, have a single-level of analysis, are heavyweight by having many model concepts or are using an informal approach. This has led to the identification of three knowledge gaps:

1. *K2 Current literature on business models has mainly proposed informal business model representations and lacks a focus on formal business model implementation design.*
2. *K3 Current literature on enterprise architecture literature often lacks an economical business model perspective.*

3. *K4 Current literature on business model –enterprise architecture alignment lacks a lightweight formal approach which can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.*

To address these knowledge gaps, this study aims to develop lightweight *formal* metamodels and a corresponding modelling procedure in UML for networked business model – enterprise architecture alignment. The formal approach supports networked enterprises with a multi-level description, analysis and visualization of their technological business model implementation through enterprise architecture concepts. For the development of the metamodels and modelling procedure, the theoretical foundations of the VISOR business model framework and the VIP business model – enterprise architecture framework will be used since (1) they both have a networked perspective, (2) VISOR is developed for analysis of digital ecosystems and digital platforms (which suits the application domain of this study, Industry 4.0), (3) VIP allows for multi-level analysis and (4) VIP is a *lightweight* conceptualization to bridge the gap between business models and enterprise architectures. Lastly, ArchiMate was selected for the enterprise architecture component of the metamodels and modelling procedure since (1) ArchiMate has an integrated approach for modelling all aspects of an organization (2) the use of ArchiMate is advocated by its representativeness and wide acceptance in the academic and practitioner communities (Iacob et al., 2012). Design requirements will be elicited from the theoretical foundations of the VISOR and VIP frameworks through theoretical analysis in the following chapters.

# Chapter 4 Research approach


In this chapter, the research approach will be used to develop the metamodels and modelling procedure will be presented. This chapter is structures as follows. First, the research strategy, comprising of design steps and activities, data collection and data analysis will be discussed. After that, the research methods used for collection and analysis of the data will be presented and discussed. Lastly, data collection issues will be explored as well.

## 4.1 The research strategy

As described in chapter one, the overall research strategy comprises of the four ADR stages with two BIE cycles of the ADR method of Sein et al. (2011). For the specific design steps and activities in the two BIE cycle of ADR, the design cycle of Verschuren and Hartog (2005) will be used. The different design steps and activities, as well as the data which is collected and analysed in each design step, are displayed in table 4.1. The first ADR stage is performed via a desk study through a literature review, which has resulted in the knowledge gaps as discussed in the previous chapters. Next, in the first BIE cycle, design requirements are elicited through theoretical analysis (Johannesson & Perjons, 2014) on mainly the theoretical foundations of VISOR and VIP (where these specific theoretical foundations will also be compared to other similar research, see section 5.1) and the problem statement. This will result in a set of initial design requirements. These initial design requirements will subsequently be used to develop initial design specifications of the metamodels and the modelling procedure. In the next step, the initial design requirements and design specifications will be discussed with researchers through ex ante evaluation interviews (ex-ante evaluation means that the artefact is evaluated without being used or even being fully developed (Johannesson & Perjons, 2014)). Feedback from these interviews will be used to refine the initial design requirements and design specifications. In the following design iteration of the BIE stage, the artefact will be applied with practitioners to the Industry 4.0 domain. During the application, the design requirements and design specifications of the artefact will be discussed as well, which will lead to a further refinement of the design requirements and the design specifications.

Table 4.1 Research strategy with different design steps and data collection and analysis.

| ADR cycle | Design step | Data collection | Data analysis | Output |
|---|---|---|---|---|
| **Problem formulation** | a. First hunch | Desk study | Literature review | Problem statement |
| | | | | Knowledge gaps |
| | | | | Research objective (or design goal) |
| **BIE Design iteration 1** | b. Define initial requirements | Desk study | Theoretical analysis | Initial design requirements for metamodels and modelling procedure |
| | b. Develop initial design specification | Desk study | Theoretical analysis | Initial design specification for metamodels and modelling procedure |
| | c. Ex ante evaluation of initial design requirements and design specification | First round interviews | Qualitative data analysis with coding | -Refined design requirements for metamodels and modelling procedure<br>-Refined design specification for metamodels and modelling procedure |
| **BIE Design iteration 2** | d. Implementation of metamodels and modelling procedure | Desk study and second-round interviews | Literature review and qualitative data analysis with coding | Applied artefact to application domain (i.e. model instantiations for the metamodels) |
| | e. Ex post evaluation of refined design requirements and design specification | Second-round interviews | Qualitative data analysis with coding | -Refined design requirements for metamodels and modelling procedure<br>-Refined design specification for metamodels and modelling procedure |
| **Formalization of learning** | - | - | - | -Adherence to ADR design principles<br>-Refined or new ADR design principles for similar settings<br>-Final design specifications of metamodels and modelling procedure |

## 4.2 Research methods for data collection: Desk study and Interviews

Data will be collected through a desk study, complemented with semi-structured interviews.

### *4.2.1 Desk study*

The first literature review is performed to be able to provide an overview of characteristics and challenges of the Industry 4.0 domain. This will lead to the identification of knowledge gaps. Furthermore, the characteristics of the domain of study will be used as input for the application of the artefact to the Industry 4.0 domain. The literature review on business models, enterprise architectures and business model – enterprise architecture alignment approaches results in limitations of these current approaches. These limitations will be stated as knowledge gaps that need further research.

Requirements can be elicited from many sources, such as surveys, case studies or theoretical analysis. For this study, theoretical analysis is used in the desk study to elicit initial design requirements for the design specifications of the artefact (Johannesson & Perjons, 2014). The theoretical foundations of VISOR, VIP and the problem statement will be the main source for the design requirements, however, additional academic literature on business models, business modelling and enterprise architecture will also be consulted, since (1) the internal relationships between the concepts of both frameworks are currently not formally defined and (2) the relationships between the concepts of both frameworks and ArchiMate are currently not formally defined. Analysis of additional literature to theoretically embed and define the relationships between the metamodel's concepts. The initial set of requirements will be used to develop the initial specification of the metamodels and modelling procedure. A disadvantage of theoretical analysis is that it lacks empirical evidence (Johannesson & Perjons, 2014). Therefore, other research methods as opposed to desk studies need to be consulted. Based on the need for empirical evidence, interviews will be conducted. These will be discussed in the following sections.

#### *4.2.2 Interviews*

Three types of interviews are often described in literature; unstructured, structured, and semi-structured interviews. With unstructured interviews, the interviewer has limited control over the direction of the conversation. Furthermore, the discussions are mostly informal since there is no predetermined interview guide. Unstructured interviews are useful for exploring new ideas when the domain is relatively new and unknown (Saunders, Lewis, & Thornhill, 2009). In contrast to unstructured interviews, structured interviews are following a rather strict sequence of questions, that the interviewer has prepared in advance, to gather specific information. One disadvantage of structured interviews is that they tend to limit the investigation of new ideas (Saunders et al., 2009). Semi-structured interviews are a combination of the two; the interviewer has a list of topics/questions that the interviewer wants to discuss and these are used to guide the interview. Since the interviews are semi-structured, it is allowed to divert from the interview guide. This allows for new ideas to be brought up during the interviews. In the following sections, the selection for the use of semi-structured interviews will be explained. Also, the interview set-up, objective and respondent selection will be discussed.

a) ***Round 1: Interviews with researchers***

The objective of the first round interviews was to evaluate whether the initial design requirements and design specifications satisfied general professional or practical criteria (Verschuren & Hartog, 2005), more specifically fidelity with real world phenomena (i.e. validity of the selected concepts and the relationships, since models aim to reflect real world phenomena (Verschuren & Hartog, 2005)), the consistency, coherency and completeness of the selected concepts. These criteria are similar to the evaluation criteria used in the evaluation of the Business Model Ontology of (Osterwalder, 2004). The first round of interviews were in the form of ex ante summative evaluation (meaning that the evaluation is part of an iterative process in which the artefact is still under design) (Johannesson & Perjons, 2014). The initial design requirements and design specifications were evaluated by researchers in the field of business models and/or enterprise architecture. Since the field of *formal* business model – enterprise architecture alignment is a relatively new field of study, new ideas on how to develop such metamodels and modelling procedure needed to be brought as well. Therefore, semi-structured interviews seemed most applicable for the first-round interviews.

b) ***Interview set-up and respondent selection first round interviews***

The first round consisted of open questions were used to gather the opinion of the researchers on the proposed initial design requirements and design specifications. Before the interviews were conducted, a PowerPoint presentation was sent to the interviewees. In the presentation, the research background, the design requirements of the metamodels and design specifications of the metamodels were presented as well. A convenience sampling approach was used where six experts were selected based on their background in (1) enterprise architecture and/or business model – enterprise architecture alignment and/or (2) business modelling in UML and/or (3) the development of the theoretical foundations of the selected frameworks/models that are used to develop the initial metamodels. The interviewee's name, organization, function, background and the date, location and the duration of the interviews are displayed in Table B.1 in Appendix B1. An interview guide was made beforehand, which also can be found in Appendix B2. The interviews were performed between 14-6-2017 and 4-7-2017.

c) ***Round 2: Interviews with practitioners***

The objective of the second-round of interviews was twofold. On the one hand, the interviewees were able to complement on the application of the metamodels and modelling procedure on Industry 4.0, which was based on the aforementioned desk study (see chapter two). On the other hand, after the practitioners had interacted with the artefact in the implementation phase, they were asked to evaluate the metamodels and modelling procedure on usefulness, ease of use and requirement fulfilment. Also, the second-round of interviews are in the form of summative interviews, meaning that the design is further refined based on the feedback from the interviews, from the perspective of ease of use, usefulness and requirement fulfilment (i.e. if the artefact addresses the design goal). Since both the Industry 4.0 and the business model – enterprise architecture domain are relatively new, semi-structured interviews seemed also most applicable for the second-round interviews.

d) ***Interview set-up and respondent selection second-round interviews***

The interviews were set-up as follows. First, the "empty" (i.e. not specified for the Industry 4.0 domain) metamodels and modelling procedure were presented. After that, the model instantiations for the Industry 4.0 domain, which were based on the literature review of chapter 2, were presented. In the first step of the interview, the experts could complement on the application of the metamodels and the modelling procedure on the Industry 4.0 domain. Secondly, be doing step one, the practitioners would also have to walk through the modelling procedure and the metamodels. This would allow them to form an opinion on the usefulness, ease of use and fulfilment of the design requirements. Summing up, conducting these interviews would lead to a fulfilment of the two objectives of the second-round of interviews, which are more specifically (1) complement and refine the application on the Industry 4 domain of the metamodels and modelling procedure and (2) evaluate the usefulness, ease of use and requirement fulfilment of the design specifcations. The second round of interviews consisted of a set of open questions which were used to gather the opinion of the practitioners on the proposed initial Industry 4.0 application. Next, a set of closed and open questions was used to evaluate the metamodels and modelling procedure on usefulness, ease of use and requirement fulfilment. Parts of the Unified Theory of Acceptance and Use of Technology (UTAUT) of Venkatesh, Morris, Davis, and Davis (2003) were used to define a questionnaire for the closed questions on usefulness and ease of use. In UTAUT, four variables with corresponding constructs are considered to have a significant impact on the user acceptance and user behaviour of a new (information) technology. Due to the scope of this research and time constraints, merely the most important constructs of this theory are used in this round of interviews. First, the construct *perceived usefulness* of the performance expectancy variable is considered to be the strongest predictor of the intention and use behaviour variables (Venkatesh et al., 2003). Therefore, the perceived *usefulness* of the performance expectancy variable will be used to evaluate the usefulness of the metamodels and modelling procedure. Secondly, the effort expectancy aspect concerns the ease of use of the (information) technology. The effort expectancy aspect has a significant impact on the usage contexts (Venkatesh et al., 2003). Therefore, the *ease of use* construct of the export efficiency variable is used in the evaluation as well. Next to the closed questions on usefulness, ease of use and requirement fulfilment, also open questions on the metamodels and modelling procedure were defined. These questions were used to ask for additional feedback on the answers on the closed questions (i.e. how could the ease of use be improved?). Again, before the interview was conducted a PowerPoint presentation was sent to the interviewees, which explained the research background, presented the metamodels and modelling procedure and the application of the metamodels and modelling procedure to the Industry 4.0 domain. A convenience sampling approach was used where four experts were selected based on their knowledge of (1) Industry 4.0/IoT and/or (2) their background in Business – IT alignment or enterprise architecture. The interviewee's name, organization, function, background and the date, location and the duration of the interviews are displayed in Table C.1 in Appendix C1. An interview guide was made beforehand, which can be found in Appendix C2. The interviews were performed between 14-6-2017 and 4-7-2017.

## 4.3 Data analysis and data issues

### *4.3.1 Data analysis for first round interviews*

A qualitative approach was used to analyse the interview data, since data collected from open questions could be seen as qualitative data. After the interviews were held, the audio recordings of the interviews were transcribed using the *Express Scribe Transcription* software. The interviews were written down as precise as possible, while filters and stop words were filtered out. Also, some detailed explanations of the researcher to the interviewees were summarized as well. The transcriptions were structured based on the questions asked during the semi-structured interviews. Next, the transcriptions were coded using the coding software *Atlas TI*. For the coding of the answers, two level coding was used. First, level-two topic coding with low inference was used, since this is very useful to summarize segments of data (Punch, 2009). The lower level-two codes where used for very specific feedback on the metamodels and modelling procedure based on the criteria. In the first-level coding, the level-two codes were interpreted and 'grouped', which resulted in the final list of level-one codes, comprising of the general topics discussed during the several interviews (Punch, 2009). These level-one codes were subsequently used to structure the analysis and discussion on how the basic concepts of VISOR, VIP, ArchiMate and concepts of additional sources could be used to develop set of refined metamodels and a corresponding modelling procedure. In Table B.2 in Appendix B3, these higher-order level-one codes are displayed.

### *4.3.2 Data analysis for second-round interviews*

Since the data collected from the open questions could be seen as qualitative data for the second-round interview also a qualitative approach was used to analyse the interview data. For the closed questions, the First, data from the second-round interviews was used to complement the initial application of the metamodels and modelling procedure, which was initially based on the literature review of chapter two. Again, the *Express Scribe Transcription* software was used to transcribe the interviews and *Atlas TI* was used to transcribe the interviews. Two-level coding was used, where the higher-order level-one codes comprised of the different metamodel concepts, and the level-second lower-order codes comprised of specific instantiations of the concepts as suggested by the interviewees. In the Table D.2 in Appendix D3, the coding scheme for the second-round interviews is displayed. Codes were only created for instantiations of the metamodel concepts which were not included already in the instantiations of the metamodels based on the literature review of chapter two.

### *4.3.3. Data issues*

As explained before, the semi-structured interviews will be mainly used to evaluate the design requirements and design specification during the BIE cycles of ADR. One potential issue is that the interviewees could lack sufficient knowledge to give their feedback. This data issue was mitigated by sending the interviewees an extensive PowerPoint presentation in advance, so that they could get an understanding of the background of the research. Another data issue is that with ex ante evaluations of the first round interviews, false positives from the interviewees can influence the design of the artefact (Johannesson & Perjons, 2014). Since the interviewees have not seen an implemented version of the artefact in the first-round interviews, it will be more difficulty for them to judge the design of the artefact, resulting in false positives. This can be mitigated by studying the background of each interviewee, and by subsequently taking the biased perspective of the interviewee into account when analysing the interview data.

## 4.4 Chapter conclusion

The research approach to reach the research objective has been described in this chapter. Through theoretical analysis, initial design requirements will be elicited and a design specification will be developed. These initial design requirements and design specifications will be refined through two rounds of interviews with researchers and practitioners. In total 10 respondents are interviewed in the two rounds. Interview data will be analysed through qualitative analysis with two-level coding. Potential data issues are mitigated by sending the interviewees a detailed description of the research background and by taking the biased opinion of interviewees into account when analysing the interview data.

# Chapter 5 BIE First design iteration


In this chapter, the results of the first design iteration will be discussed by answering research question three: A). *What are initial the design requirements and design specifications of the metamodels and modelling procedure, incorporating both business model and enterprise architecture concepts?* (B). *How do researchers evaluate these initial design requirements and design specifications?* The main objective of this research question is twofold (1) to elicit design requirements through theoretical analysis and develop a set of initial metamodels and a modelling procedure and (2) to refine these initial metamodels and modelling procedure by processing feedback from researchers. The evaluation will be based on the completeness, coherency, validity, consistency and the way the various metamodels are levelled. The results of the evaluations will be used to develop a set of refined design requirements and a set of refined design specifications for the metamodels and modelling procedure.

This chapter is structured as follows. First, design requirements retrieved from the desk study will be discussed. After that, the initial specifications of the metamodels and modelling procedure will be developed. Lastly, the results of the interviews will be discussed, which will subsequently be used for the refinement of the design requirements and design specifications.

## 5.1 Define initial design requirements

The step after a description of the first hunch (see chapters 2 and 3) in the designing cycle of Verschuren and Hartog (2005) is the definition of the design requirements. Theoretical analysis was used to elicit the design requirements, so all design requirements are derived from literature and the problem statement (Johannesson & Perjons, 2014). As stated before, most design requirements are elicited from the theoretical foundations of the selected VISOR and VIP, however, additional academic literature is also consulted (as can be seen in the 'source' column of each design requirement description). The initial design requirements will be discussed in detail in this section.

### *5.1.1 Functional requirements*

The following nine design requirements are defined as functional design requirements, meaning that they indicate the functions the artefact should fulfil once it realized, given the design goal (i.e. research objective) (Verschuren & Hartog, 2005).

| # | Functional design requirement | Source |
|---|---|---|
| 1 | The metamodels should describe and visualize the value proposition and the composition of the different elements of the value proposition. | Adapted from 'value proposition' concept of VISOR of (El Sawy & Pereira, 2013) and 'value component' concept of VDML (OMG, 2012). |

The first functional design requirement states that the metamodels should describe and visualize the value proposition and the components of the value proposition, based on the definition of the 'value proposition' concept of VISOR (El Sawy & Pereira, 2013). The value proposition describes the service or product, associated with value to the end-customer and is an essential element in most business models (Zott et al., 2011). Part of the requirement states that the metamodels also shall define the different elements of the value proposition. This is retrieved from the 'value component' concept of the Value Delivery Metamodel (VDML) (OMG, 2015). The 'value proposition component' is especially relevant from a networked enterprise perspective, where various actors deliver the different components of the joint value proposition.

| # | Functional design requirement | Source |
|---|---|---|
| 2 | The metamodels should describe and visualize the value interface and value ports through which the value proposition is delivered. | Adapted from 'value interface' concept of VISOR (El Sawy & Pereira, 2013), the 'relations' concept of the Business Model Cube (Lindgren and Rasmussen 2013), the 'channel' concept of the BMC (Osterwalder 2004) and the 'value/interface ports' concepts of Rasiwasia (2012) and J. Gordijn et al. (2000) |

The second functional design requirement states that the metamodels should describe and visualize the value interfaces and corresponding value ports through which value propositions are exchanged. The value interface is also an essential component of a value proposition, since this is the place where the networked enterprises interact with the end-customer, and is thus an important concept in many business models (Zott et al., 2011). In other words, the value proposition is delivered through value interface to the end-customer by the network enterprises. This requirement is mainly based on the definition of the 'interface' concept of the VISOR business model framework (El Sawy & Pereira, 2013), however, numerous other business model also incorporate this concept, such has the 'relations' concept of the business model cube (Lindgren & Rasmussen, 2013), the 'channel' concept of the BMC (Osterwalder, 2004) or the 'value interface' concept of the e3 value model (J. Gordijn et al., 2000). Furthermore, the value interface concept of the e3 value model J. Gordijn et al. (2000) consist of in-ports and out-ports. The ports allow for a detailed analysis of the exchange of the values between networked enterprises. Therefore, to be able to perform this analysis during the implementation of the business model, the metamodels should facilitate analysis of exchange of value and information related objects through ports and interfaces. According to J. Gordijn et al. (2000) This helps to define the viability of the business model, by checking whether value is shared evenly in the network.

| # | Functional design requirement | Source |
|---|---|---|
| 3 | The metamodels should describe and visualize the service platform upon which the actors interact which each other. | Adapted from 'service platform' concept of VISOR (El Sawy & Pereira, 2013). |

The third functional design requirement states that the metamodels should describe and visualize the service platform. In digital ecosystems, which is the domain of this research, digital service platforms play a vital role. Networked enterprises interact with each other and with the end-customer over these platforms. Therefore, it is essential that the metamodels are able to describe and visualize the digital service platform, since this forms often the centre of the interaction between the actors. This requirement is derived from the definition of the 'digital service platform' concept of VISOR (El Sawy & Pereira, 2013).

| # | Functional design requirement | Source |
|---|---|---|
| **4** | The metamodels should describe and visualize the organizing model which defines how the networked enterprises will organize themselves to effectively and efficiently deliver the value proposition. | Adapted from 'organizing model' concept of VISOR (El Sawy & Pereira, 2013), the organization domain of STOF (Bouwman et al., 2008) and 'networks' concept and 'relations' concepts of the Business Model Cube (Lindgren & Rasmussen, 2013). |

The fourth functional design requirement states that the metamodels should describe and visualize the organizing model (e.g. through an integrated network with suppliers and distributors). It is of importance that the metamodels force modellers to think about the organizing model, since (1) this will prevent misassumptions about the value network which realizes the value proposition (El Sawy & Pereira, 2013) and (2) helps to identify the partners which are needed to realize the value proposition. This requirement is mainly based on the definition of the 'organizing model' concept of VISOR (El Sawy & Pereira, 2013). However, other business models, such as the STOF model (Bouwman et al., 2008) or the business model cube (Lindgren & Rasmussen, 2013) also include concepts to define the network, such as the 'organization domain' concept of STOF or the 'networks' and 'relations' concepts of the business model cube (Lindgren & Rasmussen, 2013).

| # | Functional design requirement | Source |
|---|---|---|
| **5** | The metamodels should describe and visualize the sharing of costs and revenues amongst the networked enterprises. | Adapted from 'revenue model' concept of VISOR (El Sawy & Pereira, 2013), finance domain of STOF (Bouwman et al., 2008) and the 'value formula' concept of the Business Model Cube (Lindgren & Rasmussen, 2013). |

The fifth functional design requirement states that the metamodels should describe and visualize cost and revenue sharing. It is essential that each networked enterprise benefits evenly, since otherwise the viability of the business model cannot be ensured. Unfair sharing of profits and costs leads logically to unsatisfied networked enterprises (El Sawy & Pereira, 2013), which occurred in several case studies in research of S. Solaimani (2014). As a consequence, partners might leave the value network, which harms the realization of the business model. Therefore, the metamodels should help designers in defining the sharing of profits and costs. This requirement if mainly derived from definition of the 'revenue model' concept of the VISOR framework (El Sawy & Pereira, 2013), however, other business models also investigate financial issues, such as the finance domain of the STOF model (Bouwman et al., 2008) or the value formula of the business model cube (Lindgren & Rasmussen, 2013).

| # | Functional design requirement | Source |
|---|---|---|
| **6** | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects, information and knowledge objects. | Adapted from the 'value exchange' concept and the 'value object' concepts of the e3 value model (J. Gordijn et al., 2000), and the 'data object', 'information object' and 'knowledge object' concepts of VIP (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). |

The sixth functional design requirement states that the metamodels should describe and visualize multi-level exchanges between networked enterprises. Since insights in the interactions between networked enterprises through exchanges of value objects (i.e. resources and capabilities), data, information and knowledge objects are required to determine the feasibility and viability of the business model (S. Solaimani, 2014), the metamodels should allow for the description of these interactions on these particular levels (values, information/knowledge and processes). This results in a metamodel that facilitates multi-level and holistic analysis, taking into account a value, information/knowledge and process perspective.

| # | Functional design requirement | Source |
|---|---|---|
| **7** | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and inter-and intra-organizational business processes performed by actors. | Adapted from 'value activity' concept of the e3 value model (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) the 'information flow' concept of VIP (S. Solaimani, 2014) and 'business process' concept of ArchiMate (Lankhorst, 2017). |

The seventh functional design requirement states that the metamodels should describe and visualize creation or processing of value and information related objects. The value objects and information/knowledge objects are created by networked enterprises through the execution of value activities and business processes (J. Gordijn et al., 2000; Lankhorst, 2017; S. Solaimani, 2014). To discover who is responsible for the creation of what value objects or information/knowledge related objects, the metamodels should allow for the investigation of these aforementioned aspects. This will prevent misassumptions about who is responsible for the creation what objects, which are eventually required for the realization of the value proposition (S. Solaimani, 2014). Furthermore, it helps to identify key activities and processes which are essential for the realization of the business model. The design requirement includes both the 'value activity' and 'business process' (where business processes could be either inter-organizational or intra-organizational (Legner & Wende, 2007; Mueller, Schuldt, B., Morisse, & Petrikina, 2013)) concepts, based on the argument of Gaaloul and Proper (2012), who state that both concepts differ in their semantics. The 'value activity' concept is more related towards the networked business model and thus has a more economical and networked focus, whereas the business process concept has a more operational or functional and organizational focus, and thus is more related to the enterprise architecture.

| # | Functional design requirement | Source |
|---|---|---|
| **8** | The metamodels should describe and visualize which actor has access to what value, information, data and knowledge objects. | Adapted from 'information access' concept of VIP of (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). |

The eighth functional design requirement states that the metamodels should describe and visualize which networked enterprise has access to what value or information related objects. The networked business model is built upon the availability of value, data, information and knowledge objects. Therefore, it is important that actors know who has access to certain objects to be able to determine the feasibility and viability of the business model. If for example one actor has access to certain knowledge, but does not want to provide access to this knowledge to other actors, this will hinder the implementation of the business model. In the VIP framework, only the 'information access' concept is included. However, it is argued that the access to non-related information objects (i.e. the value objects) such as funding is equally important. Therefore, this requirement also states that the metamodels should also give insights into who has access to value objects.

| # | Functional design requirement | Source |
|---|---|---|
| **9** | The metamodels should be used in a step-by-step modelling procedure, starting from the value propositions, where it from there on helps to define all the required business model implementation concepts to realize the networked value proposition. | Based on the metamodelling concepts of Kühn et al. (2003) and the modelling sequence of VISOR (El Sawy & Pereira, 2013). |

The last functional design requirement states that the metamodels should be used in a corresponding modelling procedure. According to Kühn et al. (2003), a metamodels define the basic concepts and the relationships between these concepts of a particular modelling language. How the modelling language should be used to end up with results (i.e. models) requires a modelling procedure which guides modellers through a step-by-step process. Since networked business models start with the networked value proposition and configures the network of actors delivering it around it, the modelling procedure should start with a formulation of the value proposition (El Sawy & Pereira, 2013; Livari et al., 2016).

#### *5.1.2. Non-functional requirements*

The following four design requirements are defined as non-functional design requirements, meaning that they do not address the functionality, but instead general qualities such as usability or form related qualities ) (Johannesson & Perjons, 2014; Verschuren & Hartog, 2005).

| # | Non-functional requirement | Source |
|---|---|---|
| **1** | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts. | Based on the limitation of current business models and business model – enterprise architecture approaches, which often have an informal representation where formal relationships between the concepts are not defined (see section 1.2, section 3.2.3 and section 3.4.3). |

The first non-functional design requirement states that the metamodels should define formal relationships between the model concepts. Since currently the VIP and VISOR frameworks are conceptual frameworks, rather than concrete modelling languages, they lack concrete metamodels and a modelling procedure that can be used to describe, analyse and visualise business models and business mode implementations. In other words, no explicit concepts are defined and no explicit well-defined relationships amongst these concepts are formulated yet. Furthermore, the relationships between, on the hand the business model concepts of VISOR and VIP and on the other hand the enterprise architecture concepts of ArchiMate, are not well-defined either, so the metamodels also should define relationships between the business model (implementation) concept of VISOR and VIP and the enterprise architecture concepts of ArchiMate.

| # | Non-functional requirement | Source |
|---|---|---|
| **2** | The metamodels should be compatible with UML-modelling standards based on MOF. | Based on the limitation of business models and current business model and business model – enterprise architecture alignment approaches, which are currently often informal, expressed in in natural language (Al-Debei & Avison, 2010; Heyl, 2014a; Pateli & Giaglis, 2004)(see section 1.2, section 3.2.3 and section 3.4.3). |

The second non-functional design requirement states that the metamodels should be compatible with UML. Since most business models and business mode-enterprise architecture approaches are currently not defined in a formal annotation, the metamodels should be compatible with UML standards. UML is selected as modelling language since, (1) the choice of UML is safeguarded by its representativeness and wide acceptance in the academic and practitioner communities and (2) UML and ArchiMate could be used in combination (Armstrong et al., 2013). This makes it easier to relate the business model concepts to the ArchiMate core framework. Lastly, by being a formal language it addresses the issue of ambiguity, misinterpretation and limited ability to understand an informal design (also discussed in section 1.2 and section 3.4.3). According to Van der Wielen (2017), UML gives a better understanding of the related objects and attributes of a business model. Furthermore, UML allows to better visualize the business model design (Van der Wielen, 2017).

| # | Non-functional requirement | Source |
|---|---|---|
| **3** | Relationships between concepts should be defined according to the ArchiMate meta relationships (such as 'assignment' or 'realization' relationships). | Adapted from relationships of ArchiMate (Lankhorst, 2017). |

The third non-functional design requirement states that the relationships in the metamodels should be based on the meta-relationships of ArchiMate to allow for an easy transition and interpretation of the relations between the concepts and to ensure consistency in the way relationships between metamodel concepts are defined.

| # | Non-functional requirement | Source |
|---|---|---|
| **4** | The metamodels should be comprehensible – i.e. the ease with which an artefact can be understood or comprehended by business oriented stakeholders and IT oriented stakeholders. | Based on general design science requirement of design science approach (Johannesson & Perjons, 2014) and the need for a formal *lightweight* business model – enterprise architecture approach (see discussion on lightweight approaches of sections 1.2 and section 3.4.3). |

The last non-functional design requirement states that the relationships in the metamodels should ease to understand and is mainly derived from general design science and the need for a formal *lightweight* approach for business model – enterprise architecture alignment approach. and requires the metamodels to be understandable for the end-users (both business oriented stakeholders and IT oriented stakeholders).

## 5.2 Develop initial design specifications

In the next step of the design cycle of Verschuren and Hartog (2005), the functional and non-functional design requirements were used to develop the first design specifications. The development of the artefact is a creative process. The primary input for this creative process are the design requirements and the knowledge elicited from the literature. Since this step is creative process, this step does not have any specific research method (Johannesson & Perjons, 2014). The outcome of this step is not discussed in detail in this report to keep the size of the report reasonable. Nonetheless, a high-level overview of the design specifications is provided to get a basic understanding of the design. The first design specifications resulted in a set of five metamodels that were layered and placed on top of the existing ArchiMate metamodels. A high-level overview is displayed in figure 5.1. On top, the finance layer consists of the revenue concepts of the VISOR business model framework and several other concepts to define the revenue model in more detail. The layer aims to fulfil functional design requirement five. The resource - capability layer is a generalization of the value, data, information and knowledge objects of VIP, and is added to be able to relate the costs and revenues generated by these resources and capabilities to the finance layer. The value, information and inter-organizational process layers are added to fulfil to functional design requirement one, two, three, four, six, seven, eight and nine. The four lower layers in the design specification are the metamodels of the business, application, technology and physical layers of ArchiMate 3.0 (Lankhorst, 2017). The concepts of the layers above the ArchiMate layers are related to each other via formal well-defined UML relationships (fulfilling non-functional design requirement one, two and three). Furthermore, ArchiMate was perceived as more intra-organizational then inter-organizational, based on the arguments of Rahmati (2013) and Gaaloul and Proper (2012). So, the layers above the ArchiMate layers aimed to define the interactions between networked enterprises, whereas the ArchiMate layers were perceived as the 'internal' enterprise architecture of the organizations, supporting the inter-organizational interactions. For a detailed elaboration on the initial metamodels, an extensive table containing all the definitions of the used concepts, well-defined relationships and class attributes is available on request.

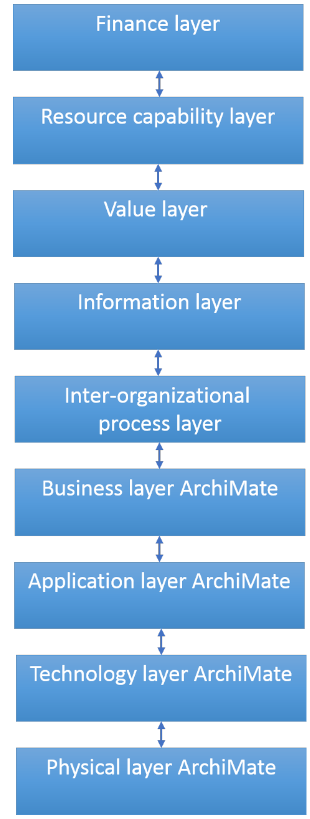



Figure 5.1 High-level overview of initial metamodels

The initial modelling procedure started at the value layer by defining the joint value proposition. From there on, it guided the modeller through a step-by-step process to define the realization of the business model by following various well-defined relationships between the various business model and enterprise architecture concepts. This resulted in concept instantiations for the value, information, inter-organizational process and ArchiMate layers. In the later stages of the modelling procedure, these concepts could be generalized into either resources or capabilities in the resource capability, which in the end should allowed for a calculation of costs and revenues. Also, this modelling procedure is available on request.

## 5.3 Evaluation of initial design requirements and design specifications

Following the research strategy of table 4.1 of section 4.1, the next step in the design cycle was the first round of interviews with the researchers to elicit empirical evidence on the design requirements and design specification and to retrieve feedback on the initial design of the artefact. Since the interviews were semi-structured, new topics were brought up during the interviews. These mainly had to do with the design specification of the metamodels and modelling procedure. The obtained insights from the interviewees were used to refine the initial design requirements and the design specifications. The feedback from the evaluation will be discussed in the following sections. The section is structured based on the coding as explained in Appendix B1.

## 5.4 Define refined design requirements

### *5.4.1 Feedback on consistency, completeness, coherency and validity*

A first point of discussion was the inclusion of 'value proposition component' concepts in functional design requirement one and the subsequent design specifications. Based on these discussions it was decided that merely a concept for the value proposition will be included and that value proposition components are excluded. This design change was based on two arguments. First, including these concepts would lead to a more complex model. The interviewees stated this would make the metamodels more heavyweight, while a lightweight approach is preferred. Second, since the theoretical foundations of VIP and VISOR do not include concepts that can be used to describe value proposition components, including these concepts was perceived as inconsistent by interviewees E/2 and E/6. Therefore, the 'value proposition component' concepts of the VDML language (OMG, 2015) are removed from functional design requirement one and the design specifications.

| # | Initial functional design requirement | Refined functional design requirement |
|---|---|---|
| **1** | The metamodels should describe and visualize the value proposition and the composition of the different elements of the value proposition. | The metamodels should describe and visualize the value proposition. |

A second point of discussion was the inclusion of the 'value port' concepts in functional design requirement two and the subsequent design specifications. The ports were initially added to be able to model the exchanges of value and information/knowledge objects in UML. A similar approach was taken by Rasiwasia (2012), who also modelled the port concepts of the e3 value model in UML. However, according to the interviewees the value ports concepts should be removed because of three reasons. First, according to E/4, these concepts are too detailed compared to the level of detail and abstraction of the other metamodel concepts. Consequently, including these concepts would lead to an incoherent set of model concepts (where with incoherency is referred to the different levels of abstraction or detail). Second, as described before, the 'value port' concepts of the initial metamodels were based on the e3 value model. The port concepts of the e3 value model enforce reciprocity when modelling value exchanges. However, according to E/1, the reciprocity concept is not relevant in the context of networked enterprises or the Industry 4.0 domain. According to E/1, from an Industry 4.0 perspective, one could provide value or information, without receiving something in return directly. In contrast to this, E/2 argued that in a networked setting, it is also possible to receive value or information in return indirectly. The value or information object provided by one actor "moves" through the network, and at some point, the value provider receives something in return. E/4 confirmed this indirect exchange of value or information objects, however, the value ports concepts force to model the *direct* counterpart and it would thus not be possible to model an indirect counterpart. Third, E/6 and E/1 state that value ports and information ports were only included in the e3 value model to artificially model the exchanges of value objects in detail, and that the port concepts do not exist in reality. As such, inclusion of these 'value port' concepts were perceived as invalid by these interviewees. Based on these three arguments, the 'value port' concepts were removed from functional design requirement two and the design specifications.

| # | Initial functional design requirement | Refined functional design requirement |
|---|---|---|
| **2** | The metamodels should describe and visualize the value interface and value ports through which the value proposition is delivered. | The metamodels describe and visualize the value interface through which the value proposition is delivered. |

A third point of discussion of the exchange of knowledge objects in functional design requirement six and the subsequent design specifications. Part of functional design requirement six states that the metamodels should allow for a description and visualization of the exchanges of knowledge objects. This was perceived as invalid by various interviewees. This is illustrated by the quote below.

[1] *Knowledge is not something that is exchanged. The interpretation of certain information leads to knowledge. I cannot exchange knowledge with you, I can exchange information with you and you get knowledge from the interpretation of that information. But I mean, knowledge is inside of your head. You could write something down, and you read it and then you acquire knowledge. When it is on paper it is information. So, exchanging knowledge in itself is difficult.* (E/4).

Also, E/5 doubted the validity of the exchange of knowledge objects and argued that knowledge could reside in an organization, but that it is not an object that is being exchanged explicitly between networked enterprises. Instead, it is information or data that is being exchanged, and the interpretation of this data or information leads to the knowledge. It has to be mentioned that from a VIP (S. Solaimani, 2014) perspective, knowledge is included in the business model implementation analysis to determine which actors possesses the knowledge to make the business model work. From that standpoint, it is not necessarily the knowledge that is being exchanged that is of relevance in the analysis but rather the knowledge that being possessed by a certain actor. Therefore, it is decided that a 'knowledge object' concept is still included in functional design requirement six and the design specifications; however, the *exchange* of knowledge objects is excluded since the exchange of knowledge was perceived as invalid by various interviewees.

| # | Initial functional design requirement | Refined functional design requirement |
|---|---|---|
| **6** | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects, information and knowledge objects. | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects and information objects. |

A fourth point of the discussion was the distinction between inter-organizational business processes and intra-organizational business processes in functional design requirement seven and in the subsequent design specifications. The explicit distinction was perceived as invalid. This is illustrated by the following quote.

[2] *The distinction between the inter-processes and intra-processes should not be incorporated in the process model, since the borders of an organization could change easily.* [..] *Making that clear distinction is dangerous. It is an arbitrary distinction, since in ArchiMate the processes are just designed based on who executes them. You could describe the ecosystem as inter-organization processes and then below them the individual organizational process, that is possible.* (E/4).

This acknowledged by E/5 and E/6, who both state that the distinction between an inter-organizational and intra-organizational business process layer is invalid. Interviewee E/6 states that the same business process is sometimes executed externally and sometimes executed internally. By making an explicit distinction between inter-organizational and intra-organizational processes the whole model can become invalid when a certain process is outsourced. Based on the arguments, the distinction between inter-and intra-organizational processes is removed from design requirement seven. Nonetheless, as illustrated with the quote above, it is possible that processes can be used on two levels. Business processes from a VIP perspective are used to describe the *primary* processes that are required to ensure the feasible and viable of the networked business model, while the internal organizational processes are more focused on the *support* of these primary networked processes or internal operations. Since VIP aims to define the processes behind a networked business model, the supporting business processes are of less interest in the VIP analysis.

| # | Initial functional design requirement | Refined functional design requirement |
|---|---|---|
| **7** | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and inter-and intra-organizational business processes performed by actors. | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and business processes performed by actors. |

### *5.4.2 Feedback on model levelling*

A fifth point of discussion was the levelling of the different models based on the theoretical foundations of VISOR, VIP and ArchiMate. It was a new topic which was brought up in the interviews. With model levelling is referred to on the one hand the level of abstraction of the concepts and on the other hand the levelling between an ecosystem and organization-centric perspective of the various metamodels. In the initial metamodels, some concepts (based on the theoretical foundations of VIP) were added as substantive freestanding concepts, residing next to the concepts of ArchiMate. For example, the "primary business process" concept of the VIP framework was included next to the 'business process' concept of ArchiMate in the initial design specification of the metamodels. The concepts were included as separately based on the argument the difference in model levelling, which could be found in two aspects. First, it was assumed that ArchiMate concepts were more focused towards the internal enterprise architecture of an organization, while the concepts of VIP were more focused towards the network or ecosystem. This argument was based on the work of Rahmati (2013) and Gaaloul and Proper (2012). In the work of Gaaloul and Proper (2012), concepts of the e3 value model (which is of relevance since VIP consists of several e3 value model concepts) are compared to ArchiMate concepts. This is illustrated by the following quote, where Gaaloul and Proper (2012) compare the 'value activity' concept of the e3 value model (which is also included in the VIP framework) to the 'business process' concept of ArchiMate: *"the value activity concept, which in e3value usually has an external focus (i.e., it is modelled in as far it is relevant in a network of enterprises) whereas the business function in ArchiMate has more of internal focus (i.e. the focus is on modelling activities within an organization)"* Gaaloul and Proper, 2012, p. 136). Second, it was assumed that on the one hand the concepts of ArchiMate are on a more detailed and functional level of abstraction, while on the other hand the VIP concepts are on a more abstract and economical level of abstraction. This argument was also partly based on the work of Gaaloul and Proper (2012), who state that the ' value object' concept of the e3 value model is usually not modelled in ArchiMate due to ArchiMate's functional nature. These two arguments led to several discussions. First, E/2 (who was highly involved in the development of VIP) confirmed the difference between the more abstract and economical level of VIP and the more detailed and functional of ArchiMate. This is illustrated by the following quote:

[3] *I consider ArchiMate to be on a more functional level.* [..] *It is all mainly about the level of analysis, the level of analysis of VIP is more on a business level, and it attempts to transition towards the operationalization of the business model, however, the real functional aspect of a business model implementation is more related to ArchiMate.* (E/2).

Interviewee E/2 supported the inclusion of separate VIP concepts. According to interviewee E/2 the VIP framework is primarily used to analyse the essential value, information and process aspects of a business model implementation, without forcing the modeller to go into many details of the entire enterprise architecture. A business model does not include a refined operational fundament from where the business model needs to build. Especially in a networked enterprise environment, where multiple organizations need to work together to realize a certain value proposition it is of importance that for example the business processes of the various organizations could be connected to each other. It is not necessary that business processes are connected on every level, but solely on the levels which are necessary to realize the joint value proposition. VIP is there to map the necessary inter-organizational processes which need to be connected to each other to be able to realize the joint value proposition. When using the VIP metamodel, it is of importance to stay nimble and agile without going into detailed functional aspects since the amount of available time in this stage of the business model development is limited (which if often the case in digital environments (Gordijn 2003)). It starts from the networked value proposition, and from there it supports analysis of the essential value objects, information objects and processes that are required for the realization of that particular networked value proposition. According to E/2, VIP could be considered to act as an analytical intermediate lens (between the more economical business model and the more functional enterprise architecture) to determine the feasibility and viability of the new business model, as illustrated by the following quote.

[4] *It (i.e. using the VIP framework for analysing the operational feasibility and viability of a business model) really systemizes your reasoning. When you have a good feeling about your business model and your operational VIP model, you could spend your time, money and attention on a more comprehensive approach, with ArchiMate or another enterprise architecture modelling approach.* [..] *you first analyse if you have a good business model, where you move between VISOR and VIP, and after that, you will make a comprehensive ArchiMate blueprint.* (E/2)

However, interviewee E/1 and E/4 (who were both highly involved in the development of ArchiMate) argued against some of the arguments of E/2 and Gaaloul and Proper (2012). First, the interviewees stated that ArchiMate does not force enterprise architects to go into functional details. According to interviewee E/4, it is also possible with ArchiMate to stay at a higher level of abstraction without going into functional details, especially with the extension of the 'resource' and 'capability' concept of ArchiMate 3.0. Second, interviewees E/1 and E/4 stated that ArchiMate was especially designed for a networked enterprise environment and thus argued against perceiving ArchiMate as a more organization-centric focused modelling language. Based on these arguments, interviewees E/1 and E/3 argued that the VIP concepts could mostly be removed from the metamodels because the concepts of ArchiMate and VIP are very similar. Nonetheless, interviewees E/1, E/3 and E/4 acknowledged that ArchiMate does indeed lack specific concepts that are more economically focused, such as the "value activity" and 'value objects' concepts of the e3 value model and VIP. As such, interviewee E/1 proposed the design approach illustrated by the quote below:

[5] *I could use ArchiMate for everything that you want to describe for the Industry 4.0 domain, except for the exchanges of value.* [..] *so interpret ArchiMate from a VISOR perspective, so with a network perspective, and you do not use the nine concepts (of the single organization business model canvas of (Osterwalder, 2004)) since that is too limited in the networked setting. And then you add the concepts that you miss, especially the value, revenue and cost structure and then see where it takes you.* (E/1)

Interviewee E/5 stated to consider ArchiMate to be either a model or an enterprise architecture drawing tool. As a drawing tool, ArchiMate could indeed be used for most of the concepts of especially the information and process layer of VIP, because the syntax of for instance the "primary business process" is equal to the syntax of "business process" of ArchiMate. However, the way the concepts of VIP and ArchiMate are *used* in the modelling procedure determines the levelling of the concepts of the various models. This is illustrated by the following quote:

[6] *You just use the ArchiMate drawing tool, but the concepts are part of the VIP model. You could use your models at every level, you just have to say that you mean that concept of ArchiMate, however, you use it for that purpose. You could use ArchiMate in many different ways. You could say, I want to model the I and P in the ArchiMate drawing tool, but it is part of the VIP model and not of the ArchiMate model.* [..] *The I and P of Sam* (i.e. interviewee E/2) *have a certain meaning, and you could use drawing components of ArchiMate for that, that does not change anything of the meaning of those concepts. The I and P of VIP are there to describe the interaction between organizations.* (E/5).

The benefits of this way of modelling was acknowledged by interviewee E/4, who is highly involved in the development of ArchiMate. By using the theoretical foundations VIP as an intermediate between the networked business model and the enterprise architecture, the business analysts, IT managers and other users of the metamodels and modelling procedure could focus on the essential concepts of business model implementation without diving into details. When they are certain about a feasible operationalization of the business model, they could use all of the detailed ArchiMate concept to design their internal enterprise architecture that supports the networked interactions. Interviewee E/4 suggested that implementing this modelling procedure might result in two ArchiMate models, one for the network interactions and multiple for the individual organizations. However, a separated modelling conceptualization with a unique syntax including duplicated concepts like "Primary business process" and "business process" was considered to be redundant by interviewee E/4. Interviewee E/6 agreed on this. Interviewee E/4 suggested to integrate the different VIP concepts into ArchiMate concepts where possible to prevent duplication and confusion. This is illustrated by the following quote:

[7] *I understand the VIP way of looking, only I think that ArchiMate concepts could be applied when you take that approach. There seems nothing wrong to me with the VIP way of analysing. Only I think it is not necessary that you add an additional set of concepts but you just use what you have in ArchiMate. And apply that on two levels* [..] *You could say, we miss this and that concept* [..] *you could say it would be a suggestion to extend ArchiMate with for example the value activity concept, because it makes the transition to the business model easier. That could be a conclusion.* [..] *I would just look which concepts of VIP could be expressed in ArchiMate, and then look where you miss things in ArchiMate. That could be input for VISOR or ArchiMate. It could become a very thin substantive VIP model. (E/4).* (E/4).

Based on the arguments of E/1 and E/4 who state that (1) ArchiMate does not need be used on a detailed functional level and (2) ArchiMate can be used on an ecosystem level, it is decided that separate concepts of VIP that are similar to the syntax of ArchiMate concepts can be redundant in the design specifications. As a substantive model, the VIP concepts are not a duplication, however, when used in combination with ArchiMate it is a duplication. Therefore, the suggestion by interviewee E/4 is followed, where ArchiMate concepts are used in the VIP analysis were possible. Since, E/1 and E/4 did acknowledge that ArchiMate does lacks more economical oriented concepts, such as the value activity concepts, it is expected that during the integration effort of VIP concepts with ArchiMate concepts the more economical oriented concepts are still included as separate substantive concepts. This should make bridging the gap between the more abstract and economical oriented business model and the more detailed and functional oriented enterprise architecture easier. The result of an integration effort would be a *lightweight* metamodel, where the theoretical foundations of VIP are used as "filter" to select the essential ArchiMate concepts (with extension of the aforementioned more economical oriented VIP and e3 value model concepts) to analyse the business model implementation, without having to dive into the numerous ArchiMate concepts (ArchiMate 3.0 now includes over 50 metamodel concepts). Based on the discussion on modelling levelling, non-functional design requirement one is refined as below.

| # | Initial non-functional design requirement | Refined non-functional design requirement |
|---|---|---|
| 1 | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts. | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts, by formally *integrating* similar business model and enterprise architecture concepts. |

#### *5.4.3 Conclusion section 5.4*

Processing the feedback of the interviewees has resulted in a refinement of four functional design requirements and one non-functional design requirement. The complete list of functional and non-functional requirements, including the refined requirements is displayed in Table 5.1.

Table 5.1 List of functional and non-functional design requirements

| # | Functional design requirements |
|---|---|
| 1 | The metamodels should describe and visualize describe the value proposition. |
| 2 | The metamodels should describe and visualize describe the value interface through which the value proposition is delivered. |
| 3 | The metamodels should describe and visualize the service platform upon which the actors interact which each other. |
| 4 | The metamodels should describe and visualize the organizing model which defines how the networked enterprises will organize themselves to effectively and efficiently deliver the value proposition. |
| 5 | The metamodels should describe and visualize the sharing of costs and revenues amongst the networked enterprises. |
| 6 | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects and information objects. |
| 7 | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and business processes performed by actors. |
| 8 | The metamodels should describe and visualize which actor has access to what value, information, data and knowledge objects. |
| 9 | The metamodels should be used in a step-by-step modelling procedure, starting from the value propositions, where it from there on helps to define all the required business model implementation concepts to realize the networked value proposition. |
| **#** | **Non-functional design requirements** |
| 1 | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts, by formally integrating similar business model and enterprise architecture concepts. |
| 2 | The metamodels should be compatible with UML-modelling standards based on MOF. |
| 3 | Relationships between concepts should be defined according to the ArchiMate meta relationships (such as 'assignment' or 'realization' relationships). |
| 4 | The metamodels should be comprehensible – i.e. the ease with which an artefact can be understood or comprehended by business oriented stakeholders and IT oriented stakeholders. |

### 5.5 Development of refined design specification

In this section, the initial and the refined design requirements are used to refine the initial design specifications of the metamodels and modelling procedure. First, feedback on the initial design specification is discussed, after which the refined design specification will be presented.

#### *5.5.1 Arrangement of the different layers of initial design specification.*

The first discussion on the design specifications comprised of the way the different layers were defined in the initial design specifications of the metamodels was discussed. Interviewee E/2 suggested to reduce the number of layers (i.e. metamodels) and just build two metamodels (i.e. two layers) for the sake of simplicity. This would result in a metamodel which includes concepts that fulfil functional design requirements one to five (which are more related to the business model) and a metamodel which includes concept that fulfil functional design requirements six to nine (which are more related to enterprise architecture). E/2 suggested to use the theoretical foundations of VISOR to develop a formal representation of a networked business model (from here on defined as VISOR metamodel) and the theoretical foundations of VIP to develop a metamodel to bridge the gap between the business model and the enterprise architecture (from here on the VIP metamodel). Concepts of the VISOR metamodel would be input for the concepts of the VIP and ArchiMate metamodels and the metamodels would be connected via two interfaces. One interface would sit between the VISOR metamodel and the VIP metamodel, while the other interface would sit between the VIP metamodel and metamodels of ArchiMate. E/4 suggested a similar approach. The interviewee underlined the suggestion of E/2, and suggested to develop two layers, consisting of two metamodels. E/4 suggested a three-step modelling procedure, where the level of detail or abstraction increases as the modelling procedure is being executed. First the more abstract business model is described and visualized using the VISOR metamodel. After that, a first step towards operationalization of the business model is described and visualized using the VIP metamodel (where ArchiMate concepts are applied where possible). Lastly, the internal enterprise architecture is defined using the comprehensive ArchiMate metamodels of The Open Group (2017). According to E/4, implementing this modelling procedure would lead to a VISOR model instantiation and two types of ArchiMate model instantiations (one VIP ArchiMate model for the network and multiple ArchiMate models for the internal enterprise architectures).

Furthermore, interviewee E/5 suggested removing the resource capability layer, since it is inconsistent considering the levelling of the other concepts and models. The resource and capability layer includes concepts on a higher level of abstraction as compared to the concepts of the lower layers. In addition, E/5 criticized the finance layer, since it was placed at the top of the metamodel. The finance layer was placed on top of the initial metamodel layers, based on the work of Fritscher and Pigneur (2011), where the financial perspective is also placed on top of the architecture. However, according to E/5, this would suggest that the revenues and costs of an organization are steering in the design of the enterprise architecture. The revenue and costs of an architecture could be constraining the design of an enterprise architecture; however, they do not steer or lead the design of an architecture. They could rather be diverted from the enterprise architecture. Also, the finance layer is mainly based on the 'revenue model' concept of VISOR. Only defining one layer for one concept of the VISOR metamodel, without defining separate layers for the other concepts was perceived as inconsistent by interviewees E/2 and E/5. Thus, the resource capability layer and finance layer both need to be removed since they are inconsistent and confusing.

Processing the feedback on the design specifications would lead to the following layers: one layer comprising of the VISOR metamodel and one layer comprising of the VIP metamodel (still including ArchiMate concepts where possible). The metamodels are levelled as follows; the VISOR and VIP metamodel are more abstract and economically focused and are mainly used for the network interactions, while the ArchiMate metamodels are a more detailed and functionally focused and are mainly used for the internal enterprise architecture. By formally integrating concepts of the VISOR, VIP and ArchiMate metamodels with each other, the modeller could transition from one model to another model. In addition, this integration effort would solve the issue of the duplication of the VIP and ArchiMate concepts as well.

### *5.5.2 Use of UML*

The second on the design specifications comprised of the use of UML. First, to keep the metamodels lightweight, it was suggested to remove the class attributes from the metamodel were possible. According to E/5, terms as "Name= String" would confuse more business oriented people. E/4 also stated that the attributes could be removed, since the attributes are too detailed and are normally not included in metamodels. Second, several detailed relationships and concepts were discussed for each layer. Furthermore, interviewee E/4 suggested to remove the cardinalities to keep the metamodels lightweight.

### *5.5.3 Developing refined design specifications*

To develop a refined version of the design specification, the following design activities were performed:

a) Development of a refined modelling procedure.
b) Development of a refined set of metamodels based on the refined design requirements.
c) Formal integration of similar metamodel concepts.
d) Define last step of the modelling procedure

The results of each design activity will be discussed in the following sections.

a) ***Development of a refined modelling procedure.***

In figure 5.2, an UML activity diagram is presented which describes the modelling procedure. The modelling procedure is mainly based on the feedback from E/2, E/4 and E/6.

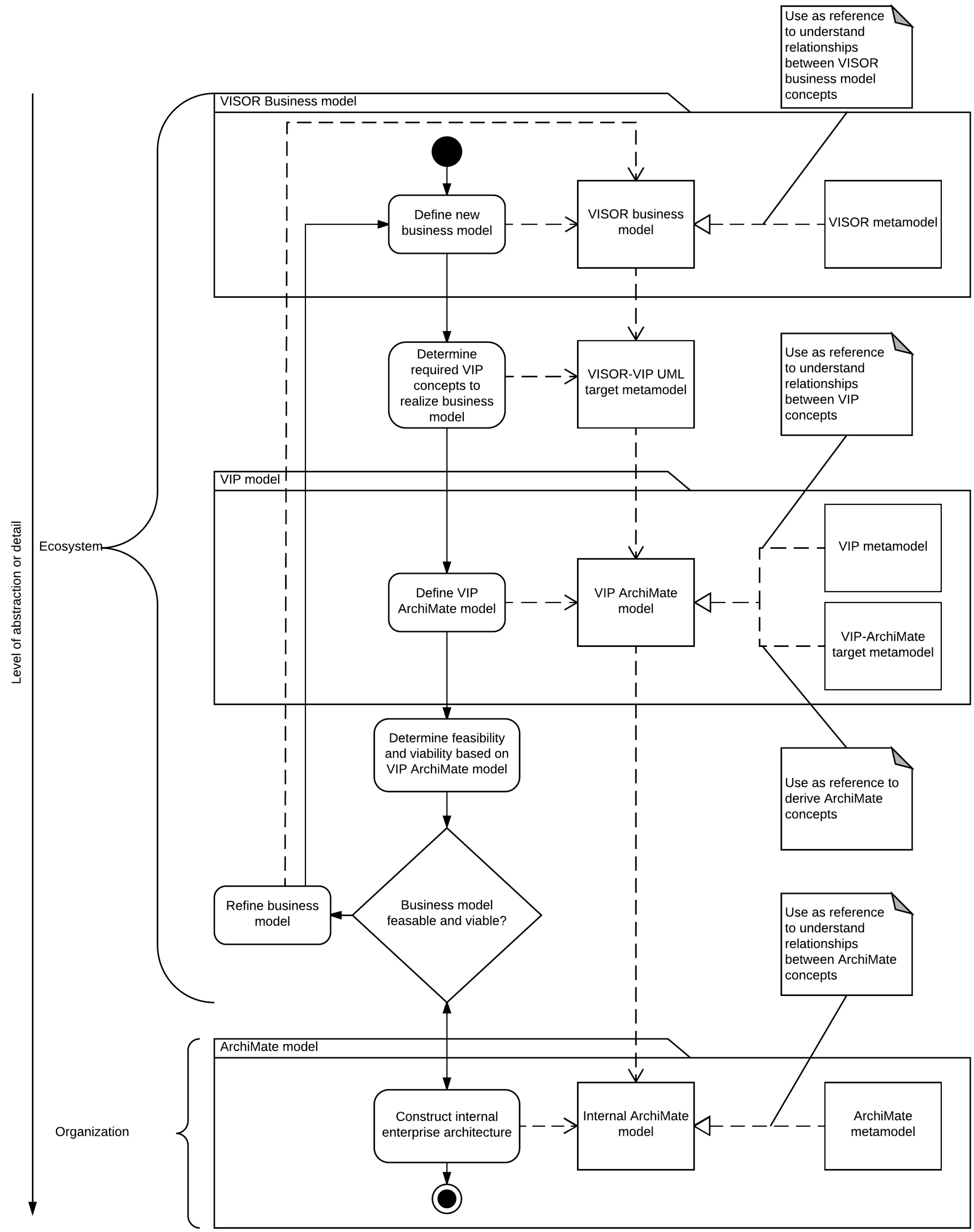



Figure 5.2 Modelling procedure in UML activity diagram

Following functional design requirement nine, the modelling procedure starts at the value proposition of the VISOR metamodel after which the business model implementation aspects are defined by a step-by-step modelling process. The relationships in the UML metamodels should support modellers in their design process by concluding implications that follow from the formal relationships between the model's concepts. Based on the discussions of section 5.4.2 on the model levelling, the VISOR UML metamodel (note: all the metamodels will be discussed in detail in the following sections) will be used on a higher level of abstraction, where for example 'Integrated partner network' could be used as specification for the 'organizing mode' concept. As can be seen on the left of figure 5.2, an arrow pointing downwards states that the level of abstraction or detail increases when the steps of the modelling procedure are followed. The separation of different levels of abstraction through the use of separate metamodels should modellers help to focus on the primary things first, without being forced to dive into various modelling details from the start.

The first step of the modelling procedure comprises of a specification of the business idea, where the VISOR metamodel used to structure the description and visualization of this business idea. After the business model is specified, the next step is towards the operationalization or implementation of the business model. In the second step, the VISOR-VIP target model will be used to define the required VIP concepts to realize the business model. The VISOR-VIP target model formally describes and visualized the relations between the concepts of the VISOR metamodel and the concepts of the VIP metamodel. This should support modellers to increasingly specify the business model implementation on a lower level of detail or abstraction. When step two is completed, the concepts of the VIP metamodel are defined for each part of the VISOR metamodel.

In the third step, the ArchiMate drawing tool is used to draw the interactions and interrelations between the networked enterprises. Two metamodels are used in the third step. First, the VIP metamodel describes and visualized the formal relations between the previous defined VIP concepts. To draw the VIP concepts in ArchiMate, the VIP-ArchiMate target metamodel is used translate the concepts of the VIP metamodel to ArchiMate concepts, which can be used to construct a VIP model in ArchiMate. The VIP-ArchiMate target metamodel structures the modelling process in ArchiMate by describing and visualizing how the various concepts are related to each other. While first only static concepts of the VIP metamodel were defined step two, the VIP ArchiMate model gives insights into how the networked enterprises should interact with each other to ensure the feasibility and viability of the business model on the level of value and information exchanges and business processes. This should give networked enterprises insights into how interactions, collaborations and relationships on these various levels can be facilitated in such a way that the business model can be sustained at an operational level.

In step four, discussions between the various networked enterprises should be conducted, based on the VIP ArchiMate model. These discussions should focus on the interfaces between the various VIP concepts, or on who is responsible for the delivery of the various VIP concepts. Based on these discussions, the feasibility and viability of the business model can be determined. The viability (recap: refers to the long-term profitability and market adoption of a business model) could for example be harmed due to unequal profit sharing. A problem on the level of feasibility (recap: refers to if the business logic is sound to be operationalized) could for example be heterogeneous business processes that cannot be connected to each other, problems regarding data exchanges due to privacy issues or incoherent and conflicting interactions between the networked enterprises (S. Solaimani, 2014). The role of the VIP ArchiMate model is here to support the discussion by describing and visualizing the interactions, interrelations and relationships between the various VIP components. This should make the discussions on the feasibility and viability of the business model implementation easier and less confusing. When certain issues occur that cannot be solved in the discussions (e.g. actors who do not want to provide access to certain information, due to privacy issues), the business model needs to be reconsidered. Therefore, the UML decision node is displayed in figure 5.2. It might be necessary to change the value proposition or to change the value interface through which the value proposition is offered to ensure the feasibility and viability of the business model. So, when at the decision node 'no' is selected, the modelling procedure should start again.

When 'yes' is selected the detailed, the functional implementation modelling step could be followed. In the fifth step, actors are going to analyse their organizations (so the ecosystem level focus shifts to an organizational focus, see left of the activity diagram of figure 5.2). In this step, actors can spend their time and money on a detailed modelling process, where they will use the all the various metamodels of ArchiMate. The level of detail increases dramatically here. They will use the specified concepts of the VISOR and VIP metamodels as input or context for their internal enterprise architecture (adapted from discussions with E/6). They should ask themselves questions such as "What do I need to organize internally to support the ecosystem business model?" or "What applications and hardware do I need to acquire to support the external ecosystem business model and deliver the required values (in terms of product/services and resources and capabilities), data, information, knowledge or business processes?". Still problems can occur in this stage. Therefore, the arrow in figure 5.2 between the decision node and the 'Construct internal enterprise architecture' activity is double arrowed. Consequently, if a certain actor could not realize the organization-centric enterprise architecture in such a way that is supports the VIP (ecosystem) ArchiMate model, the business model design still might need to be reconsidered. In the following sections, the metamodels will be discussed in detail.

b) ***Development of a refined set of metamodels based on the refined design requirements***

*1. VISOR metamodel*

The refined VISOR metamodel is displayed in figure 5.3. The metamodel mainly describes and visualizes the concepts of a networked business model corresponding to the theoretical foundations of VISOR. Since VISOR has the value proposition as its most important values, the concepts mostly are organized around the 'value proposition' concept (El Sawy & Pereira, 2013). In other words, most relationships are from the 'value proposition' concepts to the other concepts, since this force starting at the value proposition. From there on, one can reason on how the other concepts could be defined to realize the value proposition by concluding implications that follow from the formal relationships between the model's concepts. This decreases the chance of inaccurate assumptions about the value network and misinterpretations about value creation and value capture. Relationships between the metamodel concepts will be explained briefly. The 'value proposition' concept is *realized* (i.e. "*The realization relationship indicates that an entity plays a critical role in the creation, achievement, sustenance, or operation of a more abstract entity"*. The Open Group (2017)) when it is delivered to the end-customer through the 'interface' concept. The 'value proposition' concept is also *realized* by the interactions of the networked enterprises. The way the networked enterprises organize themselves is described in the 'organizing model' concept. Also, the 'digital service platform' concept supports the *realization* of the 'value proposition' concept. For example, the digital service platform Facebook support the realization of the value proposition of "connecting people around the globe". The 'value proposition' concept is *associated with* (i.e. *"An association relationship models an unspecified relationship, or one that is not represented by another ArchiMate relationship" (The Open Group, 2017)*) the 'revenue model' concept. For example, the value proposition of Netflix (which can be defined as a digital service which delivers TV shows and movies to the end-customer) is associated with a monthly subscription fee revenue model. Furthermore, the 'organizing model' concept *accesses* (i.e. *"The access relationship models the ability of behaviour and active structure elements to observe or act upon passive structure elements*". (The Open Group, 2017)) the 'digital service platform' concept to *realize* the 'value proposition' concept. Correspondingly, certain networked

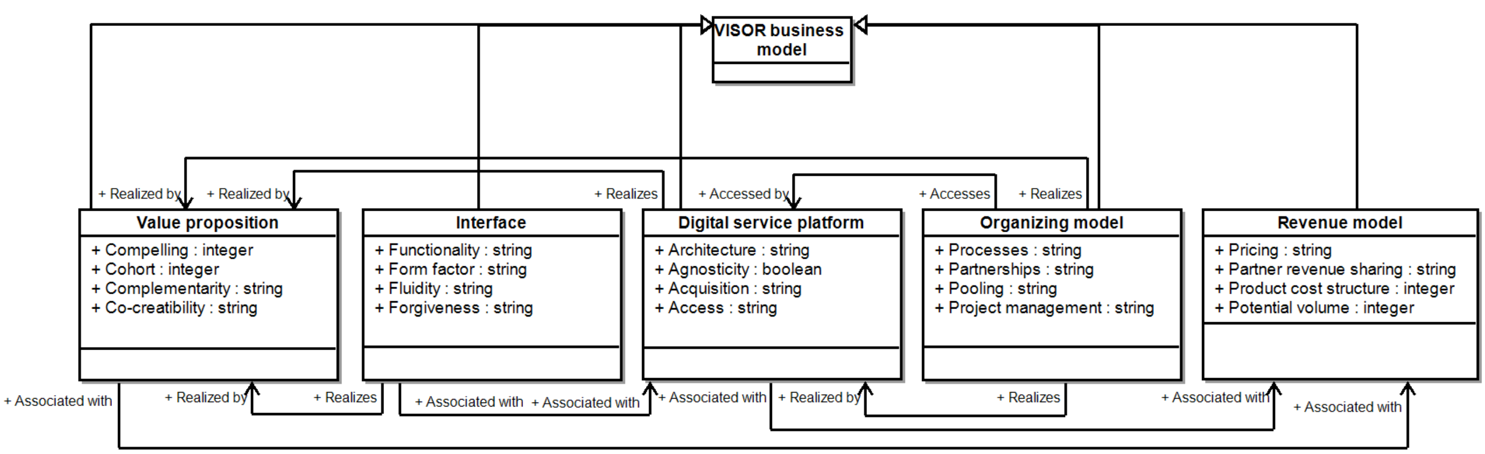



Figure 5.3 VISOR metamodel

enterprises need to be defined in the 'organizing model' concept who *realize* the 'digital service platform' concept (such as platform developers). The 'digital service platform' concept is also *associated with* certain implementation costs. Therefore, also an *associated with* relationship is defined between the 'digital service platform' concepts and the 'revenue model' concepts. The VISOR descriptors of El Sawy and Pereira (2013) are added as class attributes, which was suggested by interviewee E/6 during the first-round interviews. In Appendix A.1, the class attributes are explained in detail. The type of class attribute (e.g. String or Boolean) is based on the definition of the descriptor as provided by El Sawy and Pereira (2013). These class attributes could be used in scenario analysis to determine which descriptor is of importance in the new business model and which descriptor is of less importance. For a detailed elaboration on the use of descriptors in scenario analysis, please refer to El Sawy and Pereira (2013).

The metamodel includes concepts adhering to functional design requirements one to five. The formal relationships are added to fulfil non-functional design requirements two and three, which states that the relationships between concepts should be formally well-defined in UML and based on ArchiMate meta-relationships. In table C.1, the specific VISOR metamodel concepts are explained in detail as well as the adherence to the functional design requirements of each concept. In table C.2 in Appendix C2, the formal relationships between the VISOR metamodel concepts are discussed detail and the embedment of each relationship in literature is defined as well. The justification of the relationships between the metamodel concepts is based on an extensive literature study and feedback from the interviewees. Since the BMC (Osterwalder, 2004) and the e3 value model (J. Gordijn et al., 2000) are the only business models that have a (semi-)formal representation by being an ontology (Zott et al., 2011), these were the only business models which could be used as reference to define the relationships between the concepts. Since UML does only allow *realization* relationships between an UML 'class' concept and an 'interface' concept (which is more related to a software UML class model and the GUI through which the data is displayed to the end-user (Rumbaugh et al., 2005)), UML allows only *association* relationships between 'class' concepts. Furthermore, since the concepts of the VISOR metamodel are all on the same level of abstraction, also no UML *generalizations* or UML *compositions* relationships are used. As suggested by E/4 during the first round interviews, the ArchiMate meta relationships are used in the UML association roles, similar in the metamodels of ArchiMate (see (The Open Group, 2017)).

*2. VIP metamodel*

A refined VIP metamodel is displayed in figure 5.4. The metamodel mainly describes and visualizes the concepts of a networked business model implantation corresponding to the theoretical foundations of VIP. The relationships will be briefly explained. The 'actor' concept is *assigned to* (i.e. "*The assignment relationship expresses the allocation of responsibility, performance of behaviour, or execution*." (The Open Group, 2017)) the 'value activity' or 'business process' concept. The 'value activity' and 'business process' concepts *realize* or *access* the 'value object' concept (i.e. tangible resources (e.g., goods, contract, money) and intangible capabilities (e.g., service, credit, authority), where the 'value activity' concept *accesses* or *realizes* more economically oriented value objects and the business process more functional oriented value objects. The 'value activity' and 'business process' concepts *access* the various 'value object' 'data object', 'information object' and 'knowledge object' concepts in their execution. For example, the business process 'order processing' requires (i.e. is dependent on) the information object customer order in its execution. Next, the 'value object', 'data object', 'information object' and 'knowledge 'object' concepts are *associated with* certain actors. Therefore, the metamodel also shows the dependencies (resource dependencies) of the various networked enterprises on the level of values, information and processes. The 'value activity' concept is executed to *influence* (i.e. "*The influence relationship models that an element affects the implementation or achievement of some motivation element*." (The Open Group, 2017)) the 'value goal' concept via the realization or accesses of value objects. For example, an online movie streaming service provider (i.e. the actor) provides customized movie suggestions (i.e. the value activity) in their customized movie service (i.e. the value object) to the end-customer to influence the value goal of 'increasing customer satisfaction by customized movie suggestions'. Value goals are *associated with* actors. Lastly, also exchanges of values and information can be expressed and analysed through the use of the 'value exchange' and 'information exchange' concepts, where these types of object *flow* (i.e. "*The flow relationship represents transfer from one element to another.*" (The Open Group, 2017)) between the actors.

The metamodel includes a selection of concepts adhering to functional design requirement six to eight. A detailed description of each concept, the embedment of each concept in literature as well as the design requirement fulfilment can be found in table C.3 of Appendix C3. The justification of the defined relationships is based on an extensive literature study and feedback from the interviewees. A detailed elaboration on all the relationships between the metamodel concepts as well the embedment of each relationship in literature can be found in table C.4 of Appendix C4. The well-defined relationships between the metamodel concepts fulfil non-functional design requirements two and three, which states that the metamodel should establish well-defined formal relationships between concepts in UML which are based on the meta-relationships of ArchiMate.

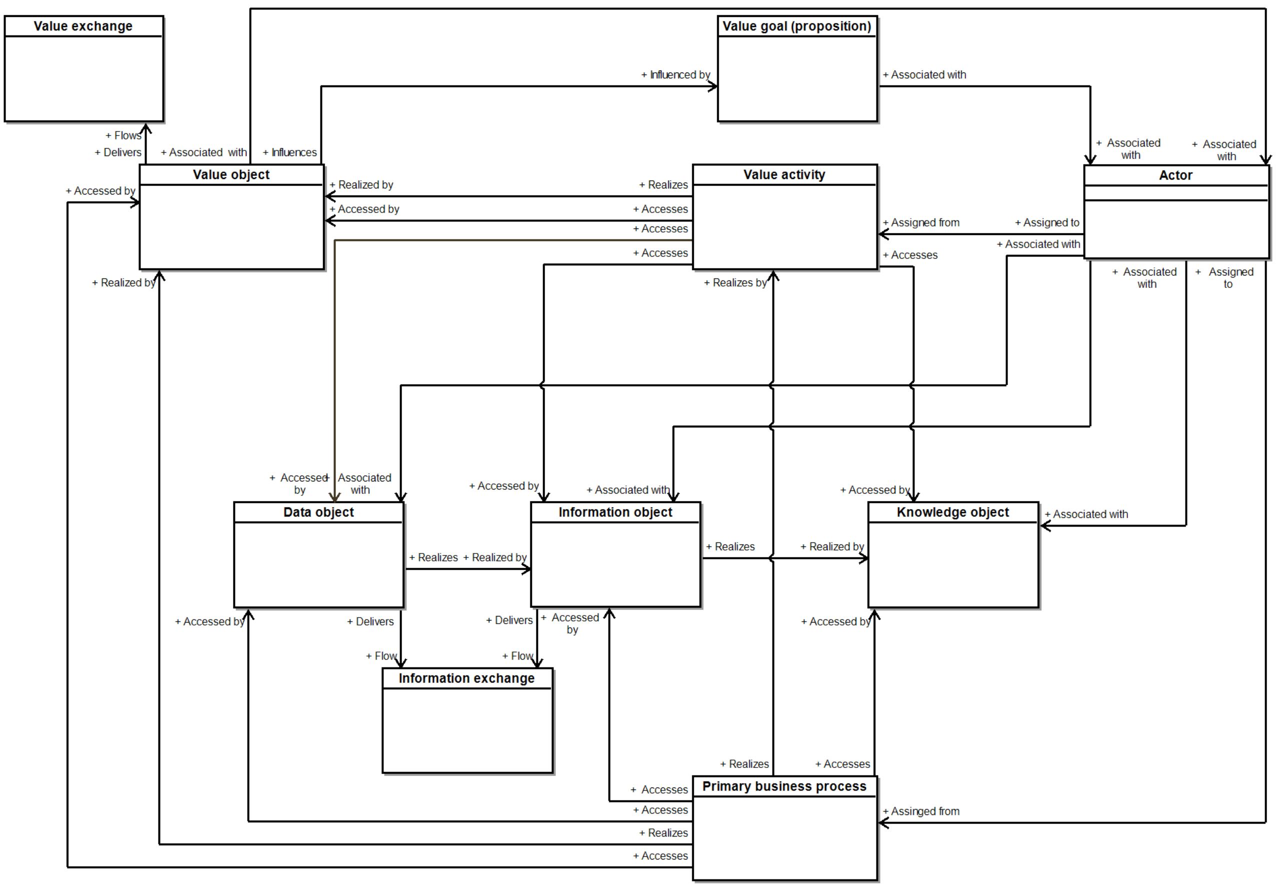



Figure 5.4 VIP metamodel

c) *Formal integration of similar metamodel concepts*

Next, following non-functional design requirement one, the aforementioned metamodels will be (1) formally integrated with each other and (2) integrated with ArchiMate concepts. To integrate the different concepts of VISOR and VIP metamodels, the work of Kühn et al. (2003) and Zivkovic and Kühn (2007) will be used, where rules are defined on how metamodels can be integrated. The mapping subtypes are: equivalence, relation (generalization, aggregation, composition, association, classification) and non-relation (see figure 5.5). A target metamodel is the result of the integration effort, where concepts of two source metamodels are integrated. The mapping of concepts could either based on equivalence of concepts or on a

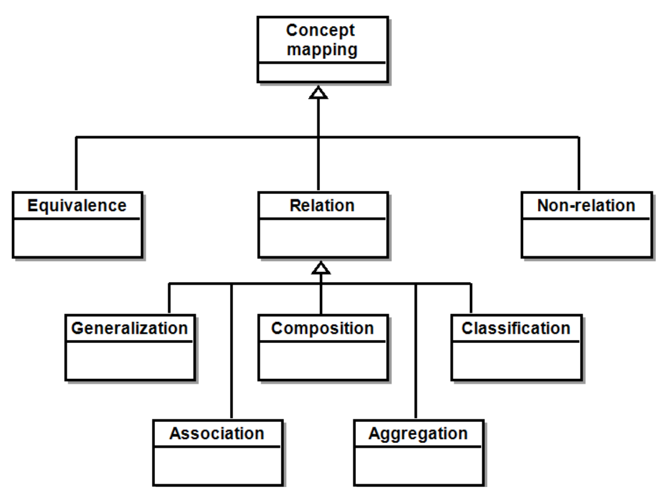



Figure 5.5 Concept mapping (Adapted from (Zivkovic & Kühn, 2007))

certain relation between concepts (Kühn et al., 2003; Zivkovic & Kühn, 2007) (see figure 5.5). Zivkovic and Kühn (2007) propose three rules for specific integration efforts:

1. The Merge rule: Two or more concepts from the source metamodels are semantically equivalent. To avoid the concept duplicity, these source concepts have to be merged into one integrated concept in the target metamodel (Zivkovic and Kühn, 2007, p. 2044).
2. The Generalize Rule: One or more concepts of the left source metamodel are specializations of the concept in the right source metamodel (and vice versa for the generalization). The concepts from both metamodels have to be included in the target metamodel and integrated by a generalization relationship (Zivkovic and Kühn, 2007, p. 2045).
3. The Embed Rule: Two concepts of the left source metamodel are related as parent and child (either with generalization or with aggregation/composition). The concept in the right model represents, on the one hand the child of the parent concept from the left metamodel, and on the other hand the parent of the child concept from the left metamodel. All concepts have to be included in the target model reflecting the new concept constellation and with preserved semantics – the concept from the right metamodel has to be embedded between the two concepts from the right metamodel (Zivkovic and Kühn, 2007, p. 2045).

First, the concepts of the VISOR and VIP metamodels (i.e. the source metamodel) will be integrated, resulting in the VISOR-VIP target metamodel (see figure 5.8). The relationships of the VIP metamodel are not integrated with the VISOR metamodel relationships (and therefore not included in the VISOR-VIP target metamodel), since (1) the mapping of the VISOR metamodel and VIP metamodel concepts only comprises of generalization mappings and (2) to allow for a simple transition between VISOR and VIP metamodel concepts, This is similar in the approach of Iacob et al. (2012), who only integrated concepts of the BMC (Osterwalder, 2004) with ArchiMate (Lankhorst, 2017). The authors explicitly mentioned that the relationships are not integrated. The authors proposed mapping of BMC relationships with ArchiMate relationships as further research. A detailed description of the application of the integration rules of Zivkovic and Kühn (2007), including the concept mappings and motivation for the applied mapping rule can be found in Table C.5 of Appendix C5. The resulting VISOR-VIP target metamodel is displayed in figure 5.6. Mostly the *generalize* and *embed* rule were applied, since the concepts of VISOR of a higher level of abstraction and thus are semantically different. As a result, the *merge* rule was not applied. Since the 'value object', 'value goal' and 'value exchange' concepts are displayed several

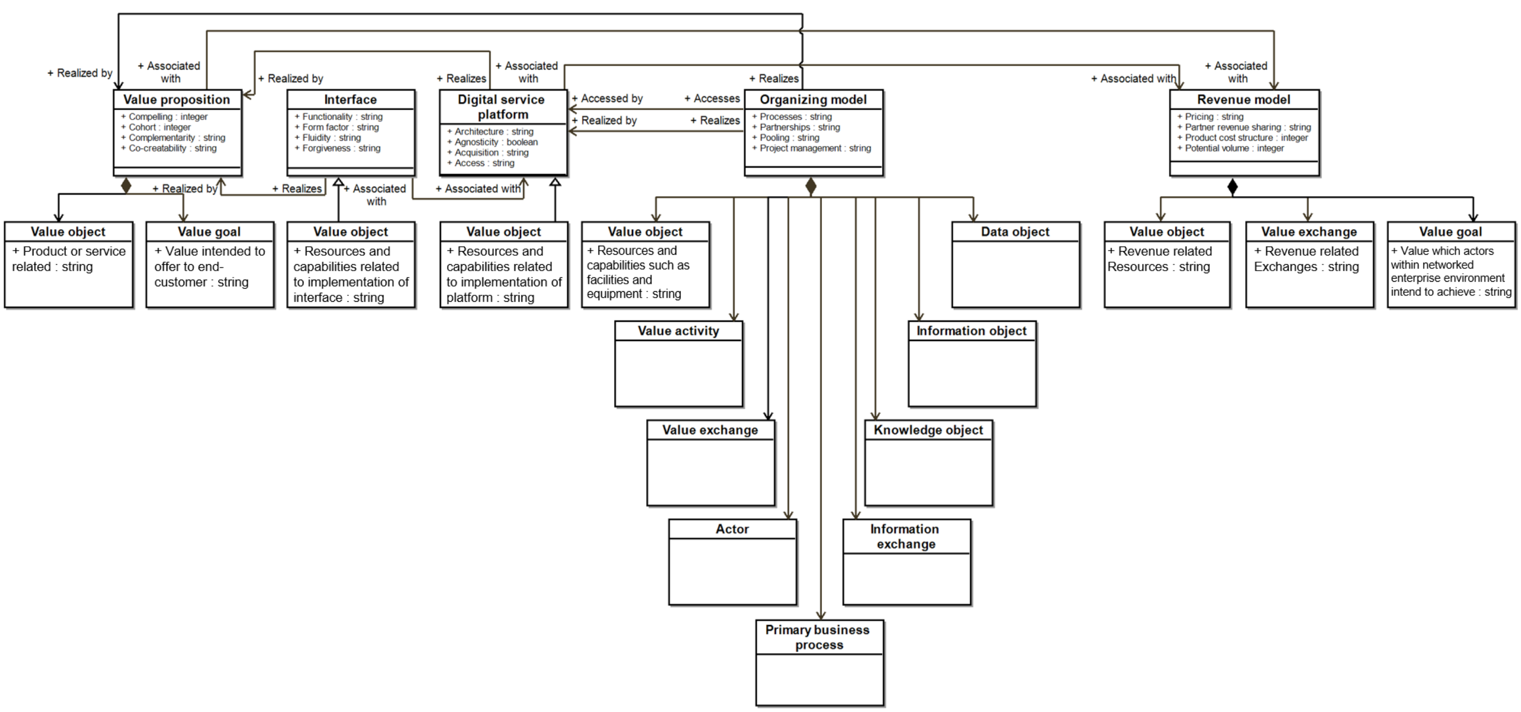



Figure 5.6 VISOR- VIP target metamodel

times, the type of 'value object', 'value goal' and 'value exchange' is expressed with a class attribute in the UML class in figure 5.6 to make the difference between the various 'value object', 'value goal' and 'value exchange' concepts clear. See table C.5 in Appendix C5 for a more detailed explanation on why the 'value object', 'value goal' and 'value exchange' concepts are displayed several times.

Second, the concepts of the VIP metamodel will be integrated with ArchiMate concepts. A detailed description of the application of the integration rules of Zivkovic and Kühn (2007) can be found in Table C.6 of Appendix C6. In Figure 5.7, the integration of the concepts of the VIP source metamodel concepts to ArchiMate concepts is displayed, which resulted in the VIP-ArchiMate target metamodel. The integration effort resulted in a metamodel comprising of various ArchiMate concepts. Mostly the *merge* rule is applied, however, for the 'value object' concept the *generalize* rule is applied because the value object concept is of higher abstraction compared to the ArchiMate concepts. The value object concept can be defined in ArchiMate with a combination of the 'resource', 'capability' and 'value' concepts. As such, new relationships had to be defined between these concepts. Based on the to the definition of S. Solaimani (2014), a value object is mapped against the 'resource' and 'capability' concepts, which are both *associated with* the 'value' concept. Also, the resource concept is *assigned to* a certain capability. In figure 5.8, the VIP metamodel is expressed in the ArchiMate modelling language. As discussed in detail before, since the 'value activity' concept cannot be mapped to an existing ArchiMate concepts, the 'value activity' concept is proposed as new ArchiMate concept. Therefore, please note that in figure 5.8 the 'business process' concept is used for the newly proposed 'value activity' concept, since current ArchiMate tooling obviously does not include 'value activity' concept notations. In addition to the newly proposed concept, two new relationships were discovered during the integration effort; (1) an *accesses* relationship between the 'resource' concept and the behaviour elements and an *influence* relationship between the 'value' concept and the behaviour elements of ArchiMate. In the following sections, the new 'value activity' concept as well as two newly proposed ArchiMate relationships will be

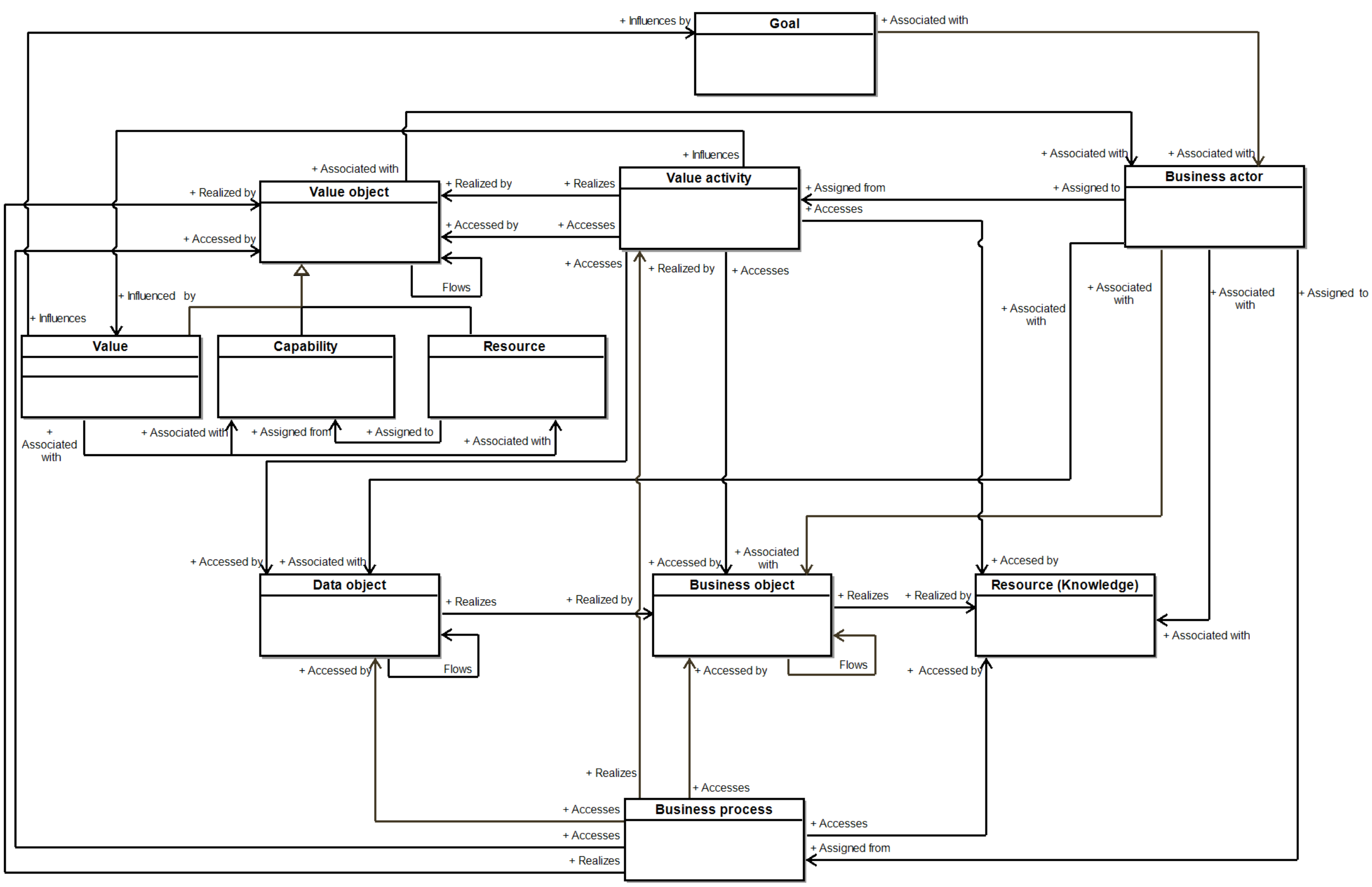



Figure 5.7 VIP-ArchiMate target metamodel

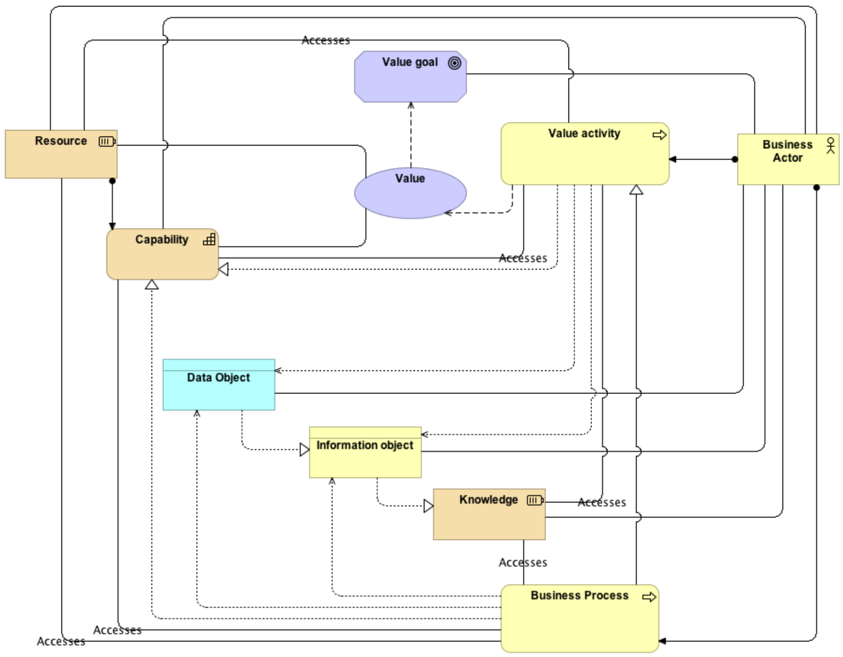



Figure 5.8 VIP-ArchiMate target metamodel in ArchiMate

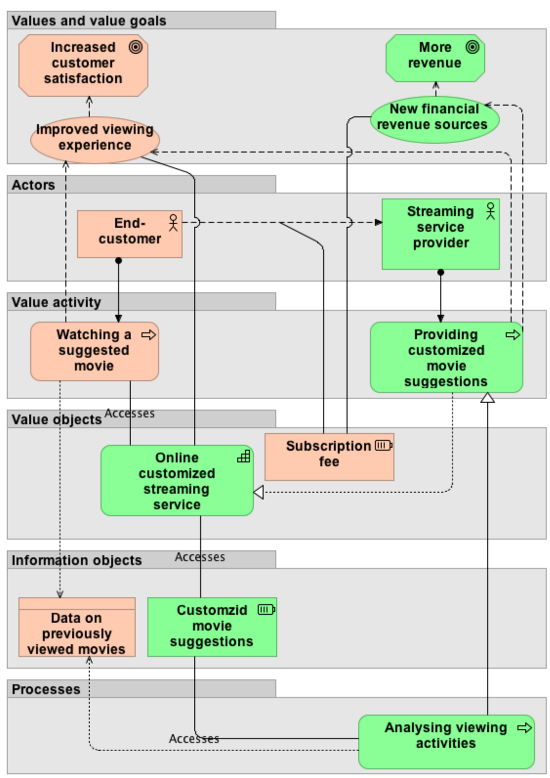



Figure 5.9 Simple example of a VIP ArchiMate model

discussed. Since ArchiMate does not allow to define an *accesses* relatioships between the 'resource' and behaviroual elements, assocation relationships were used with specified *accesses* name tags in figure 5.8. To show how the VIP-ArchiMate target metamodel can be used, in figure 5.9, a very simple VIP ArchiMate model is displayed to show how the metamodel could be used to create model instantiations. The model shows the interaction on the levels of values, information/knowledge and processes of two actors, the end-customer and the movie streaming service provider. The end-customer is *assigned to* the value activity "watching a suggested movie". This value activity *accesses* a certain value, more specifically an "improved viewing experience" This value *influences* a value goal, which is in this case "increased customer satisfaction". The value is associated with the 'Online customized streaming service' capability. This capability is *realized* through the execution of the "providing customized movie suggestions" value activity*,* which is *assigned to* the "Streaming service provider" actor. By executing the "watching a suggested movie" value activity, the end-customer *accesses* a new data object, which comprises of data on "previously viewed movies". This data object is *accessed* in the business process "Analysing viewing activities", where this data is processed to gain knowledge on what type of movies a particular end-customer likes to watch. The execution of this business process thus *accesses* the "customized movie suggestions" knowledge object and *realizes* the value activity "providing customized movie suggestions". The knowledge object is subsequently accessed in the service to improve the accuracy of the customized movie suggestions. Lastly, the end-customer exchanges the "subscription fee" with the movie streaming service provider in return for the provided services, which eventually *influences* the value goal "more revenue" of the movie streaming service provider.

d) ***Definition of the last step of the modelling procedure.***

The last step of the formal modelling procedure states that the internal detailed enterprise architecture should be defined. The ecosystem VIP-ArchiMate model forms the input for the internal enterprise architectures of the networked enterprises. In the last step, actors should look at within their own organization and use the ecosystem model to derive requirements for their enterprise architecture design. For example, if certain information or certain resources (e.g. raw material) are necessary from an ecosystem perspective to realize the networked business model, the actors should define what internal, supporting business processes, applications, hardware etc. are required to support the ecosystem VIP ArchiMate model instance.

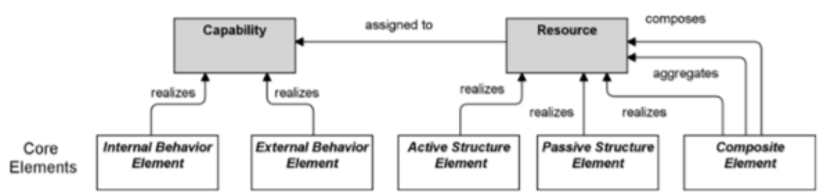



Figure 5.10 Relationships between Resource and Capability concepts and Core Elements of ArchiMate (Adapted from (The Open Group, 2017)).

Next to the differentiation between ecosystem and organizational perspective, actors can spend their time and money on defining a *detailed* organization-centric enterprise architecture blueprint. For example, if a *service platform* is a concept instantiation of the 'resource' concept in the VIP ArchiMate model, the platform provider should make a detailed architecture of the service platform in the last step, comprising of for example detailed application and hardware descriptions. Since ArchiMate is used to define the VIP ecosystem model, more detailed ArchiMate concepts could be used to specify the *detailed* organization-centric enterprise architecture. In the ArchiMate 3.0 specification (Group, 2017), the relation between the more abstract 'resource' and 'capability' concepts is defined as displayed in figure 5.10. For example, in a VIP analysis, the product delivered to the end-customer should be defined as by a 'resource' concept. However, in the last step of the modelling procedure, more detailed ArchiMate concepts can be used, such as the passive structure element 'product'.

### *5.5.4 Sub conclusion section 5.5*

Processing the feedback of the interviews and applying the refined design requirements has resulted in the design of two metamodels and two target metamodels. The formal VISOR metamodel can be used to structure the description and visualization of the business idea, while the lightweight formal VIP metamodel can be used to bridge the gap between the more abstract and economically focused VISOR metamodel and the more detailed and functional ArchiMate metamodels. To bridge this gap, the target metamodels VISOR-VIP and VIP-ArchiMate can be used to describe, visualize and analyse the interactions of the networked enterprises on the level of value, information and processes, where an ArchiMate tool can be used to draw the VIP ArchiMate model. Lastly, the modelling procedure supports modellers in the used of the metamodels, which eventually allow for an analysis of the feasibility and viability of a networked business model implantation. The formal integration effort has led to the proposal of one new ArchiMate concept and two new relationships (see table 5.2 on the following pages). These will be discussed in the following section.

### 5.6 Proposed ArchiMate extensions

The proposed ArchiMate extensions should mainly help to include a more economical business model oriented perspecrive in ArchiMate. First, the 'value activity' concept will be briefly dicsussed. The concept is added based on the first-round interviews and the integration effort of concepts of the VIP metamodel with ArchiMate concepts. Several interviewees (E/1, E/4 and E/6, among which several experts who were highly involved in the development of ArchiMate) did achknowledge that ArchiMate currently lacks a more economical perspective and stated that the value activity concept could be included to ArchiMate to add a more economical perspective to ArchiMate. The 'value activity' concept can be used to bridge the gap between the more abstract and economical business model perspective and the more detailed and functional enteprise architecture perspective. While a business process is often modelled purely from a functional perspective (without taking into account the direct value that the business process creates), the value activity concept can be used to describe and visualize more abstract and economical oriented activities that create direct value for various actors, such as "buying a product", "watching a movie" or "collaborating to increase branding image". These activities can be realized by the business process, such as demonstrated in the example in figure 5.8. Gaaloul and Proper (2012) also did acknowledge that there exists a difference between the value activity concept and the business process conept, confiming that value activites are more econmoically oriented as opposed to business processes.

Second, the integration effort resulted in the proposal of two new relationships. First, it is argued that a behavioural element *accesses* a 'resource' in the execution of the behavioural element. Iacob et al. (2012) were the first authors to introduce the *resource* and *capaiblity* concepts in ArchiMate, which were both later adopted in ArchiMate 3.0 (Lankhorst, 2017). The authors give an example of how the relationships between the new 'resource' and 'capability' concepts could be used, which is shown in figure 5.11. The relationships between the behaviour element 'business process' and the static behaviour element 'resource' is in this example defined as the more abstract *association* relationship. However, it is argued that the relationship could be defined sharper by an *acces*s relationship (recap: *The access relationship models the ability of behaviour and active structure elements to observe or act upon passive structure elements*". (The Open Group, 2017)). According to The Open Group (2017), an *access* relationship *"indicates that a process, function, interaction, service, or event "does something" with a passive structure element; e.g., create a new object, read data from the object, write or modify the object data, or delete the object*" (The Open Group, 2017). For example, the "claim handling" process of figure 5.11 would *exploits* the *vehicle present value assessment infrastructure* in the execution of the process. Another example would be the *creation* of a certain resource, where for instance in a factory the production business process *accesses* (i.e. produces or modify) material. One explanation for the missing relationship could be that the 'resource' concept is on a higher level of abstraction than the core elements of ArchiMate. Nonetheless, the 'resource' concept can be used in combination with the more detailed core elements of ArchiMate (as demonstrated by Iacob et al. (2012), who was also highly involved in the development of ArchiMate, in figure 5.11). If this is the case, it is argued that an *accesses* relationship is sharper way of defining the relationship between these concepts.

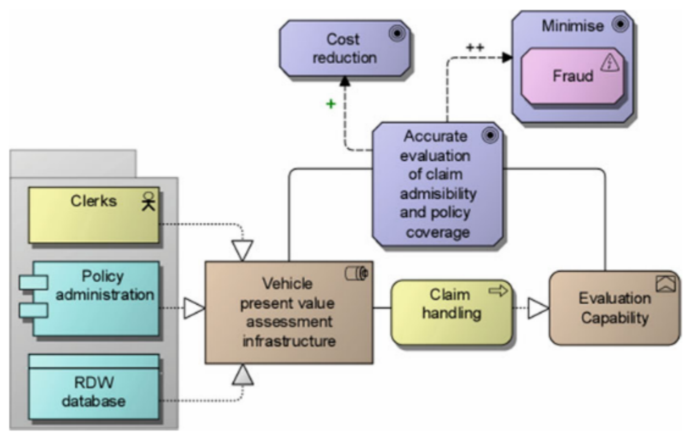


Figure 5.11 Example of the use of the 'resource' and 'capability' concept in relation with the core elements of ArchiMate (Retrieved from (Iacob et al., 2012))

Second, in the current version of ArchiMate, the business layer metamodel prescribes that the 'value' concept can generally be used in combination with the 'product' or 'service' concepts, where the value is *associated* with the product or service. However, it is argued that the 'business process', 'business function' of 'business interaction' concept (or in the case of VIP, the 'value activity' concept) also could be related to the 'value concept' in the business layer metamodel (which is also argued by (Ding, 2015)). This allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value. (i.e. *firms develop and deliver potentially-valuable offerings, and customers assemble and utilize these offerings in context to realize value"* El Sawy, 2013, p. 5). This way of modelling is also incorporated in VDML (OMG, 2015), where behaviour element 'Activity' realizes or creates the 'ValueAdd' concept. The produced value has value-in-use for buyers. An example of the use of the relationship is a customer (the active structure element) who uses (the behaviour element) a certain service (the passive structure element) that creates value for himself (i.e. the value in use, see example in figure 5.8). In this research, the *influence* relationship is used between the 'value' concept of ArchiMate and the behavioural concepts of the VIP metamodel (the 'value' activity and the 'business process' concepts), where the behavioural concept implements the value.

Table 5.2 Proposed ArchiMate extensions

| **Concept 1** | **Concept 2** | **Relationship** | **Meaning** |
|---|---|---|---|
| **Resource** | **Business process/function /interaction/ (value activity)** | Access | A behavioural element can access (i.e. create, read, process or exploit) a resource (i.e. material, IT infrastructure, human resources). |
| **Value** | **Business process/function /interaction/ (value activity)** | Influence | Value is an output of a business process/function /interaction/value activity, which has value-in-use for buyers. |
| **Concept** | | | **Definition** |
| **Value activity** | | | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors. |

## 5.7 Chapter conclusion

In this chapter, an answer was given to research question three: (A). *What are the initial design requirements and design specifications of the metamodels and modelling procedure, incorporating both business model and enterprise architecture concepts?* (B). *How do researchers evaluate these initial design requirements and design specifications?* (A): The initial design specifications were based on a set of nine functional and four non-functional design requirements. These design requirements were mainly elicited from the theoretical foundations of the in the previously selected VISOR business model and the VIP business model – enterprise architecture framework. The initial design specifications resulted in a set of five metamodels that were layered and placed on top of the existing ArchiMate metamodels. (B): Evaluation with researchers on the completeness, coherency, consistency and validity of these initial design requirements resulted in a refinement of four functional design requirements. Consequently, several metamodel concept were excluded from the design specifications due to their inconsistency, inherency or invalidity. Furthermore, discussions on model levelling were held which led to refinement of a non-functional design requirement. Also feedback on the design specifications was collected. It was suggested to only develop two metamodels to keep the approach lightweight and to keep the design specifications valid and consistent when layering the different metamodels. Processing the refined design requirements and feedback on design specifications resulted in the development of two metamodels, where the VISOR metamodel can be used to describe and visualize the business model, and the VIP metamodel can be used to describe and visualize the operationalization of the business model. Formal metamodel integration of concepts of the VISOR metamodel to the VIP metamodel has resulted in the development of a VISOR-VIP target metamodel. The VISOR-VIP target metamodel can be used to transition from the concepts of the VISOR metamodel to the VIP metamodel. Furthermore, concepts of the VIP metamodel have been formally integrated with ArchiMate concepts. To transition from the concepts of the VIP metamodel to the ArchiMate metamodel, the VIP-ArchiMate target metamodel can be used, after which the VIP ArchiMate model can be developed using the ArchiMate concepts. The metamodels and the target metamodels are used in a corresponding modelling procedure. Based on the integration effort of the VIP metamodel concepts with the ArchiMate concepts and the discussions with several ArchiMate experts, a new ArchiMate concept is proposed. The 'value activity' concept should help to bridge the gap between the more functional enterprise architecture and the more economical business model. In addition, two new relationships are proposed. First, an 'access' relationship between the 'resource' and 'business process' concept is proposed. Second, an 'influence' relationship between the 'value' and 'business process' concept is proposed. The proposed ArchiMate extensions should mainly help to include a more economical business model oriented perspecrive in ArchiMate.

# Chapter 6 BIE Second design iteration


In this chapter, the results of the second design iteration will be discussed by answering research question four (A). *What is the result of an application of the metamodels and the modelling procedure to the Industry 4.0 domain?* (B). *How do practitioners evaluate the refined design requirements and design specifications?* The main objective for this chapter is twofold: (1) apply the in the previous chapter modelling procedure and metamodels to create model instantiations to the industry 4.0 domain with practitioners. This application should also result in some first insights into business model implementation aspects for the Industry 4.0 domain. (2) evaluate the artefact on usefulness, ease of use and requirement fulfilment. Results of the evaluation will be used to further refine the metamodels and modelling procedure.

This chapter is structured as follows. The application of the artefact to the Industry 4.0 domain is presented. After that, results of the interviews will be discussed, which will subsequently be used to further refine the design requirements and design specifications.

## 6.1 Implementation of metamodel and modelling procedure

### *6.1.1 Approach to implement the metamodel and modelling procedure in the Industry 4.0 domain.*

The limited amount of available time to conduct this research has two consequences. First, it is not possible to conduct a real-life intervention through an in-depth case study. So, the implementation will be on a high level of abstraction. In other words, high level of characteristics of the Industry 4.0 domain will be used to implement the metamodel and modelling procedure, without analysing a specific case. A second consequence of the limited amount of available time is that only the first three steps of the modelling procedure will be implemented. Figure 6.1 displays the modelling procedure, where

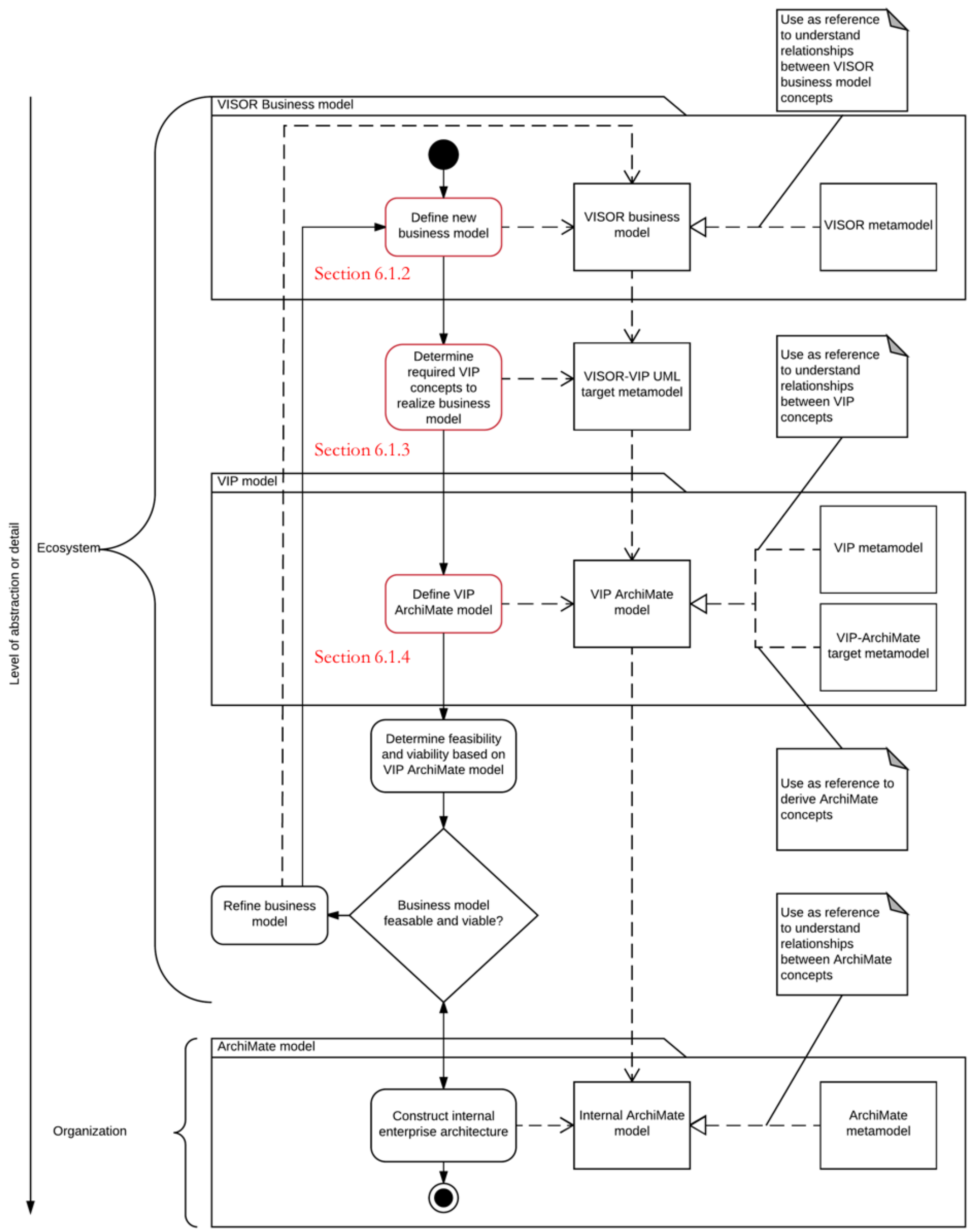



Figure 6.1 the modelling procedure with the implemented step

each implemented step is highlighted. Since it is not possible to conduct a *real* in-depth case study, implementing the fourth step of the modelling procedure (which comprised of a discussion between the networked enterprises on the feasibility and the viability of the proposed VIP ArchiMate model) would be somewhat unrealistic, since the interviewees otherwise would have to discuss the feasibility and the viability an abstract and fictional business model. The interviewees are not real-life stakeholders that have to implement the business model, so conflicts on for example heterogeneous business processes or unequal profit sharing can currently not be discussed. If the fourth step would be implemented, it is expected that this would merely lead to hypothetical discussions, where for examples interviews would "guess" at possible issues that might occur. Nonetheless, implementing the first three steps of the modelling procedure would enable practitioners to experience the modelling procedure to some extent. By implementing the first three steps of the modelling procedure, all metamodels developed in this study will be used by the interviewees. Therefore, it is expected that the interviewees can form an opinion on the usefulness, ease of use and requirement fulfilment of the artefact, which is eventually one the objectives of the second-round of interviews.

### *6.1.2. Step 1 Describe new VISOR business model for the Industry 4.0.*

The first step in the modelling process it to define the VISOR business model using the VISOR metamodel. In figure 6.2, an instantiation of the VISOR UML metamodel for the Industry 4.0 is displayed. Each of the industry 4.0 specification of the VISOR concepts will be briefly discussed.

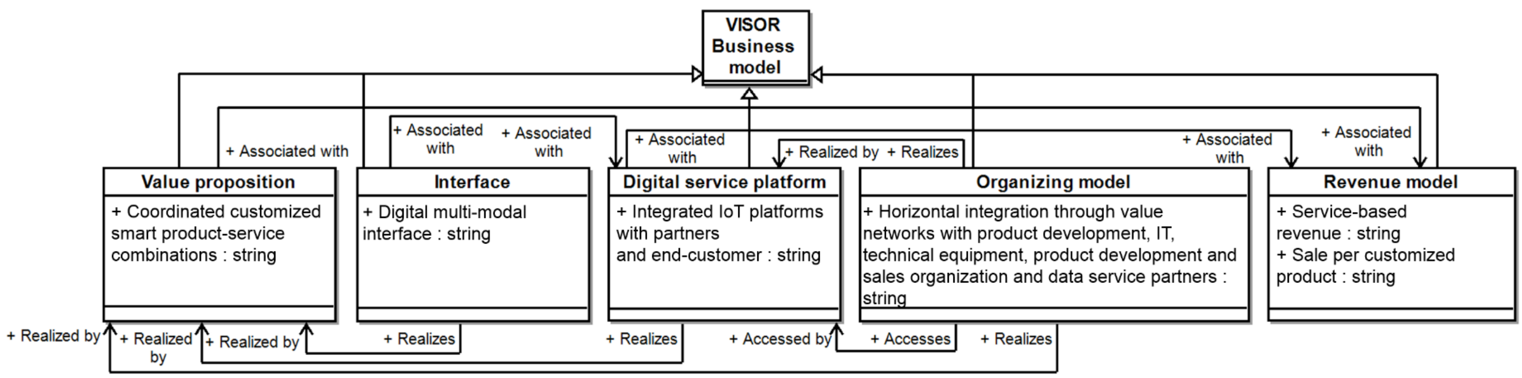



Figure 6.2 A UML VISOR metamodel instantiation for the Industry 4.0 domain

a) ***Value proposition***

The combination of *customized smart products* and *value-added services* (which can either be delivered separately or on top of the products) are the most mentioned value propositions for the Industry domain, according to literature and the interviewees (Brettel et al., 2014; Burmeiser et al., 2015; Ju et al., 2016; Kagermann, 2015; Lakhani & Iansiti, 2014; Lier, 2014; Rymaszewska et al., 2017). Since IoT allows manufacturing organizations to make their manufacturing processes more flexible, customized smart products can be produced on a large scale (Kagermann et al., 2013; Wang, Wan, Zhang, et al., 2016). Furthermore, data from the sensors of the product can be used to deliver value-added services to the end customer, such as predictive maintenance. Concluding, the 'value proposition' metamodel concept is defined as *customized products* and *customized value-added services*.

b) ***Interface***

Within the context of Industry 4.0, the interface through which the 'value proposition' concept is *realized*, is generally considered to be a web portal (Ju et al., 2016; Kagermann, 2015; Kiel, Arnold, Collisi, & Voigt, 2016; Kiel & Voigt, 2015; Schladofsky et al., 2017). Via the web portal, the customer can interact with the vendor on what kind of service or product he or she desires. Interviewee E/7 stated that a web-portal might be replaced with mobile apps, where the end-customer can provide his or her design requirements for the customized product and the services. Interviewee E/8 took it further and stated that a voice assistant would be the interface where the customer could interact with the actors, however, since it is not mentioned in literature and by the other interviewees, this suggestion is not included in the model instance. Interviewee E/10, who has a more technological background, suggested to define it as an API. This is perceived as too technological oriented; the customer does not interact with an API directly. Since multiple digital interfaces are possible (i.e. apps and web portal), the 'interface' metamodel concept is specified as a *digital multi-modal interface*.

c) ***Digital service platform***

The 'value proposition' concept is *realized* through the use of IoT platforms, which connects everything what is equipped with IoT sensors and IP capabilities, such as smart factories, end-products or mobile phones (where mobile phones are the interface *associated with* the platform since they allow partners to interact with the customer) (Kagermann et al., 2013; Vermesan et al., 2016; Wang, Wan, Zhang, et al., 2016). According to interviewees E/7, E/9 and E/10, the platforms collect all data from all the actors in the network, such as the data from the end-products, data from the machines in the smart factories or inventory data. This bulk of data can be analysed to retrieve data insights which are used to *realize* the value-added services, such as the predictive maintenance services. Furthermore, the data could be used to analyse what the future demand of customers is (e.g. they way customers like to use their products or what type of products particular customers often buy), which results in knowledge on future demand. This knowledge can subsequently be used to adjust the design of the product, to deliver customized products, tailored to specific needs of the end-customer. Consequently, the digital 'service platform' concept is specified as *Integrated IoT platforms with partners and end-customer*.

d) ***Organizing model***

To realize an Industry 4.0 business model, actors need to organize themselves through horizontal integration, which incorporates everything from product design, production planning, production and services and physical objects, such as factories and smart manufacturing machines (Kagermann et al., 2013; Wang, Wan, Li, et al., 2016; Wang, Wan, Zhang, et al., 2016). In the work of Kress et al. (2016) is stated that ecosystems in the manufacturing industry are expanding, and that the digitalization has resulted into a manufacturing ecosystem with 25 different type of organizations. On a higher-level, these organizations include a platform manager, product development and sales organizations, manufacturing organizations, equipment suppliers, data analytics service providers. In addition, the role of Software and IT providers plays an increasingly important role for the industry 4.0 domain, since they are mainly responsible for the *realization* of the IoT or CPS platform (Kress et al., 2016). Furthermore, as stated by interviewee E/10 and in the work of Kagermann et al. (2013) and Wang, Wan, Li, et al. (2016), vertical integration is also required. However, with vertical integration is meant the integration *inside* of the organization, from office floor to shop floor. Therefore, it is not included as specification of the 'organizing model' concept, since the organizing model expresses the organization design of networked enterprise. Concluding, the 'organizing model' concept is specified as *horizontal integration through value networks with IT, technological equipment, platform management, product development, sales* and *data analytics service partners,* who collaboratively *realize* the 'value proposition' concept.

e) ***Revenue model***

In the industry 4.0 domain, the revenue model expands from being merely based on payment revenues for the products, to a more service-oriented revenue models, such as the pay per use, freemiums or add-ons revenue model (Arnold et al., 2016; Fleisch, Weinberger, & Wortmann, 2014). Al interviewees did acknowledge these new revenue models. However, what was missing in the initial specification of the 'revenue model' concept, according to the interviewees, were the costs. This was acknowledged by the researcher, however, from network perspective it becomes difficult to define what can be considered costs and revenues; for one organization, a monetary value exchange is an expense, while for the other organization who receives the money is revenue. Therefore, the revenue model was purely used to express the type of revenues that are made in the industry 4.0 domain. This can also be seen in the UML metamodel, where a particular value proposition is *associated* with a certain revenue model. Furthermore, in the case studies in the work of El Sawy and Pereira (2013) where VISOR is used, only the type of revenues are displayed, such as "insurance premiums", and not the cost (El Sawy, 2013, p.45). Concluding, the 'revenue model' concept can be specified as *sale of customized product* and *service-based revenue*.

#### *6.1.3. Step 2 Transition from VISOR metamodel concepts to VIP concepts metamodel using the VISOR-VIP target metamodel*

In the next step of the modelling procedure, the VISOR-VIP target metamodel will be used to derive VIP concepts from the VISOR metamodel concepts. An instantiation of the VISOR-VIP metamodel for the Industry 4.0 domain is displayed on the page 84 in figure 6.3. Each VIP metamodel concept will be discussed briefly in this section.

a) ***Value proposition***

*Value objects*

The first composite of the 'value proposition' concept class is the value object class, which describes and visualizes the products and services which are of value to the end-customer. The 'value object' concept can easily be defined as the customized smart products and the value-added services, which both are also mentioned in literature (Burmeiser et al., 2015; Rennung et al., 2016b; Shrouf et al., 2014). Since value objects are resources or capabilities associated with value (S. Solaimani, 2014), also the value for the end-customer also has to be defined. Based on the interviews, it is argued that the value associated with the customized smart products can be defined as Product customized to personal needs for same buying price and for the value-added services logically value-added services customized to personal needs for same buying price. This is illustrated by the following quote:

[8] *Since manufactures can lower their costs, they can fabricate client specific products which are sold for the same selling price as previously un-customized products were sold* (E/7).

Other values associated for both the customized products and value-added services is improved experience/usability and comfort (Dijkman, Sprenkels, Peeters, & Janssen, 2015), since it is argued that the end-customers have enhanced experience and usability when they are using (i.e. value in-use or value conversion) product or services that fits their needs due to the possible customizations. These value objects were also acknowledged by the interviewees. Concluding, the following value objects are defined: *Product customized to personal needs for same buying price*, *Value-added services customized to personal needs for same buying price* and *Improved experience/usability and comfort.*

*Value goals*

Following the relation in the VISOR-VIP target metamodel, the second composite of the 'value proposition' concept class is the 'value goal' concept class. The value goal which the customer tends to achieve by buying and using the customized smart products and value-added services is defined as increased customer satisfaction. Since the products and services are customized, fitting the needs of the customer seamlessly, it is argued that this influences the value goal increased customer satisfaction. It has to be noted that this is not a goal that customers explicitly want to achieve, but something that they indirectly tend to achieve. Concluding, the value goal is defined as *increased customer satisfaction.*

b) ***Interface***

*Value objects*

Next, the 'value object' concept class, which is a sub-class of the supper-class of the 'interface' concept needs to be defined. The resources related to the interface can be easily translated from the multi-modal interface. Based literature and the interviews (see section 6.1.2), these can be defined as a mobile application or a web portal (Kagermann, Wahlster et al. 2013, Dijkman, Sprenkels et al. 2015, Schladofsky, Mitic et al. 2017). Via these digital interfaces, the customer provides his preferences on the customized service or product he or she wishes to receive and the order details for the customized products. Concluding, the value objects are defined as *mobile application* and a *web portal.*

c) ***Digital service platform***

*Value objects*

The supper-class of the 'digital service platform' concept class has the specialization sub-class 'value object'. The resources and capabilities required to realize the *Integrated IoT platforms with partners and end-customer* can be defined as the platform itself (Kagermann 2015, Giordano, Spezzano et al. 2016). The platform also needs to be maintained or managed, therefore interviewees E/7 and E/8 proposed to type of services. One service is more related to the technological management of the IT architecture of the platform and was identified as *IT platform management service,* while the other more organizational or people oriented service was identified as *organizational platform management service.* This is illustrated with the quote below.

[9] *We arrive at the triptych, people, systems and processes. These aspects are relevant from a platform perspective* [..] *the platform is there to increase collaboration; the rest is a consequence of the platform. Eventually you need an IT platform and an organizational platform which enables the exchanges between actors.* (E/7)

#### d) *Organizing model*

*Actors*

The 'actor' concept class is a composite of the 'organizing model' concept class. Already briefly discussed in the previous section, these can be identified as the *manufacturing organization,* the *end-customer,* the *equipment supplier,* the *Software and IT developer,* the *product development and sales organization,* the *IoT platform manager,* the *data service provider,* and the *value-added service provider.* Table 6.1 displays the actors with their responsibilities.

Table 6.1 Actors and their responsibilities in the Industry 4.0 ecosystem

| **Actor** | **Responsibility** |
|---|---|
| **Manufacturing organization** | Production of the customized smart products. |
| **End-customer** | Receives the value proposition. |
| **Equipment supplier** | Availability of the raw materials used in production. |
| **Software and IT developer** | Realization of the IoT platform. |
| **Systems integrator** | Control of the different processes across the different disciplines. |
| **Product development and sales organization** | Design and marketing of the customized smart products. |
| **IoT platform manager** | Management of IoT platform |
| **Data service provider** | Integration and processing of IoT sensor data from different sources |
| **Value added service provider** | Delivery of value added services, such as predictive maintenance |

*Value objects and value exchanges*

The 'value object' concept class is a composite of the 'organizing model' concept class. The value objects in the context of the organizing model are related to resources and capabilities, such as equipment and facilities or services, which are less valuable to the end customer (see section 5.5.3.c) and more valuable to non-customer related actors. During the interviews and the literature study, first *smart factories* are identified as value object. Smart factories are facilities equipped with smart machines. Smart machines are IoT enabled machines, such as industrial robots, in factories that produce the customized smart products. The sensors of the smart machines generate production data that can be analysed through data analytics services to provide global feedback and coordination in the production process, which leads to high production flexibility and efficiency. Therefore, the smart factory is able to produce customized products efficiently and profitably and therefore allows for the execution of smart manufacturing processes (Shrouf et al., 2014; Wang, Wan, Zhang, et al., 2016). In the primary business process section the smart manufacturing processes will be discussed in more detail. From this, also *data analytics services* can be derived as value object. According to interviewees E7, E/9 and E/10, the data analytics services offer the insights from analysis on production data from the smart factory, customer orders, supplier (or inventory) data and future demand. Knowledge on future market demand is used in the marketing and (after-) sales and customized product development processes (both will be discussed later). Lastly, since smart inventory management is going to play an important role in the realization of the flexible and efficient smart manufacturing processes (according to interviewee E/7 and E/10) raw materials are also identified as value objects.

Interviewee E/8 also stated that and ERP order system should be included, which allowed for the interaction between the customer, who orders a product, and the product development organization, who processes the order. However, this value object is not included since first of all, it was considered intra-organizational by interviewee E/7 and second, it is considered to be a more supporting value object instead of an essential value object to realize the business model (whereas VIP focuses on the essential inter-organizational concepts of a business model implementation). All of the previous described value objects need to be exchanged between the various actors. This will be visualized in the VIP ArchiMate model in the next section. Concluding, the value objects composite class of the organizing model is defined as *smart factories,* *data analytics services* and *raw materials*. The value exchange composite includes all the exchanges of the aforementioned value objects between the actors.

*Value activities*

The 'value activity' concept class is also a composite of the 'organizing model' concept class. During the interviews, it was somewhat difficult for the interviewees to come up with concrete value activities, due to their high level of abstraction. Therefore, inspiration was taken from the work of S. Solaimani (2014), where various value activities were identified in several case studies. The value activity concept seems suitable for the value-in use activities, such as for the end-customer, who uses the value-added services and customized smart products to realize the aforementioned associated values of the products and services or manufacturing organizations, who use their smart factories to realize production efficiency (El Sawy & Pereira, 2013). Based on the work of (S. Solaimani, 2014), actors who are providing certain value objects to other actors can also be defined as activities that create value for other networked enterprises. Furthermore, activities which are not executed in operational processes, such as IoT developers collaborating with manufacturing organization in the platform development (which was suggested by E/7) and platform management activities, such as the required IT and organization platform management services were also identified as value activities. Lastly, the end-customers are formulating product design requirements for their specific customized product (such as a customized car with very specific configurations) via the mobile phone application or the web portal. Concluding the value activities are defined as *Use of products, and equipment and service, providing products, equipment and services, Managing of platform, Platform development* and *Formulating product design requirements.*

*Data, information and knowledge objects and information exchanges*

The data, information and knowledge object classes are also a composite of the organizing model class. Raw IoT sensor data is defined as data object, which can generated from the use of the customized smart product by the end-customer, data generated in the smart factories by the sensors of the smart machines or data from the sensors in the inventories of the manufacturing organizations (Brettel et al., 2014; Rudtsch, Gausemeier, Gesing, Mittag, & Peter, 2014). The interviewees stated that this could be real-time data as well as offline historic data, which can for example be used to plan production more efficiently. The customized orders which are provided by the customers and translated into a customized product design specifications by the product development organizations, can both be defined as data and information objects (Brettel et al., 2014; Rudtsch et al., 2014). Next, the raw IoT sensor data is processed by the data analytics service, which results in product usage information objects and manufacturing production information. Also, inventory information was identified as information object by the interviewees. The role of inventory information is critical, since by the exchange of this information between the manufacturing organization and the supplier, smart inventory management can be realized, where inventories are managed efficient and effective, without surplus. The inventory information is used to order customized material by the supplier. All of the previous described data and information objects need to be exchanged between the various actors. Similar to the value exchanges, this will be visualized in the VIP ArchiMate model in the next section. As knowledge object, market demand forecasting knowledge was identified by interviewees E/7, E/9 and E/10. The interviewees argued that by combining different data and information sources, such as real-time and historic data and information on customized orders or information on the physical condition of the smart products or smart machines, knowledge can be created on what the future demand of customers can become. This knowledge can be used in marketing and after-sales processes to offer customized orders, productions processes and value-added services. Concluding the information related objects are defined as *IoT sensor data from smart customized product*, *IoT sensor data from smart factory*, *IoT sensor data form inventory, Customized orders, Customized product design specification, Product usage information, Manufacturing production information, Inventory information, Customized material orders* and *Market demand forecasting knowledge.*

*Primary business processes*

The 'primary business process' concept class is a composite of the 'organizing model' concept class. The customized order from the customer is accessed in the customized product development process (Kagermann et al., 2013). The result of this is are is the customized product design specification , which is subsequently used in the smart manufacturing process, which are IoT enabled processes which include dynamic, efficient, automated and real-time communication for the management and control of the manufacturing environment (Shrouf et al., 2014). The smart manufacturing process requires raw materials to create the customized smart products. The raw materials are delivered through the smart logistics and smart inventory management processes, which is a self-organized logistics and inventory management that reacts to unexpected changes in production (based on the inventory information and Customized material orders objects) such as bottlenecks and materials shortages (Lopez, 2014). According to interviewees E/7, E/9 and E/10, all the data objects from the different data sources captured in the IoT or CPS platform, such as sensor data from the smart machines in the production processes and the smart customized products from the end-customer, needs to be integrated and processed to create the information and knowledge objects. Therefore, data integration and processing is also a primary business process. The results of this business process can subsequently be used in other processes. First, the inventory information can be used in the smart inventory management processes between the material supplier and the manufacturing organization. Second, the market demand forecasting knowledge can be used in the marketing and (after)-sales process (Kress et al., 2016) and the customized product development process. Concluding, the following primary business processes are defined: *Customized product development*, *Smart manufacturing process*, *Smart logistic*s, *Smart inventory management*, *Marketing and (after)-sales process*, *Data integration and processing on production and inventory sensor data* and *Data integration and processing on customized smart product sensor data*.

e) **Revenue model**

*Value goals*

The 'value goal' concept class, non-related to values intended to offer to the end-customer in the value proposition, is a composite of the 'revenue model' concept class. The first value goal is identified as cost improvements which is based on discussions with E/7 and E/9 and mentioned in various literature (e.g. (Paulus-Rohmer, Schatton, & Bauernhansl, 2016; Qin, Liu, & Grosvenor, 2016; Rose et al., 2016; Wang, Wan, Li, et al., 2016; Wang, Wan, Zhang, et al., 2016)). Another value goal can be defined as more revenue related and is realized through the IoT powered servitization of the manufacturing industry (Geissbauer, Vedso, & Schrauf, 2016; Rennung et al., 2016b; Rose et al., 2016; Rymaszewska et al., 2017). It is also argued that the aforementioned increased customer satisfaction leads to more sales of products and services and, thus, eventually also influences the value goal more sales. Furthermore, customers are demanding shorter product life-cycles (Glas & Kleemann, 2016; Lasi et al., 2014). Due to the flexible and efficient smart manufacturing processes and inventory management, the value goal shorter time-to market value goal can also be realized. Concluding, non-customer related value goals can be defined as *cost improvements, more sales, shorter-time-to market* and *new financial revenue sources*

*Value objects and value exchanges*

The 'value object' concept class is a composite of the 'revenue model' concept class. In the context of the revenue model, these particular value objects are defined as *subscription fees* (Dijkman et al., 2015) for the *value-added services* and *fee per customized product* for the customized products. Values associated with the use of the aforementioned equipment (such as the smart factories and smart machines) in the organizing model section include *flexible and efficient production and inventory management* and *flexible and efficient logistics*. The following value objects are defined: *Subscription fee, Fee per customized product, Flexible and efficient production and inventory management* and *Flexible and efficient logistics*.

In figure 6.3 on page 86, all of the above described value, data, information, knowledge objects, value goals, actors, and primary business processes are displayed in the VISOR – VIP target metamodel on the next page.

#### *6.1.4. Step 3 Transition from VIP concepts to ArchiMate concepts and step 4 define VIP ArchiMate model using the VIP metamodel and the VIP –ArchiMate target metamodel*

The third step in the modelling procedure is to define the VIP ArchiMate model, by using the previous discussed VIP concepts. The VIP metamodel and the VIP-ArchiMate metamodel shows all the possible relationships between the metamodel concepts, which are subsequently applied in the VIP ArchiMate model instance. The model is displayed in figure 6.4 on page 87. Please note that the assignment relations are replaced with colours. The VIP ArchiMate model in figure 6.4 is developed around the customized smart products value proposition. It shows the interactions and interrelations between the actors through value activities and business processes, who is responsible for the creations of specific value, data, information and knowledge objects and how each actor benefits. The swimming lanes sort the previously defined VIP concepts in processes, information objects, value objects, value activities, actors (where each actor has their own colour, e.g. all object associated with the end-customer are orange) and values and value goals. Furthermore, groups are made of similar value and information objects, more specifically customized order information objects provided by the end-customer, information objects created by the use of the customized product by the end user, information objects created in the production process of the manufacturing organization and information objects that allow for the smart inventory management. Each group of information objects are associated with a *flow* relationships that flow from or to the IoT platform. The groups for the value objects include resources required for the interface and capabilities required for the platform management. The 'Accesses' name is added to some relationships, based on the proposed new ArchiMate relationship (see section 5.5.3.d). To keep the size of the image reasonable, the exchange of the fees was modelled in a separate model, which can be found in Appendix D4. Although the fourth step of the modelling procedure is not executed due to time constraints, the VIP ArchiMate model gave some first insights into the business model implementation aspects for the Industry 4.0 domain, which will be briefly explained. First, the model shows on the level of value that new type of revenues need to be collected by the non-customer stakeholders. The end-customer can modify its smart product by providing *Customized product design specifications*. Since all actors are involved in the realization of the value proposition of *Product customized to personal needs for same buying price,* the other actors need to make arrangements on this new type of revenue*,* the *Fee per customized product* is shared evenly between the actors. Also, the costs of the development of the execution the *Managing of platform* and *Platform development* value activities to realize the *IoT platform* needs to be shared evenly amongst the various actors, since every actor will eventually use the platform. Lastly, to ensure customer satisfaction, it is of importance that the customized products does meet the customized demands of the customer. Therefore, evaluations on the product requirement fulfilment should be conducted.

Second, on the level of information, the model shows the critical role of information in Industry 4.0 business models. One of the main value goals for the networked enterprises are the *cost improvement*s and *shorter-time-to market*. These *cost improvements* and *shorter-time-to market* can only be realized when data from the IoT sensors of the factory and inventory are processed in the data processing business processes. The processed data, resulting in the *Inventory information* and the *Manufacturing production information* is essential in the execution of the *smart manufacturing process* and the *smart logistics process,* where the *smart manufacturing process* is essential for the creation of the value proposition of *Product customized to personal needs for same buying price* offered to the end-customer. Without the processing of the aforementioned data, the values *flexible and efficient production and inventory management* and *flexible and efficient logistics* and the value proposition of *Product customized to personal needs for same buying price* cannot be realized. First, it is therefore of importance that the data analysts, technical equipment suppliers and manufacturing organizations make arrangements on the level of information, such as who has access to certain information or when does this actor has access this certain information and the actors need to explore possible interoperability issues. Second, the actors need to make arrangements how the *Market demand forecasting knowledge* is going to be shared with the *product development organizations*. This knowledge is essential to produce the value object *customized product* in advance. Third, arrangements need to be made on how the *smart factory* can process the *Customized product design specifications* from the *Product development and sales organization*. Lastly, the *IoT platform* will eventually capture all the data, so it is therefore of importance that every data and information object is compatible with the type of architecture that is used in the platform. From the end-customer perspective, privacy issues need to be discussed. By using the product, the end-customer creates the *IoT sensor data from smart customized product* data objects, which used in the data processing to create the *Product usage information* and *Market demand forecasting* information and knowledge objects. The end-customer might refuse to share this data due to privacy issues. However, as can be seen in the model, this data and the subsequent information and knowledge objects, play an important role in the realization of the *Product customized to personal needs for same buying price* and the achievement of the various value goals. As such, clear arrangements on which data is being used and when between on the one hand the end-customer and on the other and the remaining actors need to be made to ensure the feasibility and viability of the business model Lastly, on the level of processes, they need to make sure that the various processes, more specifically the *Smart manufacturing process, Smart logistics, Smart inventory management* and the *Data integration and processing on production and inventory sensor data* can be connected to each other. If some of these business processes are conflicting or heterogeneous, the feasibility of the business model cannot be ensured because these are the primary business processes for the realization of the business model.

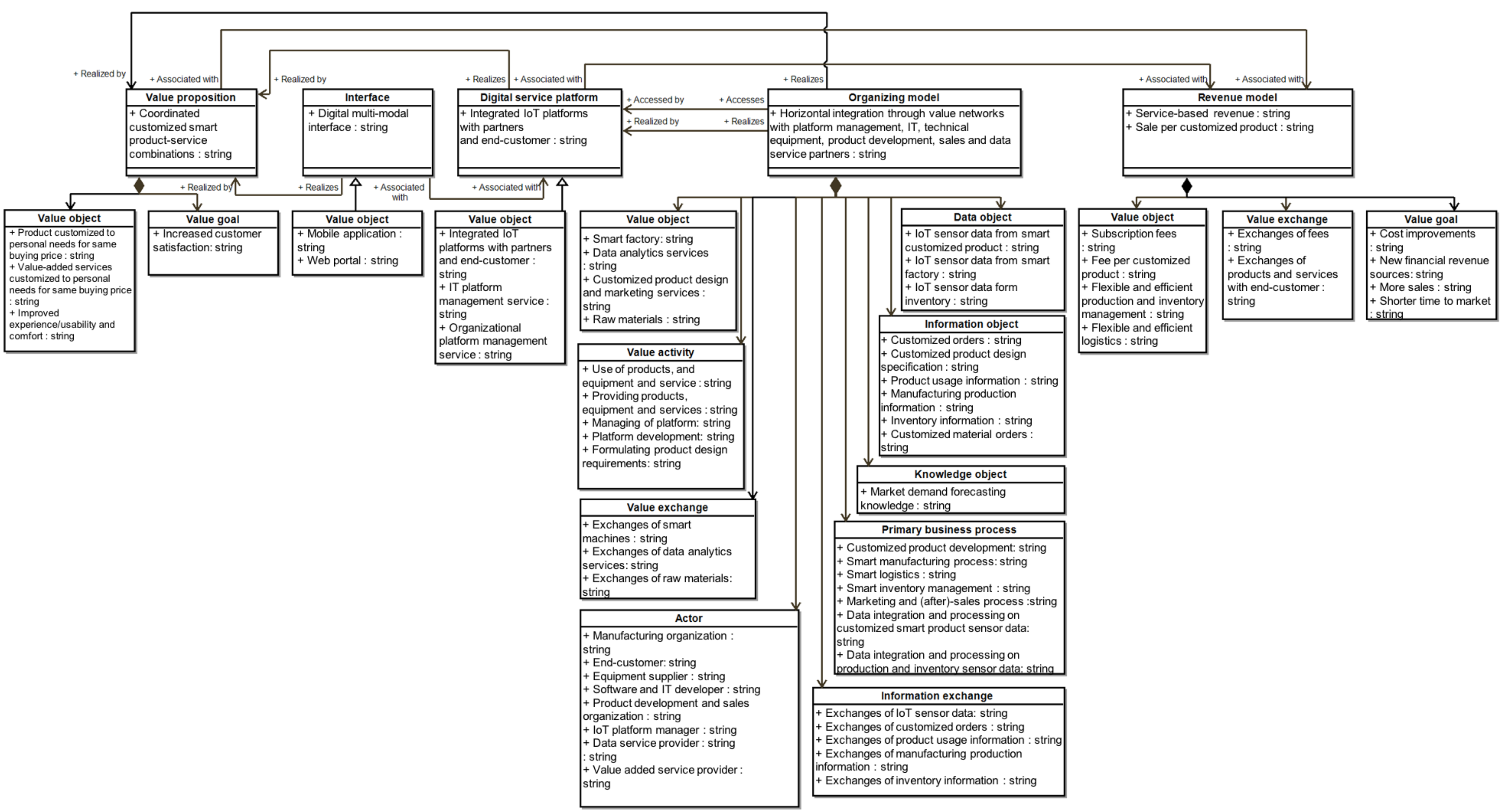



Figure 6.3 Model instance of the VISOR-VIP target meta-model

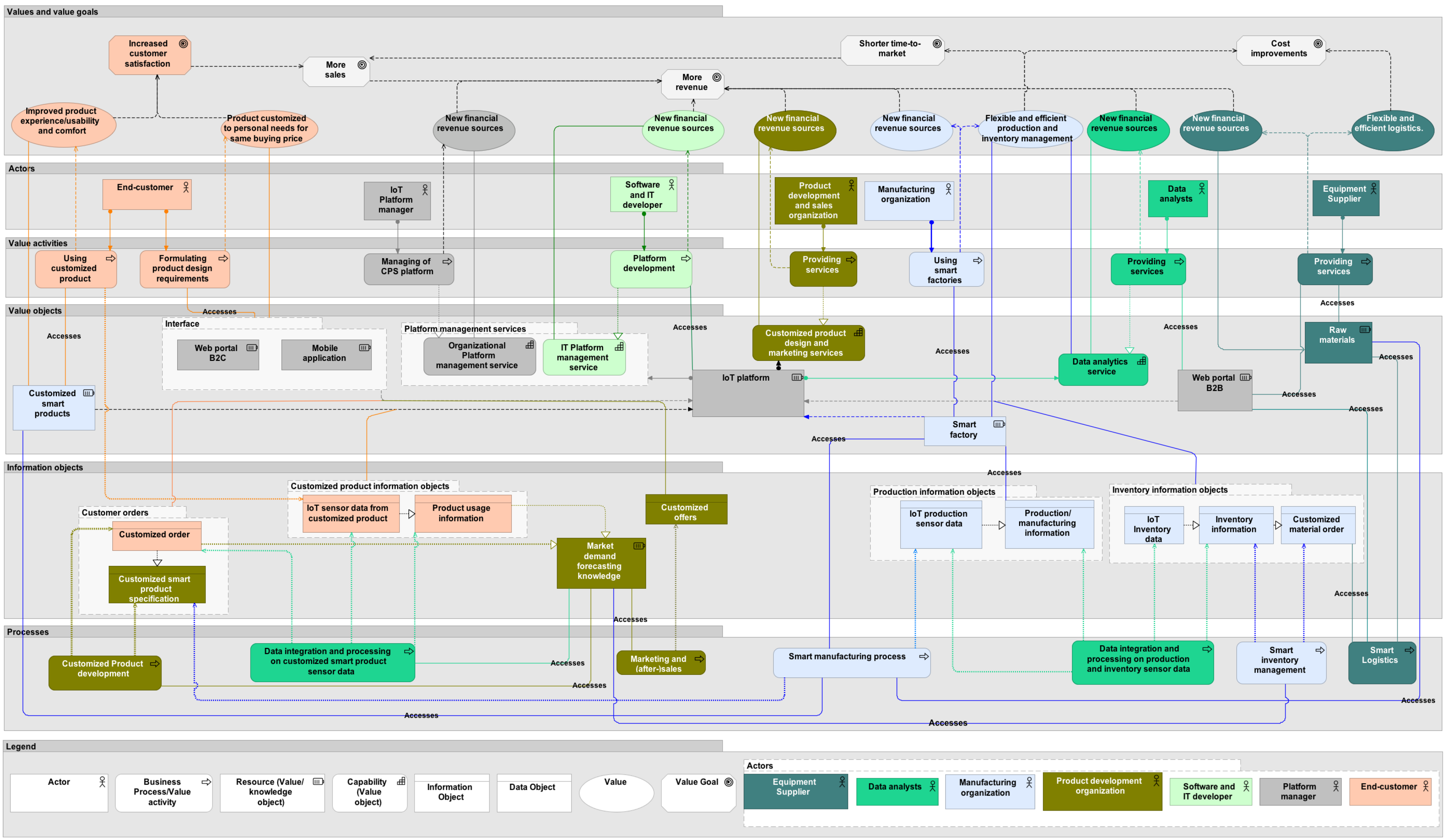



Figure 6.4 Model Instance of the VIP-ArchiMate target meta-model for the customized smart products value proposition

#### *6.1.5 Sub-conclusion section 6.1*

Answering research question four (A), *what is the result of an implemented metamodel and modelling procedure in the Industry 4.0 domain?* has led to the development of three model instantiations of the VISOR and VIP metamodels and the VISOR-VIP and VIP-ArchiMate target metamodels. The specifications of the metamodel's instantiations were based on literature and interviews. During the interviews, it became clear the interviewees were able to work with the metamodels and modelling procedure. Interviewees were able to come up with new concept specifications, which were initially not included in the initial model instantiations which were merely based on literature.

The resulting VIP ArchiMate model provided some first insights into business model implementation aspects. To ensure the feasibility and viability of the networked Industry 4.0 business model, the VIP ArchiMate model showed that it is of importance that arrangements on the level of value, information and processes are made to ensure the feasibility and viability of the business model.

### 6.2 Evaluation of refined design requirements and design specification

In this section, the second step of the second-round interviews will be discussed, which will give answer to the last research question: First the results of the questionnaire with closed questions and the open questions will be presented and discussed. Furthermore, the results on design requirement will be discussed as well. The results from the evaluation will be used to refine the design requirements and design specification.

#### *6.2.1. Closed and open questions on usefulness and ease of use*

The questionnaire comprised of 10 closed questions to evaluate the usefulness and the ease of use of the metamodel and modelling procedure.

*a) Usefulness*

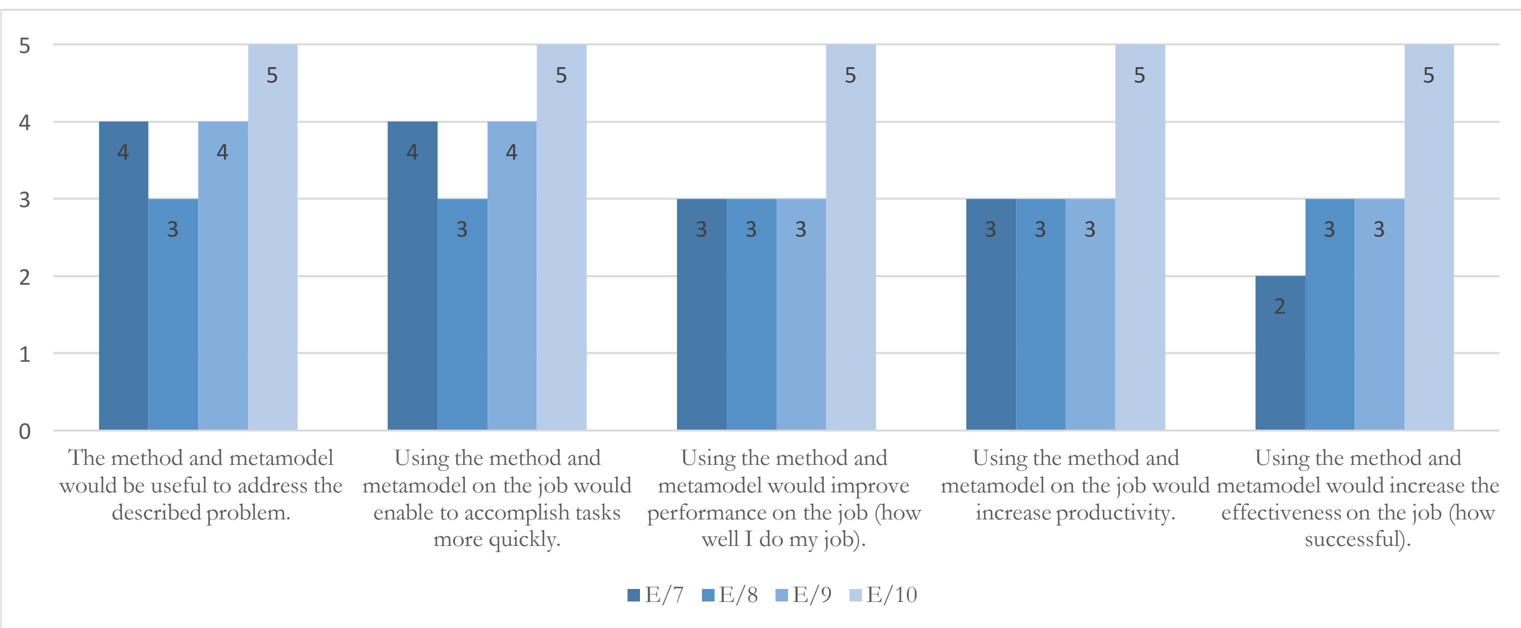



Figure 6.5 Results of usefulness closed questions

Figure 6.5 shows that most practitioners were relatively positive about the usefulness of the metamodel and modelling procedure. Most practitioners perceived the benefits of using the metamodel and modelling procedure, to address the problem of business model – enterprise architecture alignment for networked enterprises. Since some interviewees were less familiar with UML and ArchiMate, the last three closed questions on usefulness of the metamodel and modelling procedure on the job were rated slightly lower than the first two closed questions. Some of the practitioners, such as interview E/7, are used to a more informal approach, where for example VISO is used to express the relation of processes with information, data and IT systems. Therefore, some practitioners said that the metamodel and modelling procedure was too theoretical or too formal, which would only make analysis of the feasibility and viability of a business model implementation more complex. This is illustrated by the following quote:

[10] *The Method is theoretic but I think most of the methods are too theoretical.* [..] *The model makes it somewhat complex. At some point, you are searching where you should put certain aspects.* [..] *Even though the method is theoretic, I think you have tried to get the best of it.* (E/7)

In contrast, practitioners who were more familiar with UML and ArchiMate did recognize the advantage of the formal modelling language UML approach, stating that for example UML could help to define a business model in a more structured manner. This could be seen in the given score of the last interviewee, E/10, who provided an average score of five on the usefulness. Interviewee E/10 has a more technological background, and was familiar with both UML and ArchiMate. Also, interviewee E/8 and E/9 were familiar with ArchiMate, only they used it to some extend in their daily work (mainly ArchiMate). This is illustrated by the following quote.

[11] *It is a certain way to systematically define a business model. Where you normally randomly define the concepts more randomly, UML is somewhat more like a relational database, where you could define the concepts more formally. Furthermore, the relationships between the various business model concepts become more structured and clear.* (E/8)

Nonetheless, the complexity of the metamodel and modelling procedure would harm the usefulness of the method, according to most interviewees. Therefore, various interviewees proposed to make the metamodel and modelling procedure simpler, which would reduce confusion and thus increase the effectiveness of the modelling process. Interviewee E/9 and E/8 stated that, especially business oriented people on a managerial level do not have the time and money to dive into all kinds of modelling details. Therefore, multiple interviewees proposed to simplify the artefact. They provided specific details on how to achieve this. Interviewee E/7, E/9 and E/10 all stated that the 'data object' and 'information object' class could be combined into one class. Furthermore, they stated that the 'value exchange' and 'information exchange' concept classes of the VISOR-VIP target metamodel could be removed, since the exchange of values and information would be visualized in the VIP ArchiMate model. This would could enlarge the usefulness, since users of the artefact would not have to spent their time on detailed modelling, but rather could dive in the detailed analysis of the feasibility and viability of the business model implementation, by looking for example on a more detailed level at the conflicting business processes. Also, interviewee E/10 stated that it was sometimes difficult during the discussions to determine the level of abstraction of the different concepts. However, the interviewee stated that is particular a problem for this metamodel and modelling procedure, but a more general problem or challenge with enterprise architecture.

Lastly, the way the metamodel and modelling were applied to the Industry 4.0 domain made it somewhat difficult to determine the usefulness of the method for interviewee E/8 and E/10. Although they acknowledged the usefulness, they found it somewhat difficult to really experience the usefulness of the artefact. According to the interviewees, if the artefact would be applied to a more specific case in a case study, it would be clearer how the artefact could be used. This was the main reason for the lower score given by interviewee E/8 on the fifth question of the usefulness questionnaire. Both interviewees advised to apply the artefact on a more specific case study in further research.

#### b) Ease of use

Figure 6.6 shows that most interviewees evaluated the metamodel and modelling procedure as easy to use. However, some who were less familiar with UML and ArchiMate preferred to have more explanation on the different concepts. As expected, these interviewees found the metamodel and model procedure to be less easy to use. It was suggested to include a manual which should help users of the artefact who are not familiar with the specific modelling languages to guide them through the modelling procedure. Furthermore, the VIP ArchiMate model should include a legend which explains the various ArchiMate concepts (which was initially not included in the version which based merely based on literature and complemented by the interviews, in the complemented version on page 84 includes the suggested legend). Furthermore, examples of what for instance a value proposition or actor could be also would help to make the metamodel and modelling procedure easier to use.

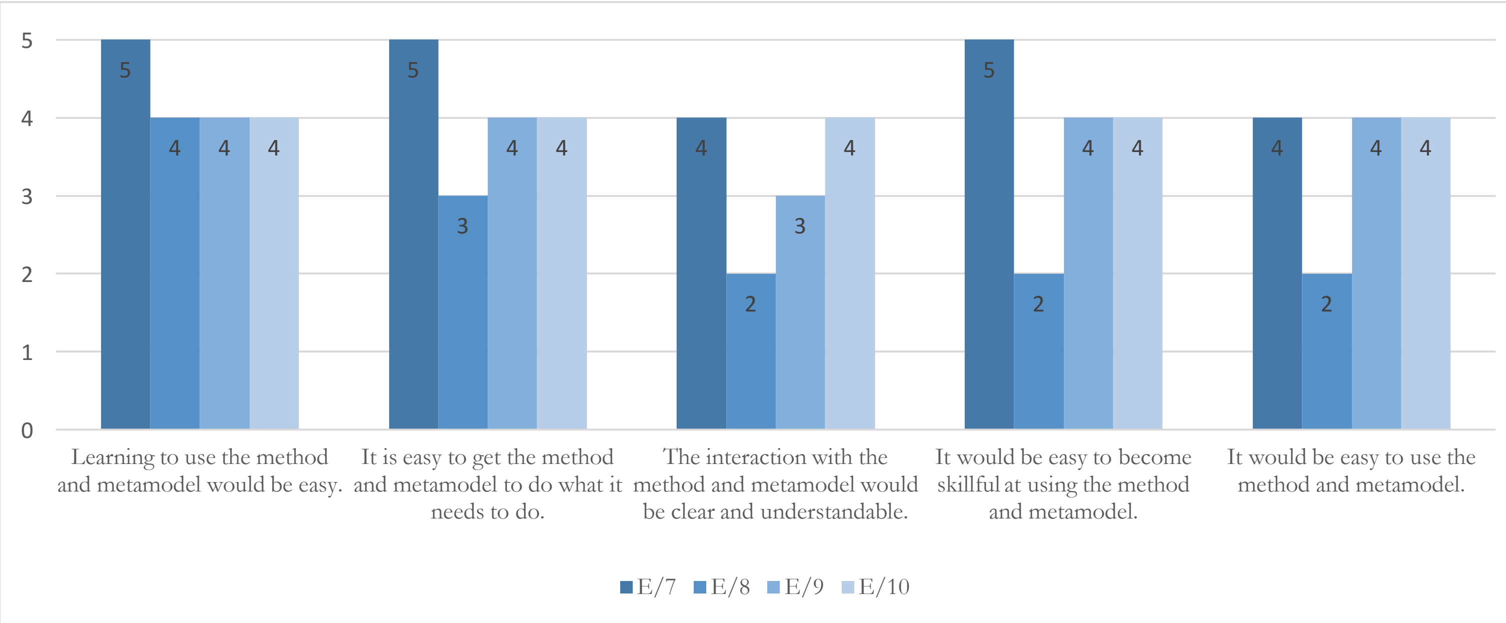



Figure 6.6 Results of ease of use closed questions

Finally, interviewee E/7 advised to consider removing the swimming lanes of the VIP ArchiMate model. Instead, the concepts had to be placed according to the way the relationships were defined. This could help to reduce the amount of overlapping relationships in the ArchiMate model. However, interviewee E/10 argued against this, by stating that the swimming lanes really could help to differentiate between the different concepts.

#### *6.2.2 Requirement fulfilment*

Next to the evaluation criteria on usefulness and ease of use, also requirement fulfilment can be a means of evaluation of an artefact (Johannesson & Perjons, 2014; Verschuren & Hartog, 2005). Table 6.2 displays the results of the evaluation on requirement fulfilment.

Table 6.2 Requirement fulfilment

| # | E/7 | E/8 | E/9 | E/10 | Score |
|---|---|---|---|---|---|
| **1** | 2 | 3 | 3 | 3 | 2.75 |
| **2** | 3 | 3 | 3 | 3 | 3 |
| **3** | 3 | 3 | 3 | 3 | 3 |
| **4** | 3 | 2 | 2 | 3 | 2.5 |
| **5** | 2 | 2 | 3 | 1 | 2 |
| **6** | 2 | 3 | 3 | 2 | 2.5 |
| **7** | 2 | 3 | 3 | 3 | 2.75 |
| **8** | 3 | 3 | 3 | 3 | 3 |
| **9** | 3 | 3 | 3 | 3 | 3 |
| **1** | 2 | 3 | 2 | 3 | 2.5 |
| **2** | 3 | 3 | 3 | 3 | 3 |
| **3** | 3 | 3 | 3 | 3 | 3 |
| **4** | 2 | 2 | 3 | 2 | 2.25 |

The interviewees assessed the requirement with a score from 1 to 3 (1=Not fulfilled, 2=partly fulfilled, 3=fulfilled). The table shows that most requirements are fulfilled and some requirements are partly fulfilled. The requirements which with the scores lower than 2.5 will be discussed briefly (since requirement 13 is on ease of use this requirement will not be discussed in this section, see section 6.2.1)

***a) Functional design requirement 4: missing interactions and interrelations on the process level***

Some interviewees missed a certain level of detail in the process concepts of the VIP metamodel to show the interactions and interrelations between the actors on the process level trough inter-organizational process collaborations. This might be influenced by the way the metamodel and modelling procedure were initially implemented. In the initial implementation (which was merely based on literature on Industry 4.0), more inter-organizational processes like the *data integration and processing* processes were not included; these were added based on suggestions from the interviewees. This might explain why some interviewees experienced the lack of inter-organizational processes.

Nonetheless, ArchiMate features the *business interaction* concept to express interactions and interrelations on the process level This concept was not included in the VIP metamodel and the VIP-ArchiMate target metamodel to ensure ease of use and to comply to the way the metamodels are used in the modelling procedure (where the VIP metamodel and VIP-ArchiMate target metamodel are used on a higher level of abstraction, allowing for a high-level overview of the business implementation without diving into the detailed modelling concepts of ArchiMate). However, based on the feedback from the interviewees, an inclusion of this particular concept can help to fulfil this requirement.

***b) Functional design requirement 5: missing cost aspects.***

According to some interviewees, the cost aspect of the requirement five was also missing. It is debatable if a substantive cost concept needs to be included, since for networked enterprises, cost/revenues are interchangeable; for some actors, certain value exchanges can be considered as costs when that specific actor acts as a buyer, while the receiver of the value exchange (i.e. the seller) considers the value exchange to be a revenue stream. An organization-centric business model, like the BMC of Osterwalder (2004), has the focus on the organization itself. So, there it would seems sensible to include a cost structure concept for the expenses of the organization. One could argue that the cost concept could be used for all combined value exchanges of networked enterprises with actors outside of the ecosystem, so with for example suppliers of suppliers (so with actors of the business ecosystem or the extend enterprise). However, due to the levelling and balancing of the VISOR and VIP analysis (which needs to stay lightweight) it is decided that a cost structure concept is not included.

***c) Non-functional design requirement 1: difficulty in differentiation between VISOR, VIP and ArchiMate metamodel concepts.***

Some interviewees experienced difficulty in understanding the relationships between the concepts of VISOR metamodel, the VIP metamodel and ArchiMate, since it was sometimes from which metamodel certain concept were. Interviewee E/9 suggested to include a guide, manual or small demonstration with the modelling procedure to help users understand which metamodels needs to be used in what step, and what concepts are from what metamodel.

### *6.2.3 New requirement on risk and compliance restrictions*

Interviewee E/9 stated that for an analysis of the feasibility and viability of a business model it is also of importance to also take restrictions that influence a business opportunity into account. Based on the design goal of the artefact it is acknowledged that an inclusion of these concepts is valuable to support the analysis of the business model implementation. For example, in certain industries restrictions (such as privacy regulations on processing of personal data) can influence the way products and services can be offered to a client, and thus the way the business model is implemented. Especially in an environment where sensitive data is being used to realize a business model, such as the Industry 4.0 domain, risks and regulations issues could influence the way the business model is implemented. Therefore, a new requirement is added to the list of functional requirements:

| # | Functional design requirement |
|---|---|
| **10** | The metamodels should describe and visualize risk and compliance related restrictions. |

#### *6.2.4 Sub-conclusion section 6.2*

In the previous sections, an answer was given to research question four (B). *How do practitioners evaluate the refined design specifications?* Overall, the interviewees were mostly positive on the usefulness, ease of use and fulfilment of requirements of the artefact. However, some suggestions were made to improve the artefact. The inclusion of the new concepts in the VISOR metamodel, the VIP metamodel and new concept mapping in the VISOR-VIP target metamodel and the VIP-ArchiMate target metamodel to fulfil functional design requirement ten is discussed in detail in Table C.8.1 to Table C.8.5 in Appendix C8 (Note: No adjustments were made to the modelling procedure). The metamodel refinements will be discussed in the next section, the chapter conclusion.

### 6.3 Chapter conclusion

In this chapter, an answer was given to research question four (A). *What is the result of an application of the metamodels and the modelling procedure to the Industry 4.0 domain?* (B). *How do practitioners evaluate the refined design requirements and design specifications?* Results of the desk study and interviewees have led to the development of three model instantiations, specified for the Industry 4.0 domain. Interviewees were able to bring up multiple valuable complements to the initial model instantiations, which were merely based on literature. Although the fourth step of the modelling procedure is not executed due to time constraints, the VIP ArchiMate model gave some first insights into the business model implementation aspects for the Industry 4.0 domain. To ensure the feasibility and viability of the Industry 4.0 business model, it is essential that on the level of value, profit sharing and cost sharing arrangements are made. Furthermore, evaluation on the customized product design should be held to discover hidden requirements. On the level of information, interoperability and privacy issues need to be addressed. For example, the IoT sensor data is being used various heterogeneous processes which could lead to interoperability issues and data from the product use of the end-customer needs to be analysed to realize the business model, which could lead to privacy issues. Lastly, on the level of processes, arrangements need to be made on how the business processes are going to be connected to each other to prevent heterogeneous and conflicting business processes.

During the use of the models, the interviewees got a feeling of the usefulness, ease of use and requirement fulfilment of the artefacts. Generally, the interviewees evaluated the usefulness, ease of use and requirement fulfilment positive. Based on the feedback of the interviews, the following refinements will be made:

1. Integration of a risk and compliance concept to fulfil functional design requirement 10

In the refined metamodel of VISOR and VIP a 'risk and compliance' concept will be included. The risk and compliance concept can be used to analyse risks and compliance to regulations restricting on the design of the value proposition. It is argued that certain risks and compliance issues influences the value an actor intends to achieve or offer to other actors. See Table C.8.1 to Table C.8.5 in Appendix C8 for how this concept is included and on what literature the inclusion of the concept is based.

2. Reducing metamodel complexity

To ensure the usefulness and ease of use of the metamodels, the following adjustments have been made: (1) Removal of the 'value exchange' and 'information exchange' concept in the VISOR-VIP target metamodel. (2) Removal of the two 'data object' and 'information object' classes, replaced by one 'data/information object' class in the VISOR-VIP target metamodel.

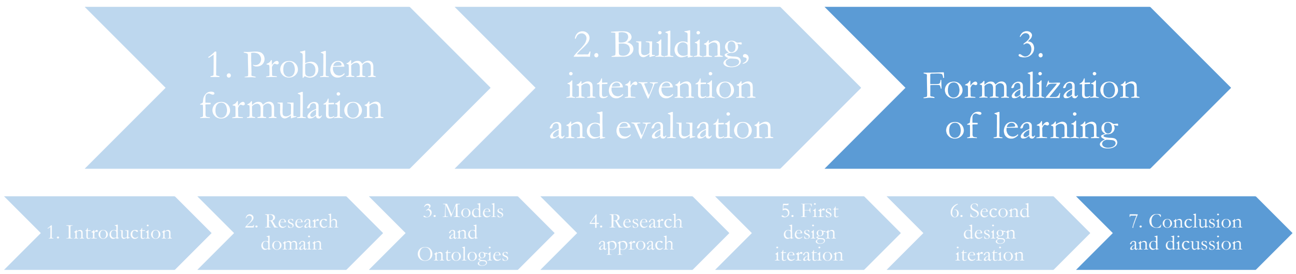
3. Inclusion of legend in VIP ArchiMate model

A legend is now included in the VIP ArchiMate model to explain the ArchiMate concepts to used who are not familiar with ArchiMate.

4. Inclusion of the 'business interaction' concept

Lastly, in the VIP –ArchiMate target metamodel, the business interaction concept of ArchiMate is included to allow for an expression of more complex inter-organizational interactions on the process level, addressing partly fulfilled design requirement 4.

# Chapter 7 Conclusion and discussion




In this chapter will be reflected on the adherence to the ADR principles. Furthermore, the research will be concluded by answering all the research questions and by describing the scientific and practical relevancy of this research. Lastly, there is a discussion section in which is reflected on the research process by discussing limitations of the study and directions for future research. This chapter is structured as follows. First, adherence of the design principles of the ADR method is discussed. Next, the research is concluded by answering all the research questions. Lastly, the practical relevance and the scientific relevance as well as the limitations and future research directions will be discussed.

### 7.1 Formalization of learning

In this section, first an explanation is given how the seven design principles of (Sein et al., 2011) have been incorporated in the research. Next, a new design principle is included when developing a

The adherence will be evaluated by the framework of Sein et al. (2011), as displayed in table 7.1.

Table 7.1 Adherence to design principles

| **Stages and Principle** | | **Artefact** |
|---|---|---|
| **Stage 1: Problem Formulation** | | |
| **Principle 1: Practice Inspired Research** | Research was driven by the need to support business analysts and enterprise architectures with formal approach for business model –enterprise architecture alignment for networked enterprises. | *Recognition:* Shortcomings of current business model – enterprise architecture approaches, that are often lacking a network focus, multi-level analysis and formal notation. |
| **Principle 2: Theory Ingrained Artefact** | No kernel theories were used; however, the artefact is embedded in business model, enterprise architecture and business model – enterprise architecture alignment academic literature. | |
| **Stage 2: BIE** | | |
| **Principle 3: Reciprocal Shaping** | Recursive cycles to the shape the metamodel and modelling procedure. | *Alpha version:* The metamodel and modelling procedure conceived as a design idea and evolved from an initial metamodel and modelling procedure to a refined metamodel and modelling procedure through two design cycles. |
| **Principle 4: Mutually Influential Roles** | The Action Design Researcher (the Master student) included researchers and practitioners in the design process to include theoretical and practical perspectives. | |
| **Principle 5: Authentic and Concurrent Evaluation** | The initial metamodel and modelling procedure were evaluated with researchers and practitioners. | *Beta Version:* The first refinement of the metamodel and modelling procedure evaluated by the researchers evaluated in a second refinement of the metamodel and modelling procedure when it implemented with practitioners in the Industry 4.0 domain. |
| **Stage 3: Reflection and Learning (entered throughout the whole design process)** | | |
| **Principle 6: Guided Emergence** | The ensemble nature of the metamodel and modelling procedure was recognized. | *Emerging Version and Realization:* New and refined design requirements for the metamodel and modelling procedure based on results from the problem formulation and BIE stage. |
| **Stage 4: Formalization of Learning** | | |
| **Principle 7: Generalized Outcomes** | A set of design principles for ADR was articulated positioning the metamodel and modelling procedure as an instance for similar settings. | *Ensemble Version:* An ensemble embodying the design principles and a new design principle for ADR research relevant in metamodelling settings. |

Below, a brief new design principles is described for ADR research in similar settings:

*Balance the subjective backgrounds of ADR participants for evaluating ADR results.*

During the evaluation with the researchers and practitioners, it became clear there exists no correct way in business modelling and enterprise architecture. Every researcher had his own idea on how one could transition from a business model to an enterprise architecture in a formal way. It became clear that most researchers somewhat propagated their own work. Researchers who were actively involved in the development of certain models or frameworks, often suggested to use their own framework or model, and stated that other models or frameworks might not be relevant. Practitioners who were less familiar with ArchiMate, suggested using methods that they were familiar with. To balance these different, sometimes biased perspectives, the design of the metamodel and modelling procedure was shaped by balancing the different perspectives. This was done by searching for proportionate design specifications. For example, some researchers stated that some of the concepts of VIP could be entirely removed from the metamodel and only use ArchiMate, while others propagated the use of the theoretical foundations of VIP. The proportionate design specification has led a to a combination of both, where the VIP way of looking is still included in the design specification (also because it was acknowledged as valuable by one researcher who was actively involved in the development of ArchiMate), however, by integrating similar concepts of the VIP metamodel with ArchiMate concepts, a combination of both perspectives is included in the design specification.

## 7.2 Conclusion

In this research, a formal set of metamodels and a corresponding modelling procedure have been developed for networked business model – enterprise architecture alignment. In the previous chapters, the complete design process, including two BIE design cycles, has been carefully described. Every chapter ended with a conclusion by answering the relevant research question. In this chapter, a conclusion is provided for the entire research, by answering the main research question. However, first the knowledge gaps, problem statement and research objective will be described.

Several knowledge gaps are identified in this study. First, current business model literature has mainly proposed informal business model representations and lacks a focus on formal business model implementation design. As a result, describing, structuring and communicating the knowledge stored in business models becomes difficult and the business model design remains isolated from the design of the business model implementation, which is often represented in formal modelling languages like UML. This introduces the second limitation of business model literature, which is the missing focus on the formal design of the business model *implementation*. Not considering the business model implementations design leads to an incomplete understanding of the gap between the business model and the business model implementation. Furthermore, severe set-backs are to be expected in the execution of the business model when implementation aspects are no considered. Even those business models that seems promising on paper, can fail when they are being technologically implemented

Second, current literature on enterprise architecture lacks a more abstract and economic business model perspective. Therefore, important questions such as who benefits from the product?", and "who will pay for it?" are not included in the design of enterprise architectures. Also, evaluating the business fit of the enterprise architecture becomes difficult.

Third, current literature on business model – enterprise architecture alignment proposed mainly approaches that are often intra-organizational, facilitate merely a single-level of analysis (by focusing on either the level of values, information or processes), are heavyweight by including many different concepts and are informal by lacking concrete metamodels and modelling procedures. A result of these limitations is that complex networked interactions are not perceived due to the intra-organizational perspective, the business model implementation cannot be described, analysed and visualized in a comprehensive manner due to the single-level of analysis and the business model implementation design process becomes rather complex and time consuming, due to heavyweight approach. Lastly, the informal approach leads to different interpretations by the various stakeholders and difficulty in consistently exploiting the knowledge stored in business models while designing enterprise architectures using the business model-driven approach. Together, these limitations hinder the analysis of the feasibility and viability of the networked business model.

Fourth, current literature on the application domain of this study, the Industry 4.0 domain, lacks a business model implementation perspective. Industry 4.0 seems promising from a business and technological perspective; however, the adoption of Industry 4.0 is still low. As such, a focus on business model implementation aspects can help to commercialize Industry 4.0.

Consequently, the following main research problem for this study is defined as follows: *lightweight formal metamodels and modelling procedures that can support networked enterprises with a multi-level analysis, description and visualization of their business model implementation through enterprise architecture concepts are currently lacking in academic literature.*

Based on the knowledge gaps and problem statement, this study aims to develop an artefact that complies with the following requirements:

1. The artefact should include a formal representation of a business model with a focus on formal business model implementation design.
2. The artefact should extend enterprise architecture with an economic business model perspective.
3. The artefact should include a formal lightweight business model – enterprise architecture alignment approach that can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

Following these requirements, the main research objective of the master thesis is defined as follows:

*The objective of this research is to develop lightweight formal metamodels and a corresponding modelling procedure in UML that can support networked enterprises with a multi-level description, analysis and visualization of their technological business model implementation through enterprise architecture concepts.*

By applying to the artefact to the characteristics of the Industry 4.0 domain, insights into business model implementation aspects for the Industry 4.0 domain should be obtained (which therefore aims to address the knowledge gap on lacking Industry 4.0 business model implementation literature)

The following main research question has therefore been stated:
*What are the design specifications of lightweight metamodels and a corresponding modelling procedure that facilitate a multi-level description, analysis and visualization of the technological implementation of a networked business model through enterprise architecture concepts?*

The following sub questions are stated to answer the main research question, and to structure the research process:

1. What are the defining technological and business characteristics of the Industry 4.0 domain and what are the challenges in the industry 4.0 domain?
2. What are the basic concepts of metamodels, business models, enterprise architectures and business model – enterprise approaches and what are limitations of current approaches?
3. A. What are initial design specifications of the metamodels and modelling procedure, incorporating both business model and enterprise architecture concepts?
   B. How do researchers evaluate these initial design specifications?
4. A. What is the result of an application of the metamodels and the modelling procedure to the Industry 4.0 domain?
   B. How do practitioners evaluate the refined design specifications?

The ADR method of Sein et al. (2011) is used to iteratively develop the metamodel and modelling procedure. To structure the design cycles, design steps from the design cycle of Verschuren and Hartog (2005) were used. With the knowledge that is obtained from this study, the sub questions can be answered as follows:

1. *What are the defining technological and business characteristics of the Industry 4.0 domain and what are the challenges in the industry 4.0 domain?*

The Industry 4.0 domain is described from a technological as well as a business oriented perspective. From the technological perspective, IoT is the technological enabler for a digitalization of the manufacturing industry. This allows manufacturing organizations to organize the manufacturing business processes in a more flexible and efficient manner. This has several implications from a business oriented perspective. Firstly, the introduction of IoT leads to the formation of horizontal and vertical networks where organizations evolve and interact around digital platforms in digital business ecosystems to co-create, co-capture and co-convert value. This results in the emergence of new value propositions for highly customized or differentiated products and value-added services (combinations).

A challenge for the Industry 4.0 domain is that many organizations are still experiencing difficulty in relating Industry 4.0 aspects to their business models and business operations. As a result, Industry 4.0 still has to become a reality. A focus on business model implementation aspects can help to commercialize Industry 4.0. However, most Industry 4.0 literature has a technological perspective, while the business model implementation perspective is underdeveloped.

2. *What are the basic concepts of metamodels, business models, enterprise architecture and business model – enterprise alignment approaches and what are the limitations of these approaches?*

Models are a formal specification of reality, while metamodels and metamodels and ontologies are models which are an explicit, shared and formal specification of a conceptualization. Business models express the business logic of an organization, while enterprise architecture generally defines the business implementation through a description of the business processes, information and ICT. A limitation of business models is that they are often represented in an informal notation and often neglect to address ICT driven implementation aspects. A limitation of enterprise architecture models is that they often miss a more economical oriented business model perspective. A few researchers have proposed approaches to align business models with enterprise architectures to gain insights into business model implementation aspects. Nonetheless, they have several limitations: they are often intra-organizational, have a single-level of analysis, are heavyweight by having many model concepts or are using an informal approach. To address these limitations, this study aims to develop lightweight *formal* metamodels and a corresponding modelling procedure in UML for networked business model – enterprise architecture alignment that support networked enterprises with a description, visualization and analysis of their technological business model implementation. For the development of the metamodels and modelling procedure, the theoretical foundations of the VISOR business model framework and the VIP business model – enterprise architecture framework are used since (1) they both have a networked perspective, (2) VISOR is developed for analysis of digital ecosystems and digital platforms (which suits the application domain of this study, Industry 4.0), (3) VIP allows for multi-level analysis and (4) VIP is a *lightweight* conceptualization to bridge the gap between business models and enterprise architectures. Lastly, ArchiMate is selected for the enterprise architecture component of the metamodels and modelling procedure since (1) ArchiMate has an integrated approach for modelling all aspects of an organization (2) the use of ArchiMate is advocated by its representativeness and wide acceptance in the academic and practitioner communities.

3. *A. What are initial design requirements and design specifications of the metamodels and modelling procedure, incorporating both business model and enterprise architecture concepts?*

The initial design specifications are a set of five metamodels that are layered and placed on top of the existing ArchiMate metamodels. The initial design specifications are based on a set of nine functional and four non-functional design requirements which are mainly elicited from the theoretical foundations of the VISOR business model and the VIP business model – enterprise architecture framework.

*B. How do researchers evaluate these initial design requirements and design specifications?*

In total, five design requirements are refined based on the evaluations. Due to the inconsistency, inherency or invalidity of various metamodel concepts, researchers suggested to exclude several metamodel concepts, which resulted in the refinement of four functional design requirements. Furthermore, discussions on the way the various metamodels are levelled leads to the refinement of a non-functional design requirement. Also feedback on the design specifications is collected. It was suggested to only develop two metamodels to keep the approach lightweight and to keep the design specifications valid and consistent when layering the different metamodels. The refined design requirements are presented in table 7.2. (please note that the tenth functional design requirements is elicited in the second-round interviews)

Table 7.2 List of functional and non-functional design requirements

| # | Functional design requirements |
|---|---|
| **1** | The metamodels should describe and visualize describe the value proposition. |
| **2** | The metamodels should describe and visualize describe the value interface through which the value proposition is delivered. |
| **3** | The metamodels should describe and visualize the service platform upon which the actors interact which each other. |
| **4** | The metamodels should describe and visualize the organizing model which defines how the networked enterprises will organize themselves to effectively and efficiently deliver the value proposition. |
| **5** | The metamodels should describe and visualize the sharing of costs and revenues amongst the networked enterprises. |
| **6** | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects and information objects. |

| | |
|---|---|
| **7** | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and business processes performed by actors. |
| **8** | The metamodels should describe and visualize which actor has access to what value, information, data and knowledge objects. |
| **9** | The metamodels should be used in a step-by-step modelling procedure, starting from the value propositions, where it from there on helps to define all the required business model implementation concepts to realize the networked value proposition. |
| **10** | The metamodels should describe and visualize risk and compliance related restrictions. |
| **#** | **Non-functional design requirements** |
| **1** | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts, by formally integrating similar business model and enterprise architecture concepts. |
| **2** | The metamodels should be compatible with UML-modelling standards based on MOF. |
| **3** | Relationships between concepts should be defined according to the ArchiMate meta relationships (such as 'assignment' or 'realization' relationships). |
| **4** | The metamodels should be comprehensible – i.e. the ease with which an artefact can be understood or comprehended by business oriented stakeholders and IT oriented stakeholders. |

Processing the feedback results in the development of two metamodels, two target metamodels and a corresponding modelling procedure. First, the VISOR metamodel can be used to describe and visualize the business model in a structured manner. Second, the VIP metamodel can be used to describe and visualize the operationalization of the business model. Third, the VISOR-VIP target metamodel can be used to transition from the concepts of the VISOR metamodel to the VIP metamodel. Fourth, to transition from the concepts of the VIP metamodel to the ArchiMate metamodel, the VIP-ArchiMate target metamodel can be used, after which the VIP ArchiMate model can be developed using the ArchiMate concepts. The VIP ArchiMate supports discussions on the feasibility and viability of a networked business model.

Based on the integration effort of the VIP metamodel concepts with the ArchiMate concepts and the discussions with several ArchiMate experts, a new ArchiMate concept is proposed. The 'value activity' concept aims to bridge the gap between the more economical business model and the more functional enterprise architecture. In addition to this newly proposed concept, two new relationships are proposed. First, an *access* relationship between the 'resource' and 'business process' concept is proposed. Second, an *influence* relationship between the 'value' and 'business process' concept is proposed in the business layer metamodel. The proposed ArchiMate extensions should mainly help to include a more economical business model oriented perspecrive in ArchiMate.

4. *A. What is the result of an application of the metamodels and the modelling procedure in the Industry 4.0 domain?*

The application of the refined metamodel results in the creation three model instantiations of the VISOR metamodel, the VISOR-VIP target metamodel and VIP-ArchiMate target metamodel for the Industry 4.0, taking into account business model implementation aspects, such as business operations as well as organizational and financial issues. With the application of the artefact to the Industry 4.0 domain, some first insights into the business model implementation aspects for the Industry 4.0 domain are obtained. To ensure the viability of the business model, it is essential that on the level of value, profit sharing and cost sharing arrangements are made. Furthermore, evaluation on the customized product design should be held to discover hidden requirements. To ensure the feasibility of the business model, on the level of information, interoperability and privacy issues need to be discussed and addressed. Lastly, on the level of processes, arrangements need to be made on how the business processes are going to be connected to each other to prevent heterogeneous and conflicting business processes.

*B. How do practitioners evaluate the refined design requirements and design specifications?*

The evaluation with practitioners shows that they are mostly positive on the usefulness, ease of use and fulfilment of requirements of the artefact. Processing the feedback of the practitioners results in the identification of a new functional design requirement and a refinement of the design specifications of all metamodels, by simplifying the metamodels, incorporating a risk and compliance concept as well as the inclusion of a new concept to define complex business process interactions on a more detailed level.

The answers of the sub questions can together be used to answer the main research question. To answer the main research question, the will be structured on artefact requirement stated in the research objective.

1. *The artefact should include a formal representation of a business model with a focus on formal business model implementation design.*

First, the VISOR metamodel is a formal representation of a networked business model, based on the theoretical foundations of VISOR. The VISOR business model framework initially lacked a formal representation and was expressed in natural language. The VISOR metamodel is used to describe and visualize the business idea in a structured manner. The formal relationships between the metamodel concepts guide the business modeller to define the implications of the value proposition on the other model concepts. Furthermore, issues regarding risks and compliance to regulations, affecting the value proposition and the revenues, can be described and visualized as well.

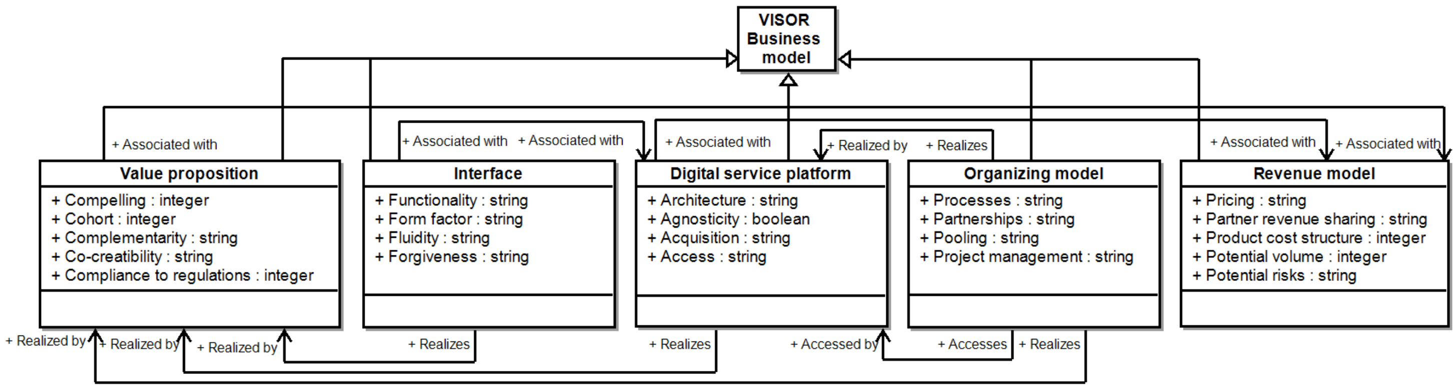



Figure 7.1 VISOR metamodel

Second, the VISOR-VIP target metamodel is a formal representation of the first step towards the implementation of the business model. The VISOR-VIP target metamodel extends the VISOR metamodel with a focus on formal business model design. Formal metamodel integration techniques were used to integrate the concepts of the VIP metamodel (which will be discussed next) into the VISOR metamodel. The target VISOR-VIP target metamodel defines the required VIP metamodel concepts to realize the business idea. The formal relationships in the target metamodel help networked enterprises to systematically define risks and compliance issues that affect the value proposition and the actors and their corresponding value goals, value objects (i.e. resources and capabilities), information related objects and primary business process that are required to realize the business idea.

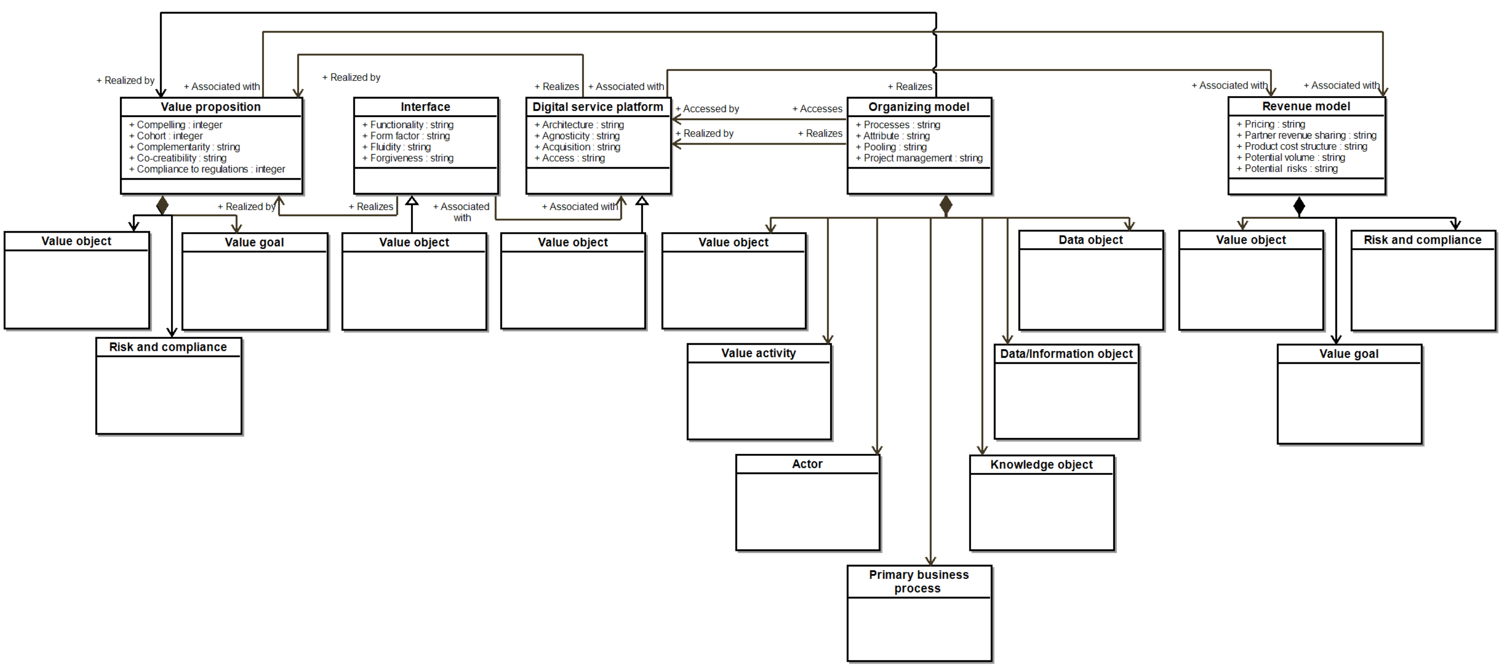



Figure 7.2 VISOR-VIP target metamodel

2. *The artefact should extend enterprise architecture with an economic business model perspective.*

The development of the VIP-ArchiMate metamodel has resulted in the proposal of a new concept and two new relationships to ArchiMate (see table 7.3). The proposal of the inclusion of a 'value activity' concept to ArchiMate is a first step towards the inclusion of a more abstract and economical business model perspective in ArchiMate. The 'value activity' concept aims to bridge the gap between the more economical business model and the more functional enterprise architecture. While a business process is often modelled purely from a functional perspective (without taking into account the direct value that the business process creates), the value activity concept can be used to describe and visualize more abstract and economical oriented activities that create direct value for various actors, such as "buying a product", "watching a movie" or "collaborating to increase branding image". The relevace of this concept is confirmed by various researchers who were involved in the development of ArchiMate. In addition, two new relationships are proposed which add to the inclusion of a business model perspective. The first poposed relationship comprises of an *access* relationship between the various behaviour elements and the static behaviour element 'resource' concept of ArchiMate. The second proposed relationship comprises of an *influence* relationship between the 'Business process/function/interaction/ (value activity)' concepts and the 'value' concept. This allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value.

Table 7.3 Proposed ArchiMate extensions

| **Concept 1** | **Concept 2** | **Relationship** | **Meaning** |
|---|---|---|---|
| **Resource** | **Business process/function /interaction/ (value activity)** | Access | A behavioural element can access (i.e. create, read, process or exploit) a resource (i.e. material, IT infrastructure, human resources). |
| **Value** | **Business process/function /interaction/ (value activity)** | Influence | Value is an output of a business process/function /interaction/value activity, which has value-in-use for buyers. |
| **Concept** | | | **Definition** |
| **Value activity** | | | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors. |

3. *The artefact should include a formal lightweight business model – enterprise architecture alignment approach that can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.*

The combination of the formal VISOR, VISOR-VIP and VIP-ArchiMate metamodels (as displayed in figure 7.1 and 7.2

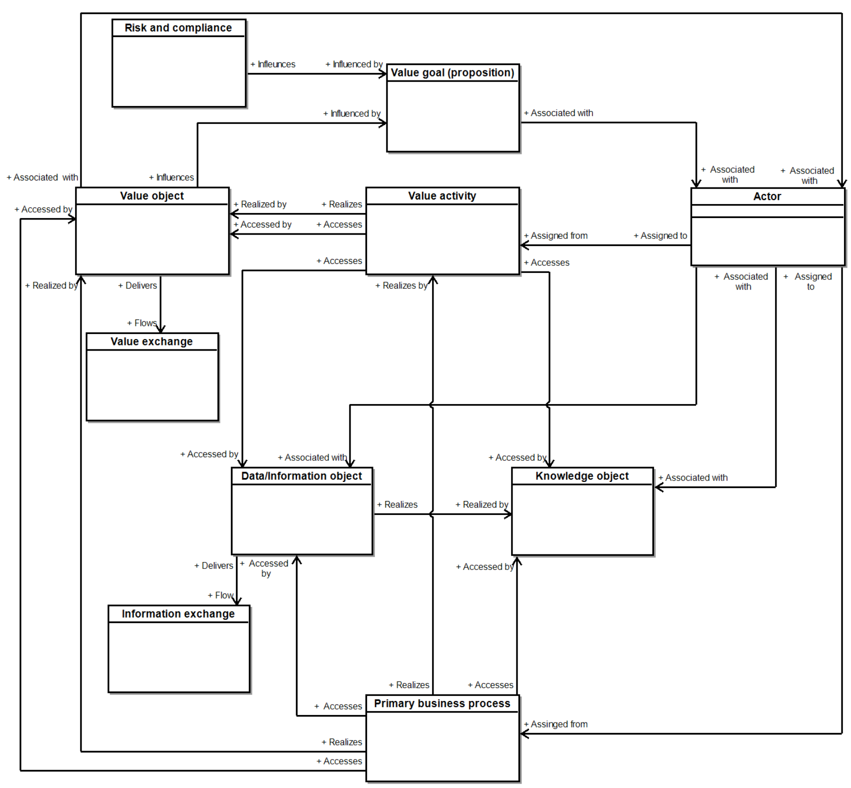





Figure 7.3 VIP metamodel

and 7.3) and a corresponding modelling procedure (see appendix E1) can be defined as a formal lightweight approach that can be used to describe, visualize and analyse the technological implementation of a networked business model through enterprise architecture concept. The VIP metamodel is a lightweight intermediate (between the VISOR business model and ArchiMate enterprise architecture metamodels) metamodel that is formally integrated with the VISOR metamodel and ArchiMate concepts (see figure 7.4). As a result, the VIP metamodel instantiations can be modelled in enterprise architecture modelling language ArchiMate. When used in combination with ArchiMate (see appendix E2), VIP ArchiMate model instantiations allow for a description, visualization and lightweight analysis of the business model implementation on the levels of values, information and processes to ensure the feasibility and viability of the VISOR business model Lastly, risk and compliance issues can also be included in the analysis.

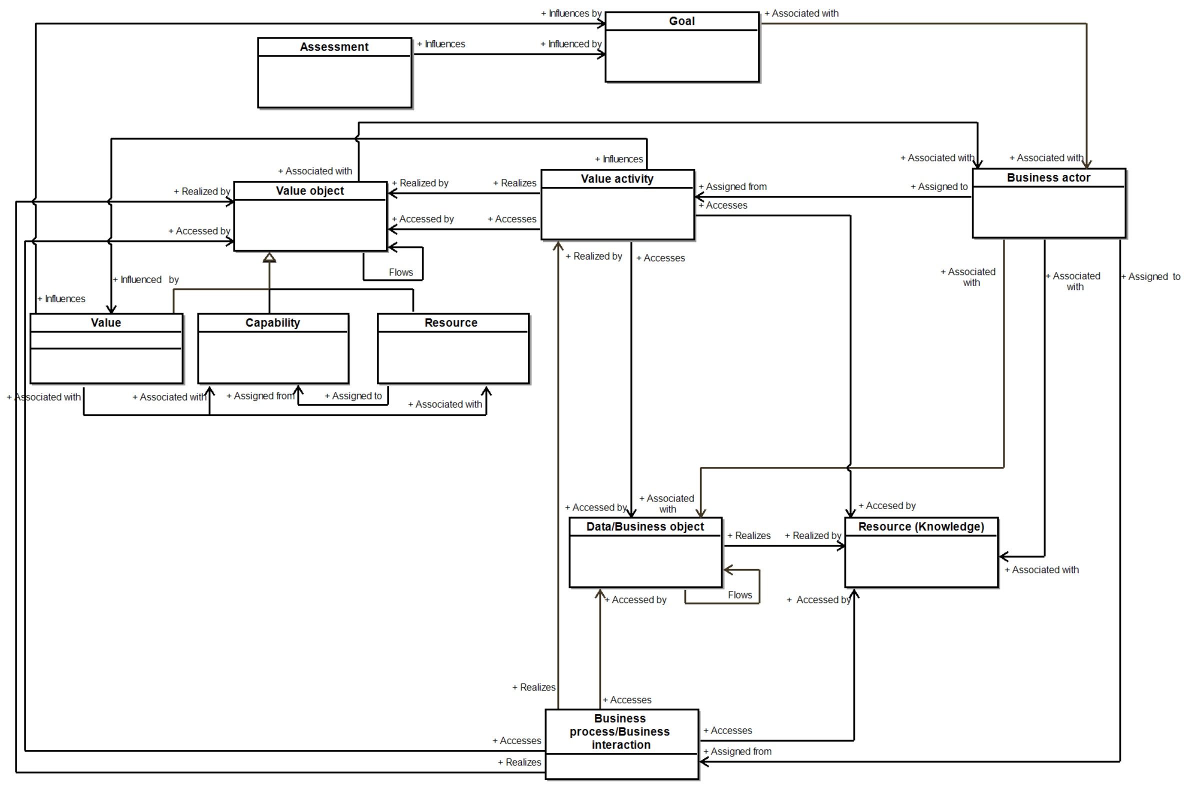



Figure 7.4 VIP ArchiMate target metamodel

The modelling procedure supports analysis and description of business model implementations within networked enterprises through a step-by-step process (see appendix E1). The first step begins by expressing the business idea on a high level of abstraction with the VISOR metamodel. In the next step, the target VISOR-VIP target metamodel defines the required VIP metamodel concepts to realize the business idea. In the next step, the VIP ArchiMate model is defined. Two metamodels are used in this step. The VIP metamodel shows the formal relations between the VIP concepts, defined in step two of the modelling procedure. To draw the VIP concepts in ArchiMate, the VIP-ArchiMate target metamodel is used translate the concepts of the VIP metamodel to ArchiMate concepts. The VIP-ArchiMate metamodel is used to structure development process of the VIP ArchiMate model. Based on the resulting VIP ArchiMate model, discussions can be held on the feasibility and viability of the business model. Issues that endanger the feasibility and viability of the business model should be addressed in this step. When it is not possible to address these issues, the business model should be refined and the modelling procedure starts again. When the issues can be addressed, the fourth step defines the internal detailed internal enterprise architecture of each actor. The VIP ArchiMate model instance forms the context from which requirements can be derived for the internal enterprise architectures.

## 7.3 Reflection and discussion

In this section is reflected on this research by discussing the scientific and practical relevance, the limitations, and directions for future research.

### *7.3.1. Reflection on design choices*

a) ***Selection of models***

By selecting the theoretical foundations of VISOR to elicit the design requirements, this research has narrowed it scope to digital business ecosystems. If another model was selected to elicit design requirements, the scope would have been different. If for example the STOF model was selected, the research would be more oriented towards business model implementations in the mobile service domain. For the enterprise architecture model, also another model could have been chosen than ArchiMate. If for example ARIS would have been selected, a different set of target metamodels would have been developed. However, since ARIS is compatible with ArchiMate standards, it should be easy to map the metamodels concepts to ARIS. Instead of VIP, DEMO could have been used to bridge the gap between the more economical oriented business model and the more functionally oriented enterprise architecture (which was the approach taken by de Kinderen et al. (2014). This would have made the alignment approach more transactional oriented, since DEMO provides strict guidance for economic transactions.

b) ***Taking a lightweight approach***

By taking a lightweight approach, the metamodels should allow for a quick analysis of the business model implementation. While J. Gordijn (2003) discovered that a lightweight approach is suitable for a first exploration of an ICT driven business idea, it is argued that also a detailed heavyweight analysis is necessary because in some cases, a business model's feasibility or viability cannot be ensured due to a very detailed and small problem. Merely analysing the business model implementation on a higher level of abstraction could result in the underestimation of important details of the business model implementation. Therefore, it is not argued in this research that the presented approach should be used to describe, visualize and analyse the *entire* business model implementation process. Instead, it should be used as a first step towards the business model implementation. Lightweight approaches are the realm of heavyweight approaches, so the output from the application of the metamodels and modelling procedures form the input for the detailed heavyweight implementation process of the business model. A lightweight approach is very valuable to provide a first clear overview of how the business mode implication could look like, just before setting up a project or pilot study to run the business model. By starting with a heavyweight approach, the first analysis of the business model implementation would become too time consuming and would only make the analysis only more confusing due to the inclusion of many different model concepts in an already complex environment.

### *7.3.2. Scientific relevance*

This study has several scientific contributions. First, this study made several contributions to business model literature. First of all, this study contributes to business model literature with the development of the VISOR metamodel, which was initially expressed in natural language. The VISOR metamodel makes it easier to understand and visualize the relations between the business model concepts, which in turn should improve communication of the business idea. Second, the development of the VISOR-VIP target metamodel adds to the lack of a focus on formal business model implementation design in business model literature. The formal representation and integration of VISOR and VIP concepts make it easier to relate the business model design with the business model implementation design. As a result, business model (implementations) can be studied in a more consistent and holistic manner. The inclusion of an information, business process and enterprise architecture perspective in the VISOR-VIP target metamodel is another addition to business model literature. Most business model literature focuses on value related aspects, such as the value network analysis of Allee (2008), while the information, business process and enterprise architecture perspective is underdeveloped. With the VISOR-VIP target metamodel, studying business model implementations should therefore become more comprehensive and holistic for researchers in the field of business models and enterprise architectures. Lastly, while the inclusion of the risk concept in the VISOR metamodel is not validated yet, it is a first attempt to include risk modelling in business model design.

Second, this study adds to literature on enterprise architecture. First, the 'value activity' concept (which was perceived as a valuable contribution to ArchiMate by various researchers who are involved in the development of ArchiMate) is proposed as extension to ArchiMate. The concept can be used to model more economic business model oriented activities. Second, two new relationships are proposed to the ArchiMate business layer metamodel. The first relationship should make modelling the interactions of processes with resources more precisely, while the second relationship allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value. This should add a more abstract and business model oriented perspective to ArchiMate. As a result, researchers in the field of enterprise architecture who use ArchiMate can evaluate the fit of the enterprise architecture with the business model more effectively.

Third, this study adds to literature on business model and enterprise architecture alignment. First, with the development of the VISOR-VIP and VIP-ArchiMate target metamodels, it is one of the first studies in the field to integrate business model concepts and enterprise architecture through the application of formal metamodel integration techniques and rules. The formal integration of business model concepts with enterprise architecture can support studies on alignment issues that hinder the feasibility and viability of the business model in a more consistent, holistic and unfragmented manner. Second, another contribution to literature on business model and enterprise architecture alignment is the development of the formal VIP metamodel, which can be used as intermediate to bridge the gap between more economical and abstract business model design and the more detailed and functional enterprise architecture design. The VIP metamodel is based on the theoretical foundations of VIP, which was initially an informal conceptual framework rather than a formal modelling approach. By being based on the theoretical foundations of the VIP framework, this VIP metamodel facilitates a multi-level description, visualization and analysis of value, information and processes related aspects, where current business model enterprise architecture approaches often facilitate a single-level description and visualization (such as approach of (Ding, 2015)). Third, by formally integrating the VIP concepts with ArchiMate concepts in the VIP-ArchiMate target metamodel, this is also the first study that applies enterprise architecture thinking in VIP analyses. Also, in current business model and enterprise alignment architecture literature, a lightweight formal intermediate was missing; current approaches often convert the more abstract business model concepts directly to *many* detailed functional enterprise architecture concepts (such as the approach of (Rahmati, 2013)). By being lightweight (consisting of a limited number of concepts and relations between these concepts (J. Gordijn, 2003)) researchers can use the VIP-ArchiMate target metamodel to study alignment issues more effectively and efficiently, by focusing on the essential concepts that play a role in business model and enterprise architecture alignment without diving into various side issues and non-relevant details. Lastly, since literature on business model and enterprise architecture alignment often has a single-organization perspective, a third contribution to literature on business model and enterprise architecture alignment is focus on *networked* enterprises.

Fourth, this study adds to Industry 4.0 literature by providing some first insights into business mode implementation aspects. These could be used as starting point for an in-depth case study on Industry 4.0 business model implementation, by focusing on essential value, information and process related aspects.

### *7.3.3. Practical relevance*

This study also has several practical contributions. First of all, the formal representation of the VISOR metamodel and the formal integration of business model concepts with enterprise architecture concepts in the VISOR-VIP target metamodel and VIP-ArchiMate target metamodel can improve communication between business oriented stakeholders, such as CxO's and IT oriented stakeholders. The formal representation of the VISOR metamodel makes structuring, visualizing and subsequently communicating the knowledge stored in business models more efficient and effective (this was also confirmed by a business oriented practitioner in the second-round interviews) According to the general benefits of formal metamodel integration considerable time and cost savings, increased quality, an enhanced acceptance in model development and more effective exchange of domain model specific knowledge can be achieved with the application of formal metamodel integrations (Bauknecht et al., 2003). The result of the formal integration of VISOR, VIP and ArchiMate concepts has resulted in a cross-domain modelling language (Zivkovic & Kühn, 2007), which could act a common grounding between business and IT oriented practitioners. This cross-domain modelling language allows various practitioners to holistically describe, visualize and analyse the business model, business process and ICT design which could reduce the number of misinterpretations. This in turn improves the decision-making processes and the planning of the business model' realization. Consequently, this results in a more consistent and unfragmented business model, business process and ICT design.

Second, the development of the lightweight intermediate VIP metamodel could make the description, analysis and visualization of the business model implementation less time consuming and easier to understand for business oriented stakeholders. By keeping the metamodels and modelling procedure *lightweight*, business oriented practitioners can still understand them, since business oriented stakeholders often do not understand very formal *heavyweight* models well (J. Gordijn, 2003). Since lightweight approaches are often used in the realm of very formal heavyweight approaches, the design could be further formalized by IT oriented practitioners, who are more used to heavyweight and very formal models (J. Gordijn, 2003). The VIP metamodel helps to bridge the gap between the more abstract and economical oriented business model and the more functional and detailed enterprise architecture. Lastly, a result of an inclusion of value, information and process related aspects in the VIP metamodel, is that networked enterprises should be able to analyse and subsequently optimize the business model implementation in a more comprehensive and harmonized manner, instead of merely analysing and optimizing value, information or process related aspects. As a result, severe set-backs that are to be expected in the implementation of the business model can be addressed in advance.

Third, by taking a *networked* perspective, insights into inter-organizational business processes and interactions on the level of values and information can be obtained. Practitioners can subsequently use these insights to determine where issues occur when the various processes and ICT resources interact with each other. Since ICT driven innovations often requires actors to become networked enterprises, this networked perspective is valuable support ICT driven networked business model implementation.

Fourth, the application of artefact to the Industry 4.0 domain could give manufacturing organizations insights into business model implementation related aspects. Organizations who want to adopt and implement Industry 4.0business models should focus on (1) hidden product design requirements and arrangements for equal profit and cost sharing (2) data interoperability issues and privacy issues when data is being processed (3) conflicting and heterogeneous business processes.

#### *7.3.4 Limitations*

Although this research has been executed carefully, there are limitations. First of all, the metamodels and modelling procedure have not been applied in a *real-life* case study. While the metamodels and modelling procedure have been used by practitioners, the lack of available time has resulted a more abstract application of the artefact. Therefore, it was not possible to analyse the feasibility and viability of the business model. This would result in hypothetical reasoning on what issues could occur on the level of feasibility and viability. Applying the metamodel and modelling procedure in a real case study could have resulted in detailed discussions on possible issues that arise during the business model implementation, which might had led to an adjustment of the business model (see decision node of the modelling procedure of Appendix E1). Although application of the artefact has showed that is possible to transition from business model concepts to enterprise architecture concepts, the ability of the artefact to analyse the feasibility and viability of a business model needs to be verified more thoroughly. Furthermore, only an ArchiMate model of the ecosystem was developed during the implementation phase. A transition towards more detailed ArchiMate concepts and the relation between the VIP ArchiMate model and the organization-centric internal enterprise architecture needs to be analysed more thoroughly.

Secondly, the inclusion of the risk and compliance concepts to the VISOR and VIP metamodels still needs to be verified. The risk and compliance concepts have not been used yet in the application of the artefact yet. A more detailed study on risk management is required to integrate risk related concepts into the metamodels. Thirdly, by integrating the VIP metamodel concepts with ArchiMate concepts, knowledge on ArchiMate is required to be able to work with the artefact. During the implementation phase, it became clear that it was sometimes difficult to understand the meaning of certain concepts for interviewees who were not familiar with ArchiMate.

Fourthly, since the amount of available time to conduct this research was somewhat limited, a more detailed and thorough literature review on the Industry 4.0 domain, business models and enterprise architectures needs to be conducted. Although the business model – enterprise architecture alignment literature has been analysed in a comprehensive manner, a more detailed literature on Industry 4.0, business model and enterprise architecture is still necessary.

Lastly, there are two limitations regarding the interviews. First, a focus group in the implementation stage would have resulted in more detailed discussions between participants on how the business model could be implemented. Due to unavailability of the interviewees, it was not possible to organize a focus group. Instead, semi-structured interviews were conducted. For the first-round interviews, it was sometimes difficult to evaluate the metamodels since they were not applied to a case yet, which resulted sometimes in abstract discussions.

#### *7.3.5 Directions for further research*

Finally, some directions for further research are provided.

- A possible research direction is a *real-life* case study where the implementation of a real-life Industry 4.0 networked business model is studied using the artefact. This would comprise of an implementation whole modelling procedure, starting with the VISOR metamodel and ending with the internal enterprise architecture with real- stakeholders. Since the Industry 4.0 domain is merely the application domain of this study, other domains with networked characteristics, such as the Smart Hone domain can also be studied with the developed approach.
- A more detailed and thorough literature review on Industry 4.0, business models (since the work of Zott et al. (2011) is the last study that thoroughly reviewed business model literature) and enterprise architectures is a possible direction for future research. This could result in an overview of newly discovered limitations of current approaches, which can be addressed in subsequent research.
- Formal integration of other types of business models, such as the STOF model, with other types of enterprise architecture models, such as ARIS, is also an interesting direction for further research.
- Another research direction would be the inclusion of a detailed quantitative financial analysis in the modelling procedure and metamodels. In the work of Iacob et al. (2012), a detailed quantitative financial analysis can be used to determine the costs and possible revenues for a business model driven enterprise architectural change. This allows to determine whether the possible revenues exceed the costs of the architectural change, and if thus the business model design change is desired. Iacob et al. (2012) also related their approach to the TOGAF framework. In further research, it can be investigated how the modelling procedure and metamodels could be integrated with this widely accepted enterprise architecture framework.
- Another research direction could be the relation between on the one hand the networked business model and networked interactions through enterprise architecture concepts and the other hand the organization-centric business model and internal enterprise architecture. While this research analysed the networked perspective, the organization perspective is not included, while organizations still have their own individual business models. The relation between for example the VISOR metamodel and the organization centric Business Model Ontology of (Osterwalder, 2004)is a possible direction for further research.
- A more detailed integration of risk concepts in the VISOR and VIP metamodels is also a possible direction for further research. In this study only a first was made to include the risk concepts in these metamodels. Future researchers can start with the last refined metamodels, were already a risk related concept is included.
- Lastly, development of a tool or inclusion of the metamodels in existing modelling tools, such as *Archi* is also a possible future research direction. By using UML, it is possible to design a user interface around the models, and to include relevant data in the different UML classes. Studies on identification of user requirements for such a tool is part of this possible research direction.

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# Appendix A Models and Ontologies

### *A1 VISOR detailed description*

a) ***The value proposition***

As described earlier, the value proposition defines why a particular customer segment would value an organization's product and services and is willing to pay a price for them. Thus, it is the sum of all the benefits the customer derives from the product or service. It should address an unmet need of a customers or an alternative way for customers to access a product or service. The value provided to the ultimate customer must be identified, even if the organization is part of a multi-organization value network and does not reach the end-customer directly. The descriptors displayed in table A.1 define a value proposition from the VISOR perspective.

Table A.1 Descriptors of the Value proposition concept (Retrieved from El Sawy and Pereira (2013)).

| **Descriptor** | **Explanation** | **Method of assessment** |
|---|---|---|
| **Compelling** | The extent to which a product or service vividly addresses a need for the customer. | Likelihood of consumption or Acquisition. |
| **Cohort** | The number of customers in a particular market segment, who view the product or service as addressing or providing a need. | Size of market niche. |
| **Complementarity** | The extent to which the product or service accentuates or improves a product or service that a customer currently owns or uses. | The number of other existing products or services that are interdependent in their consumption. |
| **Co-creatibility** | The extent to which customers can add or alter features of the digital products or service. | The number of variations that could be generated by customers. |

b) ***The Interface***

The interface concept refers to the way which customers experience success of delivery through the interface of a service. An example of an interface is a tablet, or smartphone through which a certain service is delivered to the customer. The interface concept views the customer interface as a value interface, since it could enhance or decrease the value proposition. El Sawy and Pereira (2013) provide an example of a mobile television service which is delivered through a tablet. The value proposition is reduced for movie watchers, since a tablet includes a small screen, while it might enhance the value proposition for sport fans since it ensures that they would not miss the live broadcast of a game due to the mobility of a tablet. The Interface can be described by the descriptors as displayed in table A.2.

Table A.2 Descriptors of the Interface concept (Retrieved from El Sawy and Pereira (2013)).

| **Descriptor** | **Explanation** | **Method of assessment** |
|---|---|---|
| **Functionality** | The range of types of interactions of the interface and its ease of use. | Ability to access range of service platforms, and supports multiplicity of tasks. |
| **Form factor** | The aesthetics of the interface. | Customer perception. |
| **Fluidity** | Provides the customer with flexibility, intimacy, personalization, and control. | Ease and extent of customization. |
| **Forgiveness** | The ability of the interface to automatically undo any user error. | Extent of error correction and Adaptiveness. |

c) ***The service platform***

Digital platforms shape, enable and support the business processes and relationships required for a product or service to be delivered to the customer. A digital intensive service depends on the technology infrastructures and architectures; therefore, a business cannot be modelled without the awareness of platform ecosystems. It supports the delivery of the value proposition. The descriptors of the service platform are displayed in table A.3.

Table A.3 Descriptors of the service platform concept (Retrieved from El Sawy and Pereira (2013)).

| **Descriptor** | **Explanation** | **Method of assessment** |
|---|---|---|
| **Architecture** | The topology of the hardware and software that enables the service. | Closed/proprietary or open Standards. |

| | | |
|---|---|---|
| **Agnosticity** | Whether platform supports different operating systems. | Depends on type of technology environment or the need for external APIs. |
| **Acquisition** | Addresses the question of whether to build, or piggy-back on existing technology infrastructures. | Availability of existing platforms able to deliver product or services. |
| **Access** | Defines the community which would be able to access the service. | Continuum from walled garden, to totally open. |

d) ***The organizing model***

The organizing model concept describes how an organization or a network of organizations will organize business processes, value chains and partner relationships to effectively and efficiently deliver products and services. In a digital ecosystem, the selection and configuration of organizations changes dynamically with each activity (e.g. set of organizations to deliver a certain value proposition). Therefore, the authors stress the importance to understand the value proposition's dependencies on other organizations. Descriptors of the organizing model are displayed in table A.4.

Table A.4 Descriptors of the organizing model concept (Retrieved from El Sawy and Pereira (2013)).

| Descriptor | Explanation | Method of assessment |
|---|---|---|
| **Processes** | The design of the core business processes that are necessary to deliver and support the digital product or service. | Determination of the effectiveness of key business processes such as new product introduction, order management, customer support etc. |
| **Partnerships** | Quality of business relationships with go-to-market partners for service. | Partnerships can be assessed in terms of formality, exclusivity, and<br>expected durability of relationships |
| **Pooling** | Pooling refers to the necessity of combining complementary assets or capabilities of different partners to be able provide customer value. | Extent of synergy and complementarity on various resources (talent, technology, etc.). |
| **Project management** | Coordination of effort across different partners for launch of service, and continuing service offering. | Probability of success given complexity of task and relationships. |

e) ***The revenue model***

The revenue model defines how to make money doing all of the above described concepts. It defines how money is collected, and how each partner profits. According to El Sawy and Pereira (2013), the combination of the value proposition, the way the offerings are delivered and the investments in the digital platforms are such that revenues exceed costs and attractive for all partners defines a good business model. In table A.5, descriptors of the revenue model are displayed.

Table A.5 Descriptors of the revenue model concept (Retrieved from El Sawy and Pereira (2013)).

| Descriptor | Explanation | Method of assessment |
|---|---|---|
| **Pricing** | Structure of pricing mechanism. | Type of pricing: subscription, pay-as-you go, advertising, all you can eat,<br>micropayments, etc. |
| **Partner revenue sharing** | How revenue is shared among partners who are bringing the joint offering to market. | Distribution proration among partners. |
| **Product cost structure** | Direct and indirect cost of key resources required. | Product margins and cost assessment. |
| **Potential volume** | How much demand is expected in target market segment. | Expected number of "units" sold in specified time period. |

### *A2 VIP detailed description*

To address the limitations as explained in section 3.4.3. the VIP framework is developed by Sam Solaimani and Bouwman (2012) and S. Solaimani (2014). Three layers of analysis are included as levels of analysis which are based on:

1. Value creation, exchange and interdependencies.
2. Information exchange and interdependencies.
3. The inter-organizational primary business processes.

The framework allows for a systematic analysis of inter-organizational interactions and operations and facilitates a multi-level analysis (by not merely focusing on the value exchange, but also on the information exchange and inter- organizational processes. The 'V' addresses the exchange and creation of tangible and intangible value between the organizations. The 'I' addresses the creation and sharing of information between organizations. This comprises the generation and access to unprocessed data, information transfer and knowledge production. Finally, the 'P' addresses the primary business processes. The different concepts of the VIP framework are discussed below. For a comprehensive explanation and justification of the VIP concepts, please refer to (S. Solaimani, 2014) or (Sam Solaimani & Bouwman, 2012).

a) ***Concepts of the VIP framework***

*1. The Value layer*

Table A.6 Concepts of the Value layer (Retrieved from (Solaimani 2014)).

| **Concepts** | **Description** | **Sources** |
|---|---|---|
| **Actors (or stakeholders)** | An independent economic (and often legal) entity. By carrying out value activities, an actor makes a profit or increases it utility for its own benefit as well as for other actors in the networking, including, partners, providers, and customers. | (J. Gordijn et al., 2000) |
| **Value Objects** | Tangible resources (e.g., goods, contract, money) and intangible capabilities (e.g., service, credit, authority), valuable to one or more actors within the network. | (J. Gordijn et al., 2000) |
| **Value Proposition(s) (or goals)** | Values that an actor or a network of actors intend(s) to create, offer, capture and/or sustain. | (Osterwalder, 2004) and (Chesbrough & Rosenbloom, 2002) |
| **Value Activities** | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors within or outside the network. | (J. Gordijn et al., 2000; Osterwalder, 2004) |
| **Value Dependencies** | The need for a specific value object or activity. | (Yu, 2011) |

*2. The Information layer*

Table A.7 Concepts of the Information layer (Retrieved from (Solaimani 2014)).

| **Concepts** | **Description** | **Sources** |
|---|---|---|
| **Information Access (or authorization)** | Control, authorization or ownership of data, information, and/or knowledge. | (Weill & Vitale, 2001) |
| **Information, Data, Knowledge Objects** | **Data.** Numbers, characters, images, or other method or recording, in a form that can be assessed by a human or (especially) input into a computer, stored and processed there, or transmitted on some digital channel. Data on its own has no meaning, only when interpreted by some kind of data processing system does it take on meaning and become information. An example is a database of automatically stored users' behaviour.<br>**Information.** The result of applying data processing to data, giving it context and meaning. Some examples are contracts, product specifications, or interpreted data of users' behaviour.<br>**Knowledge.** The appropriate collection of information, such that is intent is to be useful. Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference. If information is data plus meaning, then knowledge is information plus processing. Examples are experts' tacit knowledge and expert information systems. | (Ackoff, 1989), (Bellinger, Castro, & Mills, 2004), (Alavi & Leidner, 2001) and (Howe, 2010) |
| **Information Flow** | The way data, information and knowledge are created, accessed, shared or traded within and between networked enterprises. | (De Marco, 1979) |
| **Information Dependencies** | The need to access or possess a specific data, information and/or knowledge object. | (Yu, 2011) |

*3. The Process layer*

Table A.8 Concepts of the Process layer (Retrieved from (Solaimani 2014)).

| **Concepts** | **Descriptions** | **Source** |
|---|---|---|
| **Primary Business Processes** | Primary physical activities that are required to enable the physical or virtual creation of the product or service, within or across the borders of the company (e.g., in/outbound logistics, operations, marketing and sales, delivery, after sale servicing). | (Mooney, Gurbaxani, & Kraemer, 1996; Porter, 1985) |

| | | |
|---|---|---|
| **Business Process Behaviours** | The sequence, flow, iteration or condition of a process. | Adapted from BPM approaches including BPMN and UML. |
| **Business Process Units (or boundaries)** | A set of processes that are belonging to a particular system, task, team, company or network. | Adapted from BPM approaches including BPMN and UML, ArchiMate (Lankhorst, 2017); Business Architecture (Versteeg & Bouwman, 2006) |
| **Business Process Dependencies** | The need of a process to be enabled/triggered by or integrated with another process | (Yu, 2011) |

***A3 ArchiMate detailed description***

ArchiMate is an open and independent description language for Enterprise Architecture, supported by different tool vendors and consulting firms. It is developed in a joint research between companies and knowledge institutions (Jonkers et al., 2003). The ArchiMate framework provides architects a graphical modelling language with concepts to describe, analyse and visualize an architectural model with its relationships among business domains in an unambiguous way (where a model is defined by Lankhorst (2017)as *"a purposely abstracted and unambiguous conception of a domain"* (Lankhorst, 2017, p.48)). Lankhorst (2017) considers ArchiMate to be a language which facilitates high-level modelling within a domain (e.g. an application landscape) and modelling of the relations between domains (e.g. the relation between certain applications and supporting IT infrastructure). It functions both as a basis for visualization and analysis of an enterprise architecture.

a) ***Concepts of the ArchiMate 3.0 framework***

ArchiMate views the organization as a layered set of systems, where higher layers are supported by lower layers (Jonkers et al., 2004). Service orientation plays an important role in the ArchiMate language, and refers to a unit of functionality that a certain entity (e.g. a department) makes available to its environment. Services could be provided by organizations to their customers or by applications to business processes. The service orientation concept leads to a layered view of the enterprise architecture models, where it forms the main linking pins between the different layers (Lankhorst, 2017). Service layers with services made available to higher layers are interleaved with implementation layers to realize the services. The implemented IT infrastructure (implementation layer) provides infrastructural services (service layer) to the implemented application concept layer, which in turn provides application services to the implemented business process layer, which eventually provides business services to the customer. This layered service approach has led to a definition of three layers in the initial ArchiMate (ArchiMate 1.0) core framework:

1. The Business layer. The business layer offers products and services to external customers. These are realized in the organization by business processes (which in turn are performed by business actors or roles).
2. The Application layer. The application layer supports the business layer with application services. These services are realized by software application concepts.
3. The Technology layer. The technology comprises offers infrastructural services (e.g. processing, storage, and communication services). These are needed to run applications and realized by computer and communication devices and system software.

In each layer, the general structure of the models is similar, which means that the same type of concepts (i.e. elements or relationships between these elements) and relations are used. First, the behavioural elements are assigned to structural concepts, in order to show who or what displays the behaviour. Second, the active structural elements refer to subjects such as a business actor or application concept, while the passive structural elements refer to objects on which behaviour is performed. Third, Lankhorst (2017) makes a distinction between the internal and external view. Regarding the behavioural aspect, these views reflect the principles of service orientation as discussed before. A service represents a unit of essential functionality that a system exposes to its environment. The external services are accessible through interfaces. Lastly, the authors differentiate between behaviour that is performed by individual structural elements and collective behaviour that is performed by a collaboration of multiple structural elements. The three aspects-active structure, behaviour and passive structure- form the core concepts of the ArchiMate framework. The core concepts of the initial ArchiMate (i.e. ArchiMate 1.0) are displayed in figure A.1.

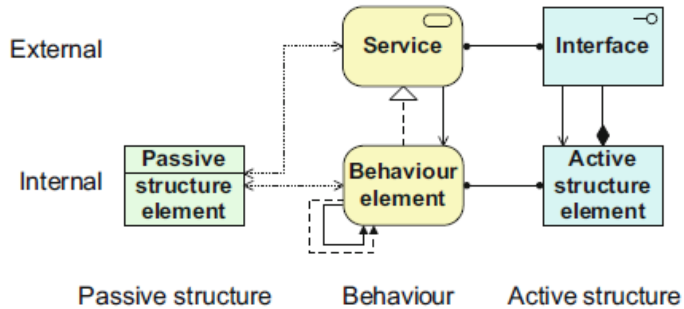



Figure A.1 The core aspects of ArchiMate.

ArchiMate 3.0 is the latest version of the modelling language. In ArchiMate 3.0, the Strategy, Physical and Implementation and Migration layer are added as well as the motivation aspect. First, the Implementation and Migration layer describes how an architecture should be implemented, i.e. which steps to take or which work packages should be implemented. Second, the motivation extension facilitates the identification, description, analysis and validation of requirements and their realization in enterprise architecture models (Iacob et al., 2012). Thirds, the physical layers refers to technology innovations that mix the IT and physical world, such as IoT. In ArchiMate 2.0, it was possible to model the "Internet" of IoT, but not the "Things". Therefore, the physical layer is added. Fourth, the strategy layer is added, since more organizations realize that enterprise architecture is not merely an IT discipline, but it is a way of realizing your business strategy. Lastly, the motivation aspect takes the motivations, or reasons, that guide the design or change of an Enterprise Architecture into account. Refer to The Open Group (2017) for a complete description of ArchiMate 3.0.

# Appendix B First round interviews

### *B1 Overview of interviewees*

Table B1 Overview interviewees.

| | Interviewee | Organization | Function | Background | Date | Location | Duration (min) |
|---|---|---|---|---|---|---|---|
| **E/1** | Not mentioned for privacy reasons | InnoValor | Managing partner/ Senior researcher | High involvement in ArchiMate development | 14-6-2017 | Skype | 50 |
| **E/2** | | Nyenrode Business University | Assistant Professor | High involvement in VIP development | 15-6-2017 | Nyenrode Business University, Breukelen, NL | 120 |
| **E/3** | | Iddink | Director Innovation & Technology | Involved in business modelling in UML | 16-6-2017 | Skype | 35 |
| **E/4** | | BiZZdesign | Managing consultant/ Researcher | High involvement in ArchiMate development | 20-6-2017 | Bizzdesign, Enschede, NL | 70 |
| **E/5** | | Fourpoints | Lead enterprise architect and management consultant | High involvement in enterprise architecture design. | 22-6-2017 | Fourpoints, Amsterdam, NL | 120 |
| **E/6** | | InnoValor / TU Delft | Senior advisor/ Senior researcher | High involvement in ArchiMate development and business model practices (VISOR). | 4-7-2017 | Hangout | 90 |

### *B2 Interview guide*

1) Objective of this semi-structured validation interview

The objective of this semi-structured interview is to discuss the metamodels based on the design requirements presented in the presentation book.

2) Main questions
   - **a)** Background information
     - i) Please state your name, your organization and role and general activities within the organization.
   - **b)** Determining the validity, consistency, completeness and coherency.
     - i) For each layer, which classes are missing in the metamodel based on the design requirements?
     - ii) For each layer, which classes should not belong to the metamodel based on the design requirements? Please explain why.
     - iii) For each layer, which attributes should not belong to the metamodel based on the design requirements? Please explain why.
     - iv) For each layer, what do you think of the defined relationships between the classes of the metamodel, which relationships could be improved (e.g. described in a different way), removed or added? Please explain why.
     - v) What do you think of the arrangement (i.e. finance, resource capability, value, information, processes) of the different layers?
   - **c)** Remaining questions
     - i) What do you think of perceiving the business layer of ArchiMate as more intra-organizationally focussed instead of inter-organizationally focussed?

3) Final discussion
     - ***ii)*** Do you have any additional sources that could be used to improve the metamodels?

***iii)*** Do you have any final comments?

***B3 Code template***

| **Table B.2 Level-one codes for first round interviews** | |
|---|---|
| **Higher-order code** | Discussions/statements |
| **Model Levelling** | This code mainly comprises of the discussions on:<br>• The levelling and balancing of the concepts which were used to build the metamodels. With levelling and balancing is meant on the level of abstraction or detail of the concepts of the VISOR, VIP and ArchiMate models/framework. E.g. comprehensive and detailed functional description of an ERP system in ArchiMate versus a high-level tactical description of an ERP system as a resource.<br>• What level of abstraction the models (i.e. VISOR, VIP and ArchiMate) itself are used via a method to transition from a business model to an enterprise architecture for networked enterprises. This model levelling determines the way the models are used to derive from a business model to an enterprise architecture. |
| **The arrangement and consistency of the different layers.** | This code mainly comprises of feedback on the arrangement of the layers of the initial metamodels (finance layer, resource capability layer, value layer, information layer, inter-and intra-organizational process layer) in the design speciation of the metamodel. |
| **Coherency, completeness, consistency and validity** | This code mainly comprises on the coherency (i.e. coherency between model's concepts) completeness (i.e. if particular concepts were missing), consistency (i.e. if the selection and use of the model concepts are consistent), and validity (i.e. if selection of concepts are reflected in realty) of the selection of model concepts. |
| **Use of UML** | Use of UML (e.g. the use of attributes in metamodels and the use of the relationships) in the metamodel. |

# Appendix C Refined metamodels concepts and relationships

### *C1 Concepts of the VISOR metamodel*

Table C.1 VISOR metamodel concepts

| Concept | Definition | Design requirement fulfilment |
|---|---|---|
| **Value proposition** | The value proposition defines why a particular customer segment would value an organization's product and services and is willing to pay a price for them. | By including the value proposition concept of the VISOR framework in the metamodel to define value proposition offered to the end-customer, functional design requirement one is fulfilled. |
| **Interface** | The interface concept refers to the way which customers experience success of delivery through the interface of a service. An example of an interface is a tablet, or smartphone through which a certain service is delivered to the customer. | The value interface concept is included to express the value interface through which the value proposition is delivered to the end-customer. By including this concept, functional design requirement two could be fulfilled. |
| **Digital Service platform** | Digital platforms shape, enable and support the business processes and relationships required for a product or service to be delivered to the customer. | The service platform concept is included to be able to express the digital service platform upon which the actors interact with each other. By including this concept, functional design requirement three can be fulfilled. |
| **Organizing model** | The organizing model concept describes how an organization or a network of organizations will organize business processes, value chains and partner relationships to effectively and efficiently deliver products and services. | The organizing model concept is included to express the way actors interact with each other for networked enterprises. By including this concept, functional design requirement four can be fulfilled. |
| **Revenue model** | The revenue model defines how to make money doing all of the above described concepts. It defines how money is collected, and how each partner profits. Examples are pay per use or insurance premiums (derived from VISOR case studies (El Sawy & Pereira, 2013). | The revenue model is included to express how the network of actors will make a profit. The cost concept also could have expressed in this concept, which is currently not included in the VISOR business model. By including this concept, functional design requirement five can be fulfilled. |

### *C2 Relationships between concepts of the VISOR metamodel*

Table C.2 Relationships between the concepts of the VISOR metamodel

| Relationship | Definition and justification | ArchiMate Association roles | Source |
|---|---|---|---|
| **Value proposition→ Organizing model** | A value proposition is *realized* by the organizing model (i.e. network of organizations, value chain and business processes (El Sawy & Pereira, 2013). Adapted from the approach of Iacob et al. (2012), where the 'based on' relation between the 'key activities' (which in the case of VISOR in part of the organizing model (El Sawy & Pereira, 2013)) concept and the 'value proposition' concept the of BMC (Osterwalder, 2004) is mapped against the r*ealization* (i.e. *The realization relationship indicates that an entity plays a critical role in the creation, achievement, sustenance, or operation of a more abstract entity.* (The Open Group, 2017)*)* relationship of ArchiMate (Lankhorst, 2017). | Realized by/Realizes | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Value proposition→ Revenue model** | The value proposition is *associated with* the revenue model (for example pay per use of the service). In other words, the revenue model *builds upon* the particular type of product or service offered to the end-customer in the value proposition. Similar in the approach of Iacob et al. (2012), where the *builds on* relation of the BMC between the 'value proposition' and 'revenue stream' concepts is mapped against the *association* relationship of ArchiMate. | Associated with/ Associated with | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Value proposition→ Value interface** | The value proposition is *realize*d through the value interface, since the value proposition delivered through a certain value interface. Based on the relation between the 'value offering' and 'value interface' concept of J. Gordijn et al. (2000), and the | Realized by/Realizes | Adapted from (Osterwalder, 2004), (J. Gordijn et al., |

| | | | |
|---|---|---|---|
| | mapping of the 'deliver' relationship between the 'channel' and 'value proposition' concept of BMC with the *realization* of ArchiMate by Iacob et al. (2012). | | 2000) and (Iacob et al., 2012) |
| **Value proposition→ Digital service platform** | The value proposition is *realized* by the digital service platform, because the service platform act as resources where the value proposition is based on. Similar to the relationship mapping of the *based on* relationship between the 'Key resources' and 'Value proposition' of the BMC with the *realization* relationship of ArchiMate by Iacob et al. (2012), the value proposition in VISOR is 'based upon' a key resource, which in this case is more specifically the service platform. | Realized by/Realizes | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Value interface→ Digital service platform** | The value interface is *associated with* the digital service platform, because the service platform *has a* certain value interface, such as a mobile phone or API. Based on the mapping of the *has a* relationship between the 'key resource' and 'channel concept' of BMC with the *association* relationship of ArchiMate by Iacob et al. (2012). | Associated with/ Associated with | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Digital service platform → Revenue model** | The digital service platform is *associated with* the revenue model since the service platform *has* certain costs (e.g. maintenance or the creation of the platform itself). Similar to the BMC, where 'key resources' have certain costs, the 'service platform' also *has* certain costs. The *has a* relationship of the BMC is mapped against the *associated* relationship of ArchiMate by Iacob et al. (2012). | Associated with/ Associated with | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Service platform → Organizing model** | The service platform is *accessed by* the organizing model because the service platform is used in activities and business processes of the various networked enterprises in the ecosystem. Business processes and activities are part of the organizing model (El Sawy & Pereira, 2013). The *access* relationship of ArchiMate is defined as follows: "*The access relationship models the ability of behaviour and active structure elements to observe or act upon passive structure elements"* (The Open Group, 2017). Therefore, similar to the way the *Fits, flows or is shared* by relationship between 'key resources' and 'key activities' concepts in the BMC is mapped against the *accesses* relationship of ArchiMate in the work of Iacob et al. (2012), for the VISOR metamodel the *access* relationship is used. | Accesses/ Accesses by | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |
| **Organizing model → Service platform** | The organizing model is *realized by* the organizing model because the resource platform also a resource which needs to be delivered or provided by networked enterprises in the organizing model. The *provided or deliver* relationship between the 'actor' and the 'key resource concepts of the BMC is mapped against the *realization* relationship of ArchiMate by Iacob et al. (2012), therefore, a similar relationship is defined between the 'organizing model' and the 'service platform' concepts. | Realized by/Realizes | Adapted from (Osterwalder, 2004) and (Iacob et al., 2012) |

### *C3 Concepts of the VIP metamodel*

Table C.3 Concepts of the VIP-metamodel specification

| Concept | Definition | Source | Design requirement fulfilment |
|---|---|---|---|
| **Actor** | An independent economic (and often legal) entity. By carrying out value activities, an actor makes a profit or increases its utility | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) | The actors concept plays an essential role in the VIP metamodel, since it is necessary to identify who is responsible for the creation of certain objects and who has access to certain objects. Therefore, it helps to fulfil functional design requirements four, seven and eight. |
| **Value activity** | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors within or outside the network. By carrying out value activities, an actor or collaboration of actors makes a profit or increases it utility for its own benefit as well as for other actors in the networking, including, partners, providers, and customers. | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) | By including the value activity concept in the metamodel, functional design requirement seven is partly fulfilled, because by using this concept, the modeller could investigate the creation of value objects for networked enterprises. |
| **Value exchange** | Value exchange represent the interactions for networked enterprises through exchange of value objects. Adapted from the 'value exchange' concept of the e3 value model (J. | Adapted from (J. Gordijn, 2003; OMG, 2015; | By including a value exchange concept, the modeller could use this concept to define the exchanges of |

| | | | |
|---|---|---|---|
| | Gordijn et al., 2000) and 'deliverableflow' (OMG, 2015) concept of VDML. Added since VIP itself does not provide a concrete concept to express the exchange of objects. According to E/2, VIP itself is all about exchanges of objects. However, to be able to model VIP in UML and to be able to express this exchange, a class that explicitly expresses this exchange is necessary. This was also suggested by interviewee E/6. | Rasiwasia, 2012) and interview with E/6 | value objects in for networked enterprises. Therefore, it partly fulfils functional design requirement six on exchanges of value objects. |
| **Value object** | Tangible resources (e.g., goods, contract, money) and intangible capabilities (e.g., service, credit, authority), valuable to one or more actors within the network. | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) | By including the value objet concept, it is possible to analyse which objects are needed to be created, accessed and exchanged to implement the business model. Therefore, it plays an important role in the fulfilment of functional design requirements six, seven and eight. |
| **Value goal** | Values that an actor or a network of actors intend(s) to create, offer, capture and/or sustain. | Adapted from (Bouwman et al., 2008; El Sawy & Pereira, 2013; Osterwalder, 2004; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) | Adapted from the VIP framework's concept's, the value goal (or also described as proposition in VIP) allows for an expression of the value proposition offered to the end-customer. Therefore, it fulfils functional design requirement one. |
| **Information, Data, Knowledge Objects** | **Data.** Numbers, characters, images, or other method or recording, in a form that can be assessed by a human or (especially) input into a computer, stored and processed there, or transmitted on some digital channel. Data on its own has no meaning, only when interpreted by some kind of data processing system does it take on meaning and become information. An example is a database of automatically stored users' behaviour.<br>**Information.** The result of applying data processing to data, giving it context and meaning. Some examples are contracts, product specifications, or interpreted data of users' behaviour.<br>**Knowledge.** The appropriate collection of information, such that is intent is to be useful. Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference. If information is data plus meaning, then knowledge is information plus processing. Examples are experts' tacit knowledge and expert information systems. | Adapted from (Ackoff, 1989; Alavi & Leidner, 2001; Bellinger et al., 2004; Howe, 2010) | Partly similar to the value objects, with the inclusion of data, information and knowledge concepts, it is possible to analyse which objects are needed to be, accessed and exchanged to implement the business model. Therefore, it plays an important role in the fulfilment of functional design requirements six and eight (although it was discussed that the knowledge object cannot be exchanged). |
| **Information Exchange** | Information exchanges represent the interactions in networked enterprises through exchanges of data and information between networked enterprises. To ensure consistency with the value exchange concept, the name of the concept is slightly modified to information exchange. | Adapted from (De Marco, 1979)(J. Gordijn et al., 2000) and interviewee E/6 | Similar to the inclusion of the value exchange concept, the information exchange allows for an investigation of exchanges of information related objects, and thus fulfils functional design requirement six. |
| **Primary Business Processes** | Primary physical activities that are required to enable the physical or virtual creation of the product or service, within or across the borders of the company (e.g., in/outbound logistics, operations, marketing and sales, delivery, after sale servicing). | Adapted from (Mooney et al., 1996; Porter, 1985) | By including a business process concept, it is possible to determine the primary business process which are essential for the creation of certain value, data, and information or knowledge objects. Therefore, it fulfils functional design requirement seven. |

### *C4 Relationships between the VIP metamodel concepts*

Table C.4 Relationships between the concepts of the VIP metamodel

| **Relationship** | **Definition and justification** | **ArchiMate association roles** | **Source** |
|---|---|---|---|
| **Actor → Value activity and Primary business process** | An actor is *assigned* to certain value activities and primary business processes. Adapted from the *assignmen*t relationship (where the *assignment* relationship is defined as follows: *"The assignment relationship expresses the allocation of responsibility, performance of behaviour, or execution."* (The Open Group, 2017)) between the 'business actor' and 'business process' concept of the ArchiMate business layer metamodel, a similar relationship could be defined between on the one hand the 'value activity' concept and the 'primary business process' concept and on the other hand the 'actor' concept of VIP. Furthermore, in the e3 value model of J. Gordijn et al. (2000); (Rasiwasia, 2012) and the VIP framework of S. Solaimani (2014) an actor is also responsible for certain value activities. | Assigned to/ Assigned from | Adapted from (J. Gordijn, 2003; J. Gordijn et al., 2000; Lankhorst, 2017; Rasiwasia, 2012; S. Solaimani et al., 2013a) |
| **Actor → Value goal** | Value goals are *associated with* certain actors (for example a certain value proposition is offered to a customer by a certain actor). Adapted from the relationship between the 'stakeholder' concept and the 'goal' concept of ArchiMate, which is also defined as an *association* relationship. | Associated with/ Associated with | Adapted from (Lankhorst, 2017; Osterwalder & Pigneur, 2002; Sam Solaimani & Bouwman, 2012) |
| **Actor → Value object, data object information object and knowledge object.** | Actors are *associated with* information related objects. First the *assignment* relationship was considered (where the actor has a certain responsibility over a certain object). However, since the *assignment* relationship of ArchiMate is defined for the assignment of a passive structure element to a behavioural element it is not possible to use the *assignment* relationship to define this relationship. The *association* relationship seems most suitable. | Associated with | Adapted from (Solaimani and Bouwman 2012, Solaimani 2014) and (Lankhorst, 2017) and interviewee E/2. |
| **Data and information objects→ Information exchange** | Data and information objects are *flowing* (i.e. *"The flow relationship represents transfer from one element to another."*(Lankhorst, 2017)) within information exchanges. Adapted from the relationship between the 'businessitem' concept and the 'deliverableflow' concept of VDML (OMG, 2015). | Flow | Adapted from VDML (Lankhorst, 2017; OMG, 2015) and interviewee E/6 |
| **Data object → Information object → Knowledge object** | Data objects *realize* information objects, where information objects *realize* knowledge objects. Since a *realization* relationship indicates that a concept plays a critical in the creation of a more abstract concept, the relationship between the 'data', 'information' and 'knowledge' object can be defined as a *realization* relationship. | Realizes/ Realized by | Adapted from (Ackoff, 1989; Lankhorst, 2017) |
| **Primary business process → Data, information or knowledge object** | A business processes *accesses* (e.g. creates, reads, writes or modifies) data, information and knowledge objects. Adapted from the relationship between the 'business process' concept and the 'business object' and 'data object' concept of ArchiMate (Lankhorst, 2017). According to The Open Group (2017), the *access* relationship could be used when a behavioural element "does something" with a passive structure element; e.g., create a new object, read data from the object, write or modify the object data, or delete the object. | Accesses/ Accessed | Adapted from (Lankhorst, 2017; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) and interviewee E/2 and E/4. |
| **Primary business process → Value object** | Similar to the relationship between the 'business process' concept and the 'data' 'information' and 'knowledge' objects, a business processes also *accesses* (e.g. processes, creates, reads, writes or modifies) value, objects (e.g. a certain resource, such as an application). In addition, business processes can also *realize* more abstract value objects (e.g. a service, which is an example of a value object according to (S. Solaimani, 2014)). This relationship is also based on discussions with interviewee E/4. The *Accesses/Accessed* and *Realizes/Realized by* relationship between a value object and the business process was considered to be valid by E/4. | Accesses/ Accessed and Realizes/ Realized by | Adapted from (Lankhorst, 2017; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) and interviewee E/2. |

| | | | |
|---|---|---|---|
| **Primary business process → Value activity** | A value activity *realizes* a primary business process. Adapted from the discussion with E/6 and the definition of the *realization* relationship, the definition between the 'primary business process' concept and the 'value activity' concept is defined as a *realization* relationship, where the 'primary business process' concept *realizes* the more abstract 'value activity' concept. Interviewee E/6 stated that value related concepts are realized by the more functional concepts of VIP. | Realizes/ Realized by | Adapted from ArchiMate (Group, 2017) and interviewee E/6 |
| **Primary business process → Data object, information object or knowledge object** | Similar to the relation between a 'primary business process' and the 'value object' concepts, a primary business process *accesses* (e.g. reads or writes) a knowledge, information or data objects. The relationship is also based on the discussions with expert E/2 and E/4. | Accesses/ Accessed | Adapted from VIP diagram (S. Solaimani, 2014), mapping of relationships of (Osterwalder, 2004) by (Iacob et al., 2012) and interview with E/2 and E/4. |
| **Value activity → Value object** | A value activity *access*es objects of which are valuable to the actor itself or another actor. Adapted from J. Gordijn et al. (2000) and OMG (2012), where the relation between a (value) activity and a value object defined as *creation* relationship. Based on the definition of the *access* and *realization* relationship of ArchiMate (Lankhorst, 2017), the *realization/accesses* relationships of ArchiMate seems most suitable to define a creation or access relationship between these two concepts. This relationship is also based on discussions with interviewee E/2. E/2 stated that a value activity *accesses* a certain resource (i.e. value object) or that a value activity *realizes* a value object.<br>This relationship is somewhat similar as the *access* relationship between 'business processes' concept and 'value object' concept. However, the difference lies in the economical and to functional/task oriented aspects of respectively the 'value activity' and 'business process' concept (Gaaloul & Proper, 2012). As such, it is required that business processes *accesses/realizes* more operational objects, such as order information, whereas the value activity *accesses/realizes* more abstract or economical objects, such as "branding", "culture", "experience" or "market image". | Accesses/ Accessed By Or Realization/ Realized by | Adapted from (Gordijn, Akkermans et al. 2000, Gordijn 2003) and Deliverableflow of VDML (OMG 2015), interviews with E/2, E/4 and E/6 and the work of (Gaaloul & Proper, 2012) on the value activity concept of the e3 value model and the business process concept of ArchiMate |
| **Value activity → Data object, information object or knowledge object** | Similar to the *access* relationship between the 'primary business process' concept and the information related objects concepts, a value activity *accesses* (e.g. reads or writes) data, information or knowledge, objects. | Accesses/ Accessed | Adapted from (Lankhorst, 2017; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) and interviewee E/2 and E/4 |
| **Value object → Value goal (proposition)** | An actor performs a certain value activity to access an object of value, which subsequently influences (i.e. implements) some motivational element, in this case the value goal. The influence relation in ArchiMate is defined as follows: *"The influence relationship models that an element affects the implementation or achievement of some motivation element."* (The Open Group, 2017). The value object can be used to express the product or service which is delivered to the end-customer, where the product or service is the carrier of the value (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). The value associated with the product or service is implemented when the product or service is *accessed* through a value activity. | Influences/ Influenced by | Adapted from (J. Gordijn et al., 2000; Janssen et al., 2015; OMG, 2015) and influence meta-relationship of ArchiMate (Lankhorst, 2017; The Open Group, 2017) |
| **Value object → Value exchange** | Value objects are exchanged in value exchanges. Similar to the relation between the 'deliverablflow' concept and the 'business' concept of VDML, which comprises of *flow* and *deliverable* association roles. | Flow | Adapted from VDML (OMG, 2015) and flow meta-relationship of ArchiMate (Lankhorst, 2017) |

***C5 Mapping of VISOR concepts to VIP concepts***

Table C.5 Mapping of VISOR concept to VIP concepts.

| **VISOR Concept** | **VIP concept** | **Concept mapping and integration rule** | **Motivation** |
|---|---|---|---|
| **Value proposition** | Value goal | Embed Rule: Relation – Composition | In VISOR, the value proposition defines the value the networked enterprises intend to offer to the end-customer. Therefore, it is composed of a value goal; the intended value offering. In UML terms, the value goal is *part-of* (i.e. composition) the value proposition so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| **Value proposition** | Value object | Embed Rule: Relation – Composition | In VISOR, the value proposition consists of product and services, associated with the intended value offering. Value objects in VIP can be products or services. Therefore, the value object is also a component of the value proposition, as the carrier of the value offering (Ding, 2015). Again, a *part-of* relationship (i.e. composition) is defined between the two concepts via the *embed* rule (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| **Interface** | Value object | Generalize Rule: Relations-Generalization | In VISOR, an Interface could be in the form of *"mobile phones, smart phone operating systems, social media, and now tablet PCs"* (El Sawy and Pereira, 2013, p.30). This concept could be easily integrated with the value object of VIP, since this concept could be used to express resources or capabilities. However, since the value proposition could be offered through multiple value objects, it is decided that a Generalization (*is-a* (Rumbaugh et al., 2005), e.g. a mobile phone *is-an* interface) relationship seems most suitable and the *generalize* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| **Service platform** | Value object | Generalize Rule: Relations-Generalization | In VISOR, the service platform is defined as a resource required to realize the networked business model. Value objects in VIP could be resources, which can be defined on a very high level of abstraction. In various case studies, the value object concept of VIP is used to express the (service) platform upon which the actors interact with each other. Therefore, the value object concept could be considered to be a specialization of the service platform concepts. In this context, the value object *is-a* service platform, and the *generalize* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| **Organizing model** | Actors | Embed Rule: Relation – Composition | In VISOR, the organizing model defines how the network of actors organizes itself to deliver the value proposition (El Sawy & Pereira, 2013). Therefore, the actor concept is a component of the organizing model concept, so actors are *part-of* the organizing model, subsequently the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| | Value activity and business processes. | Embed Rule: Relation – Composition | In VISOR, the organizing model defines how the value proposition is realized by various behavioural elements such as business processes (El Sawy & Pereira, 2013). The value activity concept also is a behaviour element, which is more economically oriented than the business process and is of a higher level of abstraction. Due to these similarities with the business process concept, the value activity concept is a component of the organizing model. As expected, the business process concept is also a component of the organizing model. In UML terms, value activities and business processes are *part-of* the organizing model, so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| | Value, data, information and knowledge objects | Embed Rule: Relation – Composition | El Sawy and Pereira (2013) compare the organizing model concept of VISOR with the Value network analysis model of (Allee, 2008), where the relations among actors include tangible flows like products, service and profit, and intangible ones like knowledge, emotion and influence (Allee, 2008). Based on this comparison, it is argued that the value, data, information and knowledge objects are a component of the organizing model, where the objects flow between the actors. The value object is for this particular concept more related to equipment or materials which are required for the creation of the product or service. So, these value objects are less valuable to the end customer. The |

| | | | |
|---|---|---|---|
| | | | knowledge object does not flow between the actors, however, according to design requirement eight, an actor can have access to certain knowledge. In UML terms, objects are *part-of* the organizing model, subsequently the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| | Value exchange and information exchange | Embed Rule: Relation – Composition<br>Embed Rule: Relation – Composition | What logically follows from the description in the row above is that that value objects and information related objects flow respectively in value exchanges and information exchanges. In UML terms, value exchanges are *part-of* the organizing model, so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| **Revenue model** | Value object | Embed Rule: Relation – Composition | In VISOR, the revenue model consists of the profit sharing between the networked enterprises. Therefore, a value object, which in this context refer to financial values, such as cash, securities, borrowing capacity or a subscription fee, seems suitable, since the value object concept could be used to express financial assets, according to (S. Solaimani, 2014). Next to more financial related value objects, also other non-financial revenues can be part of the revenue model, such as increased market position, branding or reputation. Concluding, all value objects, non-related to the end-customer, but more related to the values sellers aim to achieve are part of the revenue model. In UML terms, revenue related value objects are *part-of* the revenue model, so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| | Value exchange | Embed Rule: Relation – Composition | The 'value exchange' concept in this context refers to exchange of financial values, such as cash, securities, borrowing capacity or fees, or non-financial revenues, such as branding and reputation, which are exchanged between the networked enterprises. Therefore, the value exchange concept is also a component of the revenue model. In UML terms, the revenue related value exchanges (e.g. profit sharing) are *part-of* the revenue model, so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |
| | Value goal | Embed Rule: Relation – Composition | While the value goal related to the value proposition was aimed to express the value which the actors intend to offer to the end-customer, the value goal in the context of the revenue model comprises of the goals the actors (so not the end customer) want to achieve for themselves, such as lower costs, new revenues or increased market position. Therefore, the value goal is also a component of the revenue model. In UML terms, value goals are *part-of* the revenue model, so the *embed* rule is applied (Rumbaugh et al., 2005; Zivkovic & Kühn, 2007). |

### *C6 Mapping of VIP concepts to ArchiMate concepts*

Table C.6 Concept mapping of VIP and ArchiMate

| VIP Concept | ArchiMate concept | Mapping and integration rule | Motivation |
|---|---|---|---|
| **Value goal** | Goal | Merge rule: Equivalence - Merge | In VIP, a value goal (proposition) is defined as *"Values that an actor or a network of actors intend(s) to create, offer, capture and/or sustain."* The most suitable concept in ArchiMate is the goal concept, which is defined as follows*: "A goal is defined as an end state that a stakeholder intends to achieve."* According to the (Group, 2017), goals are usually expressed using qualitative words; e.g., "increase", "improve", or "easier", such as decrease costs. When looking at examples of Value goals of the VIP analyses in (S. Solaimani, 2014) such as "less travel cost" (Solaimani, 2014, p. 129) or "increasing market visibility' (Solaimani, 2014, p. 111), the 'goal' concept of ArchiMate seems equivalent to the 'value goal (proposition)' concept. Concluding the *merge* rule is applied. |
| **Value object** | Resource | Generalize Rule: Relation - Generalization- | In VIP, value objects are defined as "*Tangible resources (e.g., goods, contract, money etc.) and intangible capabilities (e.g., service, credit, authority etc.), valuable to one or more actors within the network"*. (S. Solaimani, 2014) A resource in ArchiMate is defined as *"an asset owned or* |

| | | | |
|---|---|---|---|
| **Value object** | Capability | Generalize Rule: Relation - Generalization- | *controlled by an individual or organization"*, a capability is defined as *"an ability that an active structure element, such as an organization, person, or system, possesses."*, while value is defined as "*relative worth, utility, or importance of a business service or product."* (The Open Group, 2017) Examples of ArchiMate resources are tangible assets – financial assets (e.g., cash, securities, borrowing capacity), physical assets (e.g., plant, equipment, land, mineral reserves), intangible assets (technology; e.g., patents, copyrights, trade secrets; reputation; e.g., brand, relationships; culture), and human assets (skills/know-how, capacity for communication and collaboration, motivation) and for the 'capability' concept marketing, customer contact, or outbound telemarketing (The Open Group, 2017). Based on these definitions and examples, the ArchiMate concepts could be considered as specializations of the 'value object' concepts of VIP. However, the scope of the 'value' concept of ArchiMate needs to be enlarged to a higher level of abstraction (so it should not only be relevant from a product or service perspective, but a higher resource and capability perspective). Concluding the *generalization* rule is applied. Since the generalization rule is applied, both source metamodel concepts have to be included in the target metamodel. |
| **Value object** | Value | Generalize Rule: Relation - Generalization- | |
| **Value activity** | - | Non-relation | As was discussed in the interviews, the value activity has no real counterpart in ArchiMate, due to its more economical focus and high level of abstraction (see discussion in section 5.4.2 and the work of Gaaloul and Proper (2012) |
| **Value exchange** | Flow relationship | Merge rule: Equivalence-Merge | The added concept allows modellers to define how value is exchanged or flows through the network. In ArchiMate, a flow relationship is defined as follows: "*The flow relationship represents transfer from one element to another."* These definitions are very similar, so the concepts could be merged. Concluding the *merge* rule is applied. |
| **Actor** | Business actor | Merge rule: Equivalence-Merge | In VIP, an actor is defined as *"an independent economic (and often legal) entity. By carrying out value activities, an actor makes a profit or increases it utility for its own benefit as well as for other actors in the networking, including, partners, providers, and customers."* The 'business actor' concepts seems most suitable, based on the definition as provided by (The Open Group, 2017): *"A business actor is defined as an organizational entity that is capable of performing behaviour."* The 'business role' concept is considered to have a lower level of abstraction compared to the Actor concept of VIP, since the business role concept requires a detailed specification a certain role which an actor performs. Once the VIP analysis has been performed, the ArchiMate model on the organizational level could be used to specify the specific more detailed roles in the organization. Concluding the *merge* rule is applied. |
| **Information object** | Business object | Merge rule: Equivalence-Merge | In VIP, an information object is defined as *"the result of applying data processing to data, giving it context and meaning."* The 'business object' concept of ArchiMate is defined as: *"A business object is defined as a passive element that has relevance from a business perspective"* (The Open Group, 2017). Although the definitions are not very similar, the 'business object' concept is often used to express information, such as order information. Furthermore, interviewee E/4, who was highly involved in the development of ArchiMate, proposed this mapping as well. Concluding the *merge* rule is applied. |
| **Data object** | Data object | Merge rule: Equivalence-Merge | In VIP, a data object is defined as "*Numbers, characters, images, or other method or recording, in a form that can be assessed by a human or (especially) input into a computer, stored and processed there, or transmitted on some digital channel."* This similar to the data object of ArchiMate, which is defined as "A data object is defined as a passive element suitable for automated processing" (The Open Group, 2017). Furthermore, interviewee E/4, proposed this mapping as well. Concluding the *merge* rule is applied. |
| **Knowledge object** | Resource | Merge rule: Equivalence-Merge | In VIP, a knowledge object is defined as *"The appropriate collection of information, such that it is intent is to be useful. Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference. If information is data plus meaning, then knowledge is information plus processing. Examples are experts' tacit knowledge and expert information systems."* The most suitable concept seems the 'resource' concept (see definition above) of ArchiMate, since The Open Group (2017) provides skills or know-how as examples of the 'resource' concept (The Open Group, 2017). Concluding the *merge* rule is applied. |

| | | | |
|---|---|---|---|
| **Information exchange** | Flow relationship | Merge rule: Equivalence-Merge | In VIP, an information flow is defined as *"The way data, information and knowledge are created, accessed, shared or traded within and between networked enterprises."* The flow relationship in ArchiMate is defined as *"The flow relationship represents transfer from one element to another."* (The Open Group, 2017) During discussions with E/2 it was decided that creation of information is not relevant from a VIP perspective, the flow relationship seems suitable. These definitions are very similar so they could be merged. Concluding the *merge* rule is applied. |
| **Primary business process** | Business process | Merge rule: Equivalence-Merge | In VIP, a primary business processes are defined as "*Primary activities that are required to enable the physical or virtual creation of the product or service, within or across the borders of the company (e.g., in/outbound logistics, operations, marketing and sales, delivery, after sale servicing)"*. In ArchiMate, the business process concept is defined as *"as a behaviour element that groups' behaviour based on an ordering of activities. It is intended to produce a defined set of products or business services."* These definitions are very similar, so they could be merged. Concluding the *merge* rule is applied. |

### *C7 New relationships in VIP – ArchiMate Target metamodel*

Table C.7 New relationships between the concepts of the VIP-ArchiMate target metamodel

| Relationship | Definition and justification | ArchiMate association roles | Source |
|---|---|---|---|
| **Resource → Capability** | Resources are assigned to certain capabilities. | Assigned to/ Assigned from | Adapted from (The Open Group, 2017) |
| **Value → Resource and capability** | According to the definition of the concept ' value object' of (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012), value objects are resources and capabilities that are of value to one or more actors within the network. As such, the resources and capabilities are *associated* with a certain value. | Associated with | Adapted from (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |
| **Value activity→ Value** | According to the definition of 'value activities' of (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012), value activities create value for and from other actors within or outside the network. Therefore, an *influence* relationship (recap: *a relationship that models that an element affects the implementation or achievement of some motivation element*) is defined between the 'value activity' and 'value concept'. | Influences/ Influenced by | Adapted from (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |

### *C8 Inclusion of risk concepts*

Table C8.1New concepts for the VISOR metamodel

| Class attribute | Description | Source |
|---|---|---|
| **Compliance to regulations** | Compliance to regulations that restrict the type of products or services that could be offered to the end-customer | Adapted from (Hastenteufel, 2015) |
| **Potential risks** | Risks on an operational and financial level that threaten revenues. | Adapted from risk concept of STOF model (Bouwman et al., 2008) |

Table C8.2 New concept for the VIP metamodel

| Concept | Description | Source | Design requirement fulfilment |
|---|---|---|---|
| **Risk and compliance** | Financial and operational risks and compliance to regulations that restrict the value proposition design or endanger revenues. | Adapted from the risk concept of the STOF model (Bouwman et al., 2008) and risk concept as added to the STOF model by (Hastenteufel, 2015) | By including a concept which allows for the expression and investigation of risks and compliance to regulations, the business models feasibility and viability can be ensured. It has to be noticed that this is a first attempt to include risks concepts in the VIP metamodel, and that further research could investigate how the inclusion of this concept in could be further refined. By including this concept, functional design requirement 10 can be fulfilled. |

| Table C8.3 New relationship for the VIP metamodel | | | |
|---|---|---|---|
| **Relationship** | **Definition and justification** | **ArchiMate Association roles** | **Source** |
| **Risk and compliance→ Value goal** | Financial and operational risks and compliance to regulations influence the goal a certain actor wants to achieve or offer to other networked enterprises. If for example an operational risk are considered to be too high, the value goal needs to be adjusted. Or if a product or service provider wants to offer a certain value to a client that needs processing of privacy sensitive data, the value intended to value intended to be offered to the end-customer needs to be adjusted when regulations forbid the processing of privacy sensitive data. | Influences/influenced by | Adapted from (Grandry, Feltus, & Dubois, 2013; Hastenteufel, 2015) |

| Table C8.4 New concept mapping for the VISOR-VIP metamodel | | | |
|---|---|---|---|
| **VISOR Concept** | **VIP concept** | **Concept mapping and integration rule** | **Motivation** |
| Value proposition | Risk and compliance | Embed Rule: Relation – Composition | Risk and compliance issues need to be considered in the design of the value proposition. In UML terms, risk and compliance issues are *part-of* (i.e. composition) (Rumbaugh et al., 2005) the value proposition, so the *embed* rule is applied (Zivkovic & Kühn, 2007). |
| Revenue model | Risk and compliance | Embed Rule: Relation – Composition | Risk and compliance issues that endanger revenues need to be considered to determine the feasibility of the business model, so they are *part-of* the revenue model, so the *embed* rule is applied (Zivkovic & Kühn, 2007) |

| Table C8.5 New concept mapping for the VIP-ArchiMate metamodel | | | |
|---|---|---|---|
| **VIP Concept** | **ArchiMate concept** | **Mapping and integration rule** | **Motivation** |
| Risk and compliance | Assessment | Merge rule: Equivalence - Merge | Based on the mapping of the 'risk' concept with the 'assessment' concept of (Grandry et al., 2013), a similar concept mapping is used. An assessment of on risks and compliance influences the value an actor intends to achieve or offer to other actors. |

# Appendix D Second-round interviews

### *D1 Overview of interviewees*

Table D.1 Experts and their background used for the interviews of round 2.

| # | Interviewee | Organization | Function | Background | Date | Location | Duration (min) |
|---|---|---|---|---|---|---|---|
| **E/7** | Not mentioned for privacy reasons | KPMG | Director Enterprise Solutions | High involvement in VIP development | 13/18-7-2017 | KPMG, Amstelveen, NL/ Skype | 90 |
| **E/8** | | KPMG | Manager Enterprise Solutions | High involvement in ArchiMate development | 18-7-2017 | KPMG, Amstelveen, NL | 60 |
| **E/9** | | KPMG | Senior Manager Enterprise Solutions | Involved in business modelling in UML | 21-7-2017 | KPMG, Amstelveen, NL | 60 |
| **E/10** | | KPMG | Consultant Infrastructures and Architectures | High involvement in ArchiMate development | 25-7-2017 | KPMG, Amstelveen, NL | 60 |

### *D2 Interview guide*

Open questions

1. Opening questions
    a. Are you familiar with ArchiMate and UML?
    b. Are you familiar with business modelling (like canvas) and enterprise architecture?
2. Questions regarding Industry 4.0 application
    a. For each concept in the VISOR UML model:
        i. What do you think about the value proposition in the VISOR Industry 4.0 business model? What are the products and services and what is the intended value for the end-customer in the Industry 4.0 domain?
        ii. What do you think of the defined interface through which the interaction between the customers and partners take place?
        iii. What do you think about the defined service platform for the Industry 4.0? How could the digital platform upon which the services and products are offered to the end-customer be defined?
        iv. What do you think about the type of organizational model as defined in the VISOR UML model? How should the networked enterprises organize themselves?
        v. What kind of revenue models are relevant from an Industry 4.0 perspective?
    b. For each concept in the VISOR-VIP UML transitional model:
        i. What do you think of the product/service related value objects and the value goals defined for Industry 4.0? Is the VIP specialization complete as currently defined in the UML diagram?
        ii. What do you think of the interface related value objects defined for Industry 4.0? Is the VIP specialization complete as currently defined in the UML diagram?
        iii. What do you think of the service platform related value object? Is the VIP specialization complete as currently defined in the UML diagram?
        iv. Organizing model
            1. What actors are involved in an implementation of the prior discussed value propositions for the Industry 4.0? Is the VIP specialization complete as currently defined in the UML diagram?
            2. What type of data, information and knowledge need to be shared to successfully implement the prior discussed Industry 4.0 value propositions? Is the VIP specialization complete as currently defined in the UML diagram?

3. What type of equipment needs to be shared to successfully implement the prior discussed Industry 4.0 value proposition? Is the VIP specialization complete as currently defined in the UML diagram?
4. What kind of process would support the realization of the prior discussed value proposition for the Industry 4.0? Is the VIP specialization complete as currently defined in the UML diagram?

v. Revenue model

1. What revenues can be generated from the prior discussed Industry 4.0 value proposition? Is the VIP specialization complete as currently defined in the UML diagram?
2. How is revenue (i.e. fee or money) exchanged between actors?

**c.** Remaining questions:

i. What do you think of the level of abstraction of the defined Industry 4.0 components in the models?

ii. Does UML help you to understand the VISOR business model and the transition towards the more operational VIP model? If so, how? If not, why not?

Closed and open questions regarding the usefulness and ease of use of the method

**1.** Usefulness of method and metamodel

**a.** Please fill in the checkboxes below

| **Statement** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| The method and metamodel would be useful to address the described problem. | | | | | |
| Using the method and metamodel on the job would enable to accomplish tasks more quickly. | | | | | |
| Using the method and metamodel would improve performance on the job (how well I do my job). | | | | | |
| Using the method and metamodel would increase the effectiveness on the job (how successful). | | | | | |

**b.** What are your suggestions for improvement regarding the usefulness of the method and metamodels?

| |
|---|
| |

**c.** What are your remaining comments regarding the usefulness of the method and metamodels?

| |
|---|
| |

2. Ease of use of method and metamodel

a. Please fill in the checkboxes below

| Statement | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Learning to use the method and metamodel would be easy. | | | | | |
| It is easy to get the method and metamodel to do what it needs to do. | | | | | |
| The interaction with the method and metamodel would be clear and understandable. | | | | | |
| It would be easy to become skilful at using the method and metamodel. | | | | | |
| It would be easy to use the method and metamodel. | | | | | |

b. What are your suggestions for improvement regarding the ease of use of the method and metamodels?

c. Do you have any remaining comments regarding the ease of use of the method and metamodels?

| Requirement fulfilment (1=no, 2=partly and 3=yes) | | | | |
|---|---|---|---|---|
| **#** | **Functional design requirements** | | | |
| **1** | The metamodels should describe and visualize describe the value proposition. | | | |
| **2** | The metamodels should describe and visualize describe the value interface through which the value proposition is delivered. | | | |
| **3** | The metamodels should describe and visualize the service platform upon which the actors interact which each other. | | | |
| **4** | The metamodels should describe and visualize the organizing model which defines how the networked enterprises will organize themselves to effectively and efficiently deliver the value proposition. | | | |
| **5** | The metamodels should describe and visualize the sharing of costs and revenues amongst the networked enterprises. | | | |
| **6** | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects and information objects. | | | |
| **7** | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and business processes performed by actors. | | | |
| **8** | The metamodels should describe and visualize which actor has access to what value, information, data and knowledge objects. | | | |
| **9** | The metamodels should be used in a step-by-step modelling procedure, starting from the value propositions, where it from there on helps to define all the required business model implementation concepts to realize the networked value proposition. | | | |
| **#** | **Non-functional design requirements** | | | |

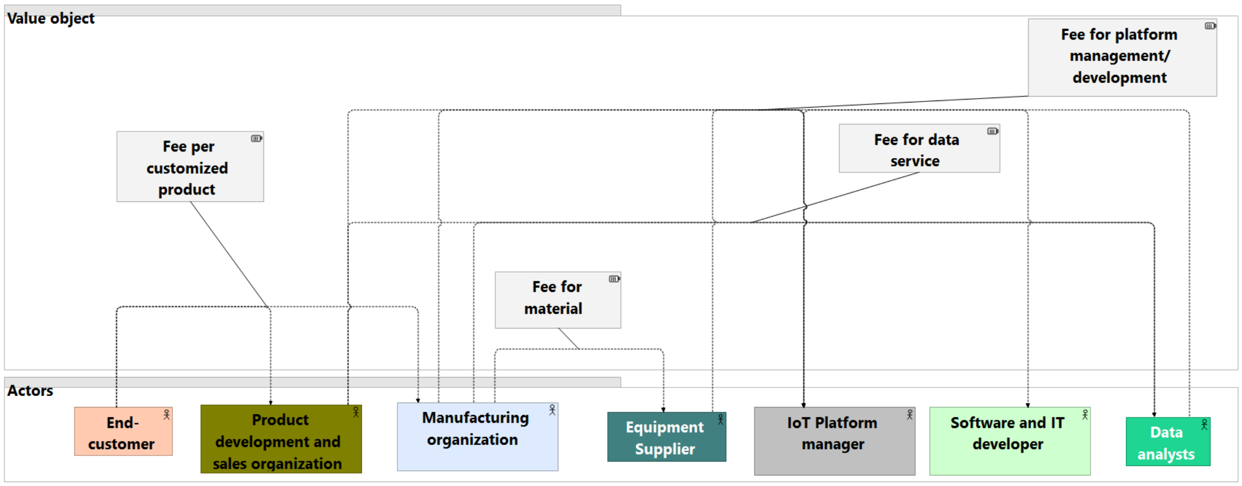
| | | | | |
|---|---|---|---|---|
| **1** | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts, by formally integrating similar business model and enterprise architecture concepts. | | | |
| **2** | The metamodels should be compatible with UML-modelling standards based on MOF. | | | |
| **3** | Relationships between concepts should be defined according to the ArchiMate meta relationships (such as 'assignment' or 'realization' relationships). | | | |
| **4** | The metamodels should be comprehensible – i.e. the ease with which an artefact can be understood or comprehended by business related stakeholders as well as IT related stakeholders. | | | |

***D3 Code template***

Table D.2 Coding template for second-round interviews

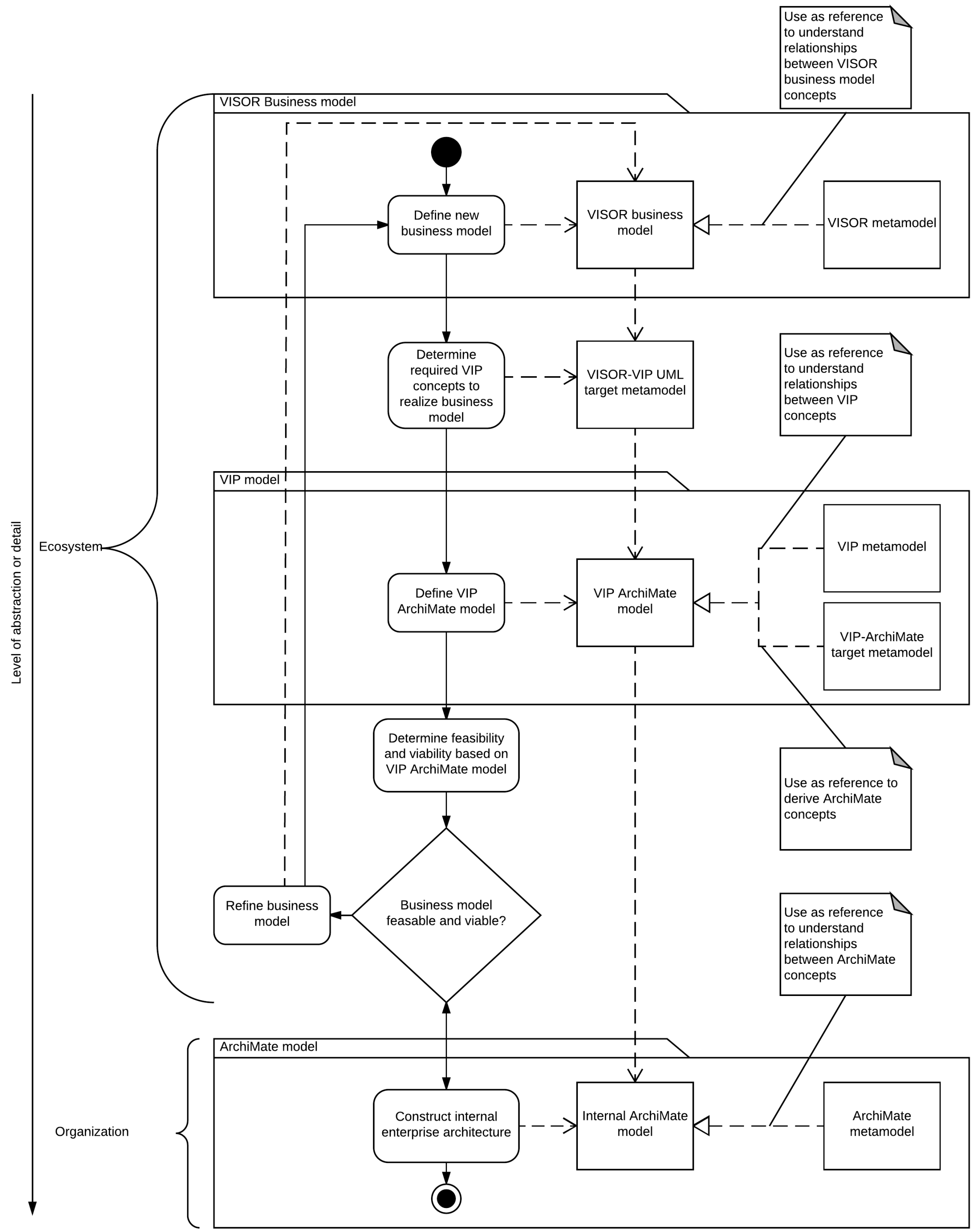
| **VISOR Level-one code** | **Level-two code** | **#** | **VIP Level-one code** | **Level-two code** | **#** |
|---|---|---|---|---|---|
| **Value proposition** | -Highly customized coordinated smart products and services (combinations) | 2 | Value object | -Highly customized smart products for same buying price | 3 |
| | | | | -Value added services for same buying price | 3 |
| | | | | -Enhanced product and service experience | 1 |
| **Interface** | -Digital Multi-modal interface | 3 | Value object | -Web portal | 1 |
| | | | | -Mobile phone application | 2 |
| | | | | -Agent based system for voice interaction | 1 |
| **Service platform** | -Digital IoT or CPS platform | 4 | Value object | -Service platform for information exchange integrated with networked enterprises in the digital ecosystem. | 4 |
| | | | | -IT platform management service | 2 |
| | | | | -Organizational platform management service | 2 |
| **Organizing model** | -Point to point integration with end-customer | 1 | Value object | -ERP order system (for client business interaction) | 2 |
| | | | Value activity | -Adopting industry IoT to increase branding/reputation | 1 |
| | | | Primary business process | -Marketing and sales | 2 |
| | | | | -Smart Inventory management | 2 |
| | | | | -Finance (from product to service) | 2 |
| | | | | -Automated Integrated business planning | 3 |
| | | | | -Data integration and processing | 4 |
| | | | Information exchange | -IoT sensor data (Real-time and Offline) exchange | 2 |
| | | | | -Inventory information exchange | 1 |
| | | | Data object | -IoT sensor data (Real-time and Offline) | 2 |
| | | | Information object | -Inventory information | 2 |
| | | | Knowledge object | -Market demand forecasting gained from data insights | 4 |
| | | | | -Marketing & Sales | 3 |
| | | | | -Telecommunications organization | 1 |
| | -Vertical integration from shop floor to office floor | 1 | | | |
| | -Horizontal and vertical networking with B2B partners | 3 | | | |
| **Revenue model** | - | - | Value goal | -Cost improvements due to flexible manufacturing process and inventory management | 4 |
| | | | | -New revenue sources from value added services | 4 |
| | | | | -Competitive advantage from marketing knowledge based on data insights | 4 |
| | | | Value object | -Service subscription fee | 1 |
| | | | | -Product fee | 1 |

*D4 Revenue exchanges VIP ArchiMate model Customized products*

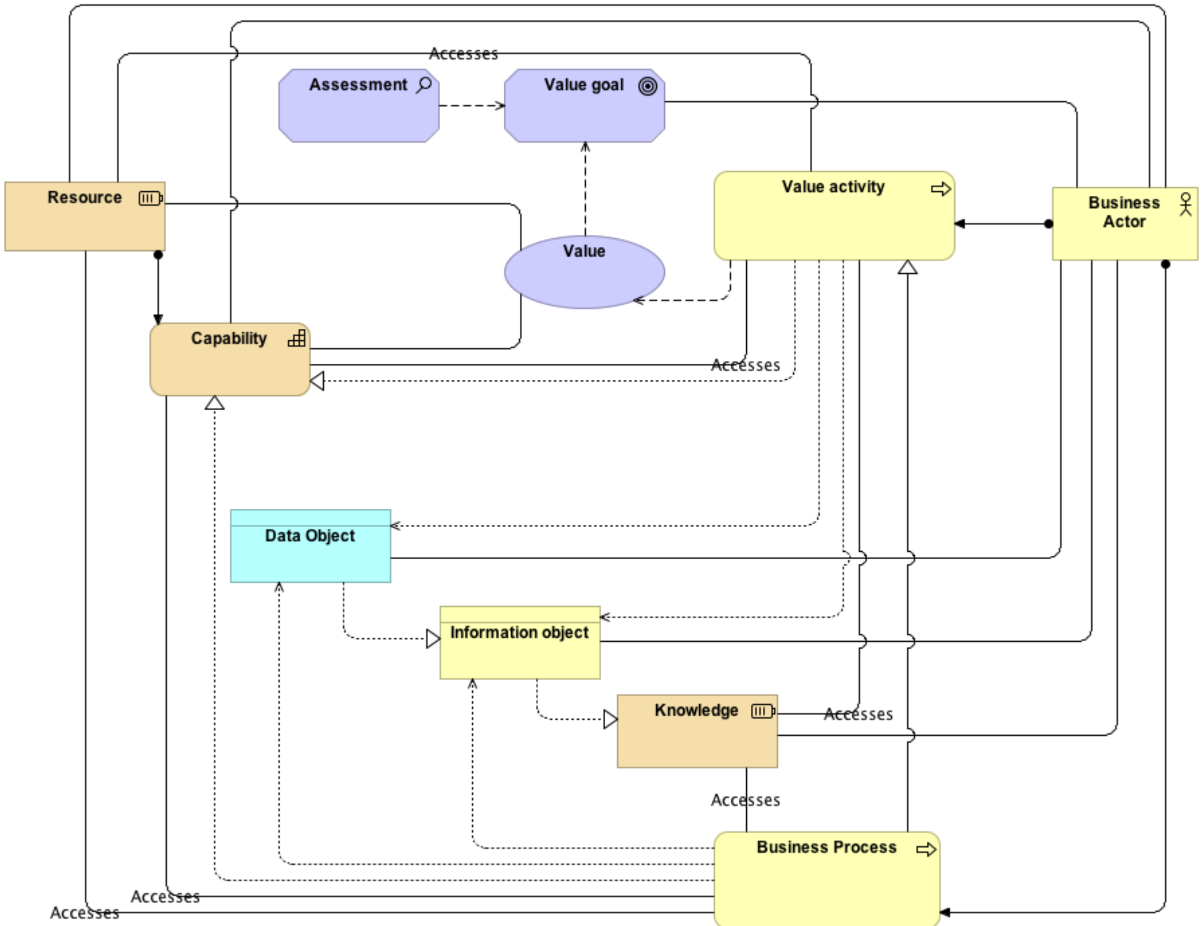


# Appendix E Final modelling procedure and VIP ArchiMate annotation

## *E1 Modelling procedure*



*E2 VIP metamodel in the ArchiMate modelling language*



# Appendix F Scientific article

Scientific article for a master thesis Systems Engineering, Policy Analysis and Management (SEPAM) at the Delft University of Technology.
Martijn Cligge – 4152220 – [m.e.cligge@student.tudelft.nl](mailto:m.e.cligge@student.tudelft.nl)

# Metamodelling for networked business model implementations

*A formal approach for networked business model – enterprise architecture alignment*

**Abstract** Although aligning business models with enterprise architecture concepts can provide insights into business model implementation aspects, current approaches that facilitate business model enterprise architecture have several limitations: they often lack a network perspective, facilitate one level analysis of the business model implementation, are heavyweight or have an informal approach. Therefore, this research presents a formal representation for business model – enterprise architecture alignment, which is developed though an iterative design process with researchers and practitioners. Findings of this study have resulted in a formal business metamodel, a formal business model – enterprise architecture metamodel, two target metamodels and a corresponding modelling procedure. These metamodels facilitate a multi-level description, visualization and analysis of the technological implementation of business models through enterprise architecture concepts. Main contributions of this study are the formal approach, the development of an intermediate lightweight metamodel to bridge the gap between business models and enterprise architectures, and the proposal of various extensions to enterprise architecture modelling language ArchiMate. Further research could focus on the inclusion of a quantitative financial analysis in the business model implementation approach.

## 1. Introduction

The emergence of Information and Communication Technologies (ICT) has offered organizations opportunities to differentiate themselves from competitors by providing innovative ICT driven product and service offerings and to improve their oppertational efficiency. The *business model* is a rather newly developed concept that supports ICT driven innovations by describing the general logic for creating business value (J. Heikkilä, Tyrväinen, & Heikkilä, 2010; Osterwalder, 2004). A limitation of current business models is that they often have informal representations (Zott, Amit, & Massa, 2011). As a result, describing, structuring and communicating the knowledge stored in business models becomes difficult and the design of the business model remains isolated from the design of the business model implementation, which is often represented in formal modelling languages like UML. This introduces the second limitation of business model literature, which is the missing focus in business model literature on the formal design of the business model *implementation*. The implementation of the business model, addressing aspects such as organizational arrangements as well as financial arrangements, business processes and IT. (Bouwman, De Vos, & Haaker, 2008; El Sawy & Pereira, 2013; Osterwalder, Pigneur, & Tucci, 2005; Sam Solaimani & Bouwman, 2012). The lack of a business model implementation perspective in current business model literature could lead to an incomplete understanding of the gap between the business model and the implementation (Bask, Tinnilä et al. 2010). Furthermore, severe set-backs are to be expected in the execution of the business model when implementation aspects are no considered. Even those business models that seems promising on paper, can fail when they are being technologically implemented (S. Solaimani, 2014). Especially in ICT driven business model innovation, where organizations are increasingly collaboratively implementing business models through complex interactions and exchanges of (ICT) resources, capabilities and information and inter-organizational business processes, insights into business model implementation aspects are required to ensure the operational feasibility (refers to if the business logic is sound to be operationalized) and viability (refers to the long-term profitability and market adoption of a business model) of the business model (Janssen & Gordijn, 2005; Osterwalder, 2004; Sam Solaimani & Bouwman, 2012). A business model's feasibility and viability is ensured when the business model is coherent, supporting and supported by the processes and ICT of the networked organizations (Solaimani 2014). Insights into business model implementation aspects can help to facilitate the collaborations, interactions and relationships in such a way that the business model can be sustained at an operational level.

*Enterprise architecture* focuses on establishing a coherent view of an organization, by describing the business processes, applications, information and technological ICT infrastructure (Janssen & Gordijn, 2005;

Lankhorst, 2017). A limitation of enterprise architecture is that they are often lacking a business model component (Rahmati, 2013). Therefore, the questions such as "who will benefit from the product or service" or "who will pay for it" remain unanswered (Iacob et al., 2012). Furthermore, the business fit of the enterprise architecture design cannot be evaluated effectively. Aligning business models with concepts of enterprise architecture offers the insights into the implications of business model design changes on the business processes and IT (Fritscher & Pigneur, 2011; Iacob et al., 2012; S. Solaimani, 2014). Furthermore, underutilized assets can be addressed and key resources and activities required for the realization of the business model can be identified (Fritscher & Pigneur, 2011; Petrikina, Drews, Zimmermann, & Schirmer, 2014). By aligning business models with enterprise architectures, these limitations can be addressed.

While approaches that help organizations to transform their business models to operational, real-life business processes and corresponding IT are still underdeveloped (J. Heikkilä et al., 2010; Heyl, 2014), a few researchers have proposed approaches to align business models with enterprise architecture, such as Fritscher and Pigneur (2011), Iacob et al. (2012), or S. Solaimani (2014). However, current approaches often intra-organizational, facilitate merely a single-level of analysis (by focusing on either the level of values, information or processes), are heavyweight by including many different model concepts and are informal by lacking concrete metamodels and modelling procedures. Based on these limitations and the limitation of business model and enterprise architecture, the following research gaps are stated:

1. Current literature on business models has mainly proposed informal business model representations and lacks a focus on formal business model implementation design.
2. Current literature on enterprise architecture literature often lacks an economical business model perspective.
3. Current literature on business model – enterprise architecture alignment lacks a lightweight formal approach which can be used to describe, analyse and visualize the implementation of networked business models on the level of values, information and processes.

This paper presents set of metamodels and a corresponding modelling procedure for networked business model – enterprise architecture alignment that aims to address these research gaps. The metamodels and modelling procedure can be used to determine the feasibility and the viability of a new networked business model. This is done by first providing a comprehensive background on metamodelling, business models, enterprise architecture and business model – enterprise architecture approaches that form the foundation of the design specification of the meta-models and modelling procedure in section 2. In section 3 the research approach is described. In section 4 the main research findings are discussed, which are the result of two completion of two design iterations of the *building, intervention* and *evaluation* design cycles of the ADR method (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011) in combination with the design cycle of Verschuren and Hartog (2005). In section 5, the research is concluded, while limitations and directions for further research are discussed in section 6.

# 2. Background knowledge

## 2.1 Models, ontologies and metamodels

In this sub-section, the fundamental terms '(meta-) model' and 'ontology' are discussed. First, models are generally considered to be a representation of things existing in reality (Aßmann, Zschaler, & Wagner, 2005). Second, models which are representing and specifying models can be defined as metamodels. A metamodel is a prescriptive model of a modelling language, where the modelling language contains the concepts with which a model instantiation can be described (Kühn, Bayer, Junginger, & Karagiannis, 2003; Kühn & Karagiannis, 2005). Third, ontologies are defined by Aßmann et al. (2005) as *"formal explicitly specifications of a shared conceptualization"* (Gruber, 1993, p. 201). With conceptualization if referred to an abstract model of some phenomenon in the world (for example the logic of a business in the business model ontology of (Osterwalder, 2004)). With explicit is referred to the explicit definition of the concepts. Lastly, with shared refers the notion that the ontology should capture consensual knowledge that is accepted by a group. A model can be defined as an ontology when it meets the conceptualization, explicit, and shared knowledge criteria. Therefore, metamodels are closely related to ontologies, since a metamodel is also an explicit model of the concepts within a domain of interest (Kühn et al., 2003). Lastly, the modelling procedure describes the steps applying the modelling language (i.e. metamodel) to create models (Kühn et al., 2003; Kühn & Karagiannis, 2005; Zivkovic & Kühn, 2007)

There exist numerous models and metamodels (i.e. ontologies) for various domains, such as metamodels that could be used to describe business process models (i.e. instantiations of the BPMN metamodel). In projects in practice, different model instantiations are created from metamodels of different domains, such as combinations of data model instantiations and business process model instantiations. The use of different metamodels is often challenging due to the heterogeneity of the different modelling languages. Metamodel integration techniques address the semantic heterogeneity of different metamodels through concept mapping and integration rules (Zivkovic & Kühn, 2007). Metamodel integration has various advantages, such considerable time and cost savings, increased quality, an enhanced acceptance in model development and more effective exchange of domain model specific knowledge can be achieved (Bauknecht, Tjoa, & Quirchmayr, 2003).

In the next two sections, two types of domain specific models will be discussed; business models and enterprise architecture models. Also, the justification of the selection of certain models and approaches to elicit design requirements will be discussed.

## 2.2 Business models

There does not exist a unified view on what a business model is, while business models are of importance for expressing the business logic of an organization or network of organizations, (Zott et al., 2011). However, what is common between the various business models is they can be used to express the earlier value related concepts, more specifically the value proposition, the value creation activities and the value capturing. An example of a widely accepted organization-centric business model is the Business Model Canvas (BMC) of Osterwalder (2004), while the STOF model (Bouwman et al., 2008) and the e3 value model (J. Gordijn, Akkermans, & Vliet, 2000) or the VISOR business model framework (El Sawy & Pereira, 2013) are examples of networked business models. The theoretical foundations of the VISOR business model framework (El Sawy & Pereira, 2013) will be used to design a formal business model representation since (1) it has a network-centric perspective and (2) it is especially developed for digital business ecosystem environments (which both suits the domain of this study, more elaboration on this in section 3.2).

El Sawy and Pereira (2013) developed the unified VISOR business model framework to help organizations to better navigate through the digital business model world by helping to understand the dynamic environment of digital business ecosystems and corresponding digital platforms. El Sawy and Pereira (2013) divide the business model concepts of VISOR in five categories which cover the dimensions of a digital service. First, the *Value proposition* defines why a particular customer segment would value an organization's product and services. The value proposition if delivered through the *Interface*, which can be for instance a smart phone or tablet. The *Digital service platform* shapes, enables and supports the business processes and relationships required for a digital product or service to be delivered to the customer. The *Organizing model* describes how an organization or a network of organizations will organize business processes, value chains and partner relationships. Lastly, the *Revenue model* defines how to make money doing all of the above described concepts.

## 2.3 Enterprise Architecture

While a business model emphasis on the value proposition, value creation and value capturing of an organization, enterprise architecture describes the connection between business processes and IT. The relation between business models and enterprise architecture is described by Janssen and Gordijn (2005) as follows: *"Enterprise Architecture and business modelling methodologies meet in service offering and realization. In general, business models focus on the service value generated by a business, whereas enterprise architecture models show how a business realizes these services."* (Burren, Janssen et al., 2005, p. 2). According to Gaaloul and Proper (2012), enterprise architecture guards the cohesion and alignment between the different aspects of the organization such as the ICT and business processes.

Although there exist numerous approaches in the enterprise architecture community, such as the Zachman framework (Zachman, 1987), ArchiMate (Jonkers et al., 2006) or the Open Group Architecture Framework (TOGAF) (The Open Group, 2017), for the development of the formal business model implementation approach, concepts of the open standard and enterprise architecture modelling language ArchiMate will be used for the following reasons: (1) ArchiMate has an integrated approach for modelling all aspects of an organization (2) The use of ArchiMate is advocated by its representativeness and wide acceptance in the academic and practitioner communities (Iacob et al., 2012). ArchiMate is an open and independent description language for Enterprise Architecture, supported by different tool vendors and consulting firms. The ArchiMate core framework provides architects a graphical modelling language with concepts to describe, analyse and visualize an architectural model with its relationships among business domains in an unambiguous way.

### 2.4 Business model implementation for networked enterprises.

As stated before, ICT driven business innovations are increasingly realized through collaborating organizations i.e. networked enterprises. The term networked enterprise is defined by Solaimani (2014) follows: *"hardly/non-substitutable linked companies that collaboratively aim at enabling or implementing the collective Business Model by means of offering service and product and/or sharing resources and capabilities."* (Solaimani, 2014, p. 61). Networked enterprises collaboratively implement networked business models in which all stakeholders are involved through exchanges of resources, capabilities, information, knowledge, inter-organizational business processes, and IT (S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012). Networked actors are (inter)dependent on its partners to realize the joint value proposition (M. Heikkilä, 2010; S. Solaimani, 2014). This is where the motivation to join a network comes from; the attainment of goals that are unachievable by the organizations independently (M. Heikkilä, 2010).

The interactions between networked enterprises are often characterized by cross-domain, heterogeneous and geographically distributed business processes, resources and capabilities (Chung, Yam, & Chan, 2004; Weske, 2007). The dynamic and heterogeneous nature of networked enterprises makes collaboration between networked enterprises challenging. Therefore, the realization of feasible and viable business models can become complicated. According to S. Solaimani (2014), a business model's feasibility and viability is ensured when the business model is coherent, supporting and supported by the processes and IT within and among the stakeholders involved (S. Solaimani, 2014). Insights in the complex interactions on various levels (i.e. processes, data, information, knowledge, resources and capabilities) between the actors is necessary to ensure the feasibility and viability of the business model.

### 2.5 Aligning business models and enterprise architecture

Based on the characteristics of networked enterprises and the previous discussed and advantages of formal representations, it can be stated that current approaches have several limitations. First, current approaches that facilitate business model implementation through aligning business models with enterprise architectures often do not take a multi-level interaction into account (Example is the approach of Ding (2015), where the Value Delivery Metamodel (VDML) (OMG, 2015) is integrated with concept of the business layer of ArchiMate (Lankhorst, 2017). Furthermore, they often have an intra-organizational perspective (Examples are the approaches of Iacob et al. (2012) or Fritscher and Pigneur (2011), who both transform the intra-organizational Business Model Canvas of Osterwalder et al. (2005) into a single organization enterprise architecture), are heavyweight by including many model concepts (such as the approaches of Iacob et al. (2012), Ding (2015) or Rahmati (2013)) and have informal representations (such as the approach of Janssen and Gordijn (2005) Fritscher and Pigneur (2011), S. Solaimani (2014) or Rahmati (2013)).

The VIP (i.e. Values, Information and Processes) framework of S. Solaimani (2014) and Sam Solaimani and Bouwman (2012) *does* have a network-centric perspective, *does* takes a lightweight approach and *does* facilitate multi-level analysis by taking the exchanges of values, information and processes into account. Therefore, is will be used in the alignment approach. However, the framework is represented by an incomprehensive informal notation without concrete metamodels and without the support of tooling to analyse the business model implementation. VIP is rather a conceptual *framework* or theoretical lens expressed in natural language that helps researchers focus on important aspects of networked business implementations, instead of a formal *modelling language*, consisting of concrete metamodels and a modelling procedure, that can be used the analyse, describe and visualize a networked business model implementation.

# 3. Research approach

### 3.1 Design process

Through the execution of two BIE cycles of the ADR method (Sein et al., 2011), using the specific design steps of the design cycle of Verschuren and Hartog (2005), the meta-models and modelling procedure will be continuously evaluated and refined. Ten experts, including researchers and practitioners, were consulted to evaluate and refine the design requirements and design specifications of the metamodels and modelling procedure.

The first design iteration comprised of theoretical analysis (Johannesson & Perjons, 2014) to define the initial functional and non-functional design requirements for the artefact. The initial design requirements are mainly based on the theoretical foundations of the aforementioned models/frameworks, however also additional literature on business models, enterprise architecture and business model – enterprise architecture was also consulted. These initial design requirements and design specifications were subsequently evaluated through semi-structured interviews with six researchers in the field of business modelling and/or enterprise architecture on validity, coherency, completeness and consistency. This led to a refined set of design requirements and a refined design specification. In the second design iteration, the refined metamodels and modelling procedure were applied to a case in the Industry 4.0 domain. The application of the metamodels and modelling procedure was based on semi-structured interviews with four practitioners with a background in Industry 4.0, Business-IT alignment, and/or enterprise architecture. This led to three model instantiations of the metamodels and modelling procedure. Furthermore, the second-round of interviews was also used to evaluate the metamodels on usefulness, ease of use and requirement fulfilment. This led to a further refined set of design requirements and a refined design specification. The final design requirements are displayed in Appendix A. In the next section, the developed networked business model – enterprise architecture approach will be presented.

# 4 Research findings

## 4.1 Final metamodels and modelling procedure

Processing the feedback results in the development of two metamodels, two target metamodels and a corresponding modelling procedure. First, the VISOR metamodel can be used to describe and visualize the business model in a structured manner. Second, the VIP metamodel can be used to describe and visualize the operationalization of the business model. Third, the VISOR-VIP target metamodel can be used to transition from the concepts of the VISOR metamodel to the VIP metamodel. Fourth, to transition from the concepts of the VIP metamodel to the ArchiMate metamodel, the VIP-ArchiMate target metamodel can be used, after which the VIP ArchiMate model can be developed using the ArchiMate concepts. The VIP ArchiMate supports discussions on the feasibility and viability of a networked business model.

### *a) VISOR metamodel*

First, the VISOR metamodel is a formal representation of a networked business model, based on the theoretical foundations of VISOR (see Appendix B). The VISOR business model framework initially lacked a formal representation and was expressed in natural language. The VISOR metamodel is used to describe and visualize the business idea in a structured manner. Relationships between the metamodel concepts will be explained briefly. The 'value proposition' concept is *realized* (i.e. "*The realization relationship indicates that an entity plays a critical role in the creation, achievement, sustenance, or operation of a more abstract entity"*. The Open Group (2017)) when it is delivered to the end-customer through the 'interface' concept. The 'value proposition' concept is also *realized* by the interactions of the networked enterprises. The way the networked enterprises organize themselves is described in the 'organizing model' concept. Also, the 'digital service platform' concept supports the *realization* of the 'value proposition' concept. For example, the digital service platform Facebook support the realization of the value proposition of "connecting people around the globe". The 'value proposition' concept is *associated with* (i.e. *"An association relationship models an unspecified relationship, or one that is not represented by another ArchiMate relationship" (The Open Group, 2017)*) the 'revenue model' concept. For example, the value proposition of Netflix (which can be defined as a digital service which delivers TV shows and movies to the end-customer) is associated with a monthly subscription fee revenue model. Furthermore, the 'organizing model' concept *accesses* (i.e. *"The access relationship models the ability of behaviour and active structure elements to observe or act upon passive structure elements*". (The Open Group, 2017)) the 'digital service platform' concept to *realize* the 'value proposition' concept. Correspondingly, certain networked enterprises need to be defined in the 'organizing model' concept who *realize* the 'digital service platform' concept (such as platform developers). The 'digital service platform' concept is also *associated with* certain implementation costs. Therefore, also an *associated with* relationship is defined between the 'digital service platform' concepts and the 'revenue model' concepts.

The VISOR descriptors of El Sawy and Pereira (2013) are added as class attributes, which was suggested by interviewee E/6 during the first-round interviews. In Appendix A.1, the class attributes are explained in detail. The type of class attribute (e.g. String or Boolean) is based on the definition of the descriptor as provided by El Sawy and Pereira (2013). These class attributes could be used in scenario analysis to determine which descriptor is of importance in the new business model and which descriptor is of less importance. For a detailed elaboration on the use of descriptors in scenario analysis, please refer to El Sawy and Pereira (2013). A descriptor on risk and compliance issues was added, as suggested by interviewees in the second-round interviews.

*b) VIP metamodel*

Second, the VIP metamodel is a lightweight intermediate (between the VISOR business model and ArchiMate enterprise architecture metamodels) metamodel that can be used to bridge the gap between the business model and the enterprise architecture. See table C in Appendix C for a detailed description of every metamodel concept. The VIP metamodel mainly expresses the first stage towards the implementation of the business model. The metamodel is displayed in figure 1. The relationships will be briefly explained. The 'actor' (concept is *assigned to* (i.e. "*The assignment relationship expresses the allocation of responsibility, performance of behaviour, or execution*." (The Open Group, 2017)) the 'value activity' or 'business process' concept. The 'value activity' and 'business process' concepts *realize* or *access* the 'value object' concept (i.e. tangible resources (e.g., goods, contract, money) and intangible capabilities (e.g., service, credit, authority), where the 'value activity' concept *accesses* or *realizes* more economically oriented value objects and the business process more functional oriented value objects. The 'value activity' and 'business process' concepts *access* the various 'value object' 'data object', 'information object' and 'knowledge object' concepts in their execution. For example, the business process 'order processing' requires (i.e. is dependent on) the information object customer order in its execution. Next, the 'value object', 'data object', 'information object' and 'knowledge 'object' concepts are *associated with* certain actors. Therefore, the metamodel also shows the dependencies (resource dependencies) of the various networked enterprises on the level of values, information and processes. The 'value activity' concept is executed to *influence* (i.e. "*The influence relationship models that an element affects the implementation or achievement of some motivation element*." (The Open Group, 2017)) the 'value goal' concept via the realization or accesses of value objects. For example, an online movie streaming service provider (i.e. the actor) provides customized movie suggestions (i.e. the value activity) in their customized movie service (i.e. the value object) to the end-customer to influence the value goal of 'increasing customer satisfaction by customized movie suggestions'. Value goals are *associated with* actors. Also exchanges of values and information can be expressed and analysed through the use of the 'value exchange' and 'information exchange' concepts, where these types of object *flow* (i.e. "*The flow relationship represents transfer from one element to another.*" (The Open Group, 2017)) between the actors. Lastly, the 'risk and compliance' concept *influences* the 'value proposition' concept.

*c) Metamodel integration*

Next, following non-functional design requirement one, the aforementioned metamodels will be (1) formally integrated with each other and (2) integrated

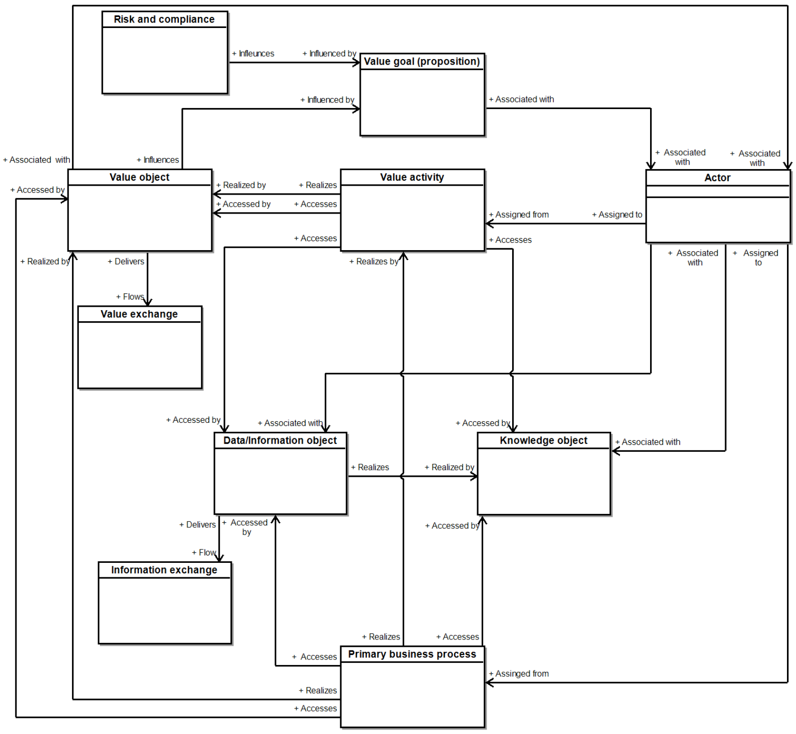



Figure 1 VIP metamodel

with ArchiMate concepts. To integrate the different concepts of VISOR and VIP metamodels, the work of Kühn et al. (2003) and Zivkovic and Kühn (2007) will be used, where rules are defined on how metamodels can be integrated. The mapping subtypes are: equivalence, relation (generalization, aggregation, composition, association, classification) and non-relation. A target metamodel is the result of the integration effort, where concepts of two source metamodels are integrated. Formal metamodel integration of concepts of the VISOR metamodel to the VIP metamodel has resulted in the development of a VISOR-VIP target metamodel (see Appendix C) and the VIP ArchiMate target metamodel (see Appendix D). The VISOR-VIP target metamodel can be used to transition from the concepts of the VISOR metamodel concept to the VIP metamodel concepts. The VISOR-VIP target metamodel extends the VISOR metamodel with a focus on formal business model design. To transition from the concepts of the VIP metamodel to the ArchiMate metamodel concepts, the VIP-ArchiMate target metamodel can be used (see Appendix E). As a result, the VIP metamodel instantiations can be modelled in enterprise architecture modelling language ArchiMate. The metamodels and the target metamodels are used in a corresponding modelling procedure.

### *d) The Modelling procedure*

The modelling procedure supports analysis and description of business model implementations within networked enterprises through a step-by-step process (see Appendix D). The first step begins by describing and visualizing the business idea on a high level of abstraction with the VISOR metamodel. In the next step, the target VISOR-VIP target metamodel defines the required VIP metamodel concepts to realize the business idea. In the next step, the VIP ArchiMate model is described and visualized. Two metamodels are used in this step. The VIP metamodel shows the formal relations between the VIP concepts, defined in step two of the modelling procedure. To draw the VIP concepts in ArchiMate, the VIP-ArchiMate target metamodel is used translate the concepts of the VIP metamodel to ArchiMate concepts. The VIP-ArchiMate metamodel is used to structure development process of the VIP ArchiMate model. Based on the resulting VIP ArchiMate model, discussions can be held on the feasibility and viability of the business model. Issues that endanger the feasibility and viability of the business model should be addressed in this step. When it is not possible to address these issues, the business model should be refined and the modelling procedure starts again. When the issues can be addressed, the fourth step defines the internal detailed internal enterprise architecture of each actor. The VIP ArchiMate model forms the context from which requirements can be derived for the internal enterprise architectures.

### *e) A simple demonstration of the VIP metamodel and VIP-ArchiMate target metamodels*

To show how the VIP-ArchiMate target metamodel can be used, in figure 2, a very simple VIP ArchiMate model is displayed to show how the metamodel could be used to create model instantiations. The model

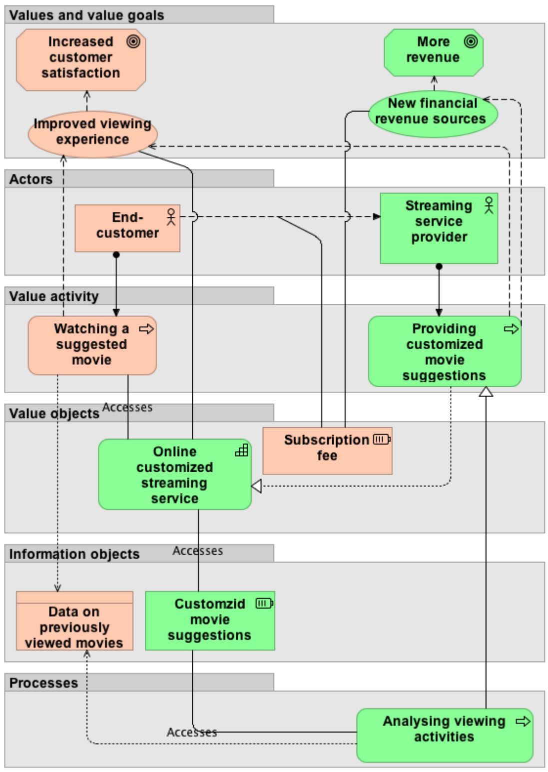



Figure 2 Simple example of a VIP ArchiMate model

shows the interaction on the levels of values, information/knowledge and processes of two actors, the end-customer and the movie streaming service provider. The end-customer is *assigned to* the value activity "watching a suggested movie". This value activity *accesses* a certain value, more specifically an "improved viewing experience" This value *influences* a value goal, which is in this case "increased customer satisfaction". The value is associated with the 'Online customized streaming service' capability. This capability is *realized* through the execution of the "providing customized movie suggestions" value activity, which is *assigned to* the "Streaming service provider" actor. By executing the "watching a suggested movie" value activity, the end-customer *accesses* a new data object, which comprises of data on "previously viewed movies". This data object is *accessed* in the business process "Analysing viewing activities", where this data is processed to gain knowledge on what type of movies a particular end-customer likes to watch. The execution of this business process thus *accesses* the "customized movie suggestions" knowledge object and *realizes* the value activity "providing customized movie suggestions". The knowledge object is subsequently accessed in the service to improve the accuracy of the customized movie suggestions. Lastly, the end-customer exchanges the "subscription fee" with the movie streaming service provider in return for the provided services, which eventually *influences* the value goal "more revenue" of the movie streaming service provider.

*f) New ArchiMate extensions.*

The development of the VIP-ArchiMate metamodel has resulted in the proposal of a new concept and two new relationships to ArchiMate (see table 1). The proposal of the inclusion of a 'value activity' concept to ArchiMate is a first step towards the inclusion of a more abstract and economical business model perspective in ArchiMate. The 'value activity' concept aims to bridge the gap between the more economical business model and the more functional enterprise architecture. While a business process is often modelled purely from a functional perspective (without taking into account the direct value that the business process creates), the value activity concept can be used to describe and visualize more abstract and economical oriented activities that create direct value for various actors, such as "buying a product", "watching a movie" or "collaborating to increase branding image". The relevace of this concept is confirmed by various researchers who were involved in the development of ArchiMate. In addition, two new relationships are proposed which add to the inclusion of a business model perspective. The first poposed relationship comprises of an *access* relationship between the various behaviour elements and the static behaviour element 'resource' concept of ArchiMate. The second proposed relationship comprises of an *influence* relationship between the 'Business process/function/interaction/ (value activity)' concepts and the 'value' concept. This allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value.

Table 1 Proposed ArchiMate extensions

| Concept | Concept | Relationship | Meaning |
|---|---|---|---|
| **Resource** | **Business process/function /interaction/ (value activity)** | Access | A behavioural element can access (i.e. create, read, process or exploit) a resource (i.e. material, IT infrastructure, human resources). |
| **Value** | **Business process/function /interaction/ (value activity)** | Influence | Value is an output of a business process/function /interaction/value activity, which has value-in-use for buyers. |
| **Concept** | | **Definition** | |
| **Value activity** | | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors. | |

# 5 Conclusions

Business models express the business logic of an organization, while enterprise architecture generally defines the business implementation through a description of the business processes, information and ICT. A limitation of business models is that they are often represented in an informal notation and often neglect to address ICT driven implementation aspects. A limitation of enterprise architecture models is that they often miss a more economical oriented business model perspective. A few researchers have proposed approaches to align business models with enterprise architectures to gain insights into business model implementation aspects and to extend enterprise architecture with a business model perspective. Nonetheless, they have several limitations: they are often intra-organizational, have a single-level of analysis, are heavyweight by having many model concepts or are using an informal approach.

To address these limitations, this study proposed a set of lightweight *formal* metamodels and a corresponding modelling procedure in UML for networked business model – enterprise architecture alignment that support networked enterprises with a multi-level description, visualization and analysis of their technological business model implementation. For the development of the metamodels and modelling procedure, the theoretical foundations of the VISOR business model framework and the VIP business model – enterprise architecture framework were used in combination with ArchiMate. Execution of two BIE cycles of the ADR method resulted in the development of a VISOR metamodel, a VIP metamodel, VISOR-VIP target metamodel and a VIP-ArchiMate metamodel. Furthermore, a corresponding modelling procedure was developed which shows how the various metamodels should be used to create model instantiations.

This study has several scientific contributions. First of all, this study contributes to business model literature with the development of the VISOR metamodel, which was initially expressed in natural language. The

VISOR metamodel makes it easier to understand and visualize the relations between the business model concepts, which in turn should improve communication of the business idea. Second, the development of the VISOR-VIP target metamodel adds to the lack of a focus on formal business model implementation design in business model literature. Most business model literature focuses on value related aspects, such as the value network analysis of Allee (2008), while the information, business process and enterprise architecture perspective is underdeveloped. With the VISOR-VIP target metamodel, studying business model implementations should therefore become more comprehensive and holistic for researchers in the field of business models and enterprise architectures. The formal representation and integration of VISOR and VIP concepts make it easier to relate the business model design with the business model implementation design. As a result, severe set-backs that are to be expected in the implementation of the business model can be addressed in advance.

Second, this study adds to literature on enterprise architecture by proposing the 'value activity' concept (which was perceived as a valuable contribution to ArchiMate by various researchers who are involved in the development of ArchiMate) and the two new relationships to the ArchiMate metamodels. The first relationship should make modelling the interactions of processes with resources more precisely, while the second relationship allows to model value-in-use or value conversion where behaviour of a certain actor results in the creation of value. This extension should add a more abstract and business model oriented perspective to ArchiMate.

Third, this study adds to literature on business model and enterprise architecture alignment. First, with the development of the VISOR-VIP and VIP-ArchiMate target metamodels, it is one of the first studies to integrate business model concepts and enterprise architecture through the application of formal metamodel integration techniques. The formal integration of business model concepts with enterprise architecture can support studies on alignment issues that hinder the feasibility and viability of the business model in a more consistent, holistic and unfragmented manner. Second, another contribution to literature on business model and enterprise architecture alignment is the development of the formal VIP metamodel, which can be used as intermediate to bridge the gap between more economical and abstract business model design and the more detailed and functional enterprise architecture design. The VIP metamodel is based on the theoretical foundations of VIP, which was initially an informal conceptual framework rather than a formal modelling approach. By being based on the theoretical foundations of the VIP framework, this VIP metamodel facilitates a multi-level description, visualization and analysis of value, information and processes related aspects, where current business model enterprise architecture approaches often facilitate a single-level description and visualization. Third, by formally integrating the VIP concepts with ArchiMate concepts in the VIP-ArchiMate target metamodel, this is also the first study that applies enterprise architecture thinking in VIP analyses. Also, in current business model and enterprise alignment architecture literature, a lightweight formal intermediate was missing; current approaches often convert the more abstract business model concepts directly to *many* detailed functional enterprise architecture concepts (such as the approach of (Rahmati, 2013)). By being lightweight (consisting of a limited number of concepts and relations between these concepts (J. Gordijn, 2003)) researchers can use the VIP-ArchiMate target metamodel to study alignment issues more effectively and efficiently, by focusing on the essential concepts that play a role in business model and enterprise architecture alignment without diving into various side issues and non-relevant details.

Lastly, since literature on business model and enterprise architecture alignment often has a single-organization perspective, a third contribution to literature on business model and enterprise architecture alignment is focus on *networked* enterprises.

# 6 Limitations and Further research

Although this research has been executed carefully, there are limitations. First of all, the metamodels and modelling procedure have not been applied in a *real-life* case study yet. Applying the metamodel and modelling procedure in a real case study could result in detailed discussions on possible issues that arise during the business model implementation, which might lead to an adjustment of the business model. Furthermore, this would further validate the metamodels and modelling procedure.

Secondly, the inclusion of the risk and compliance concepts to the VISOR and VIP metamodels still needs to be verified. The risk and compliance concepts have not been used yet in the application of the artefact yet. A more detailed study on risk management is required to integrate risk related concepts into the metamodels.

Thirdly, by integrating the VIP metamodel concepts with ArchiMate concepts, knowledge on ArchiMate is required to be able to work with the artefact. During the implementation phase, it became clear that it was sometimes difficult to understand the meaning of certain concepts for interviewees who were not familiar with ArchiMate.

Fourthly, since the amount of available time to conduct this research was somewhat limited, a more detailed and thorough literature review on business models and enterprise architectures needs to be conducted. Although the business model – enterprise architecture alignment literature has been analysed in a comprehensive manner, a more detailed literature on business models and enterprise architectures is still necessary.

Finally, some directions for further research are provided.

- A possible research direction is the application of the artefact to a *real-life* case study.
- A more detailed and thorough literature review on business models (since the work of Zott et al. (2011) is the last thorough literature review on business models) and enterprise architectures is a possible direction for future research. This could result in an overview of newly discovered limitations of current approaches, which can be addressed in subsequent research.
- Formal integration of other types of business models, such as the STOF model, with other types of enterprise architecture models, such as ARIS, is also an interesting direction for further research.
- Another research direction would be the inclusion of a detailed quantitative financial analysis in the modelling procedure and metamodels. In the work of Iacob et al. (2012), a detailed quantitative financial analysis can be used to determine the costs and possible revenues for a business model driven enterprise architectural change. This allows to determine whether the possible revenues exceed the costs of the architectural change, and if thus the business model design change is desired. Iacob et al. (2012) also related their approach to the TOGAF framework. In further research, it can be investigated how the modelling procedure and metamodels could be integrated with this widely accepted enterprise architecture framework.
- Another research direction could be the relation between on the one hand the networked business model and networked interactions through enterprise architecture concepts and the other hand the organization-centric business model and internal enterprise architecture. While this research analysed the networked perspective, the organization perspective is not included, while organizations still have their own individual business models. The relation between for example the VISOR metamodel and the organization centric Business Model Ontology of (Osterwalder, 2004) is a possible direction for further research.

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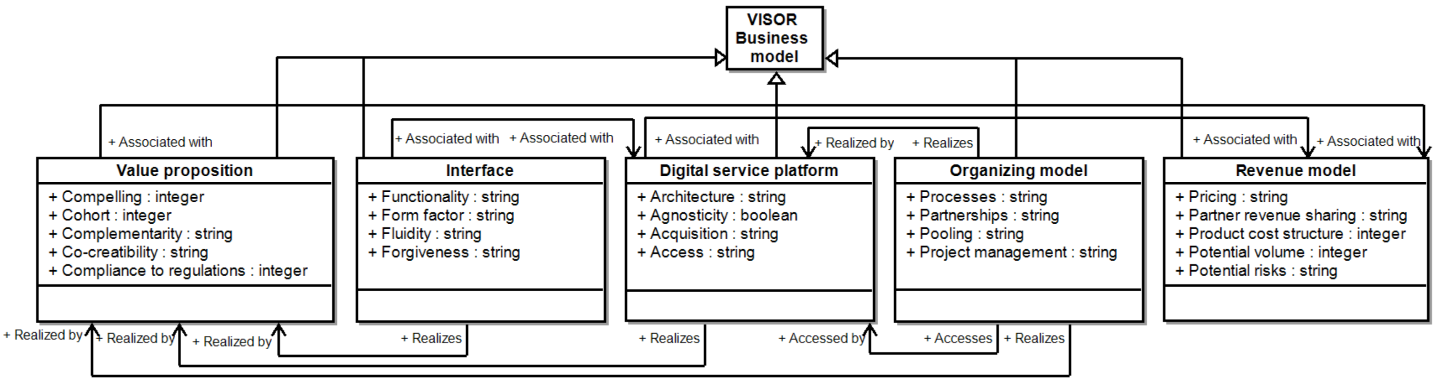
# Appendices

## Appendix A Design requirements

| List of functional and non-functional design requirements | |
|---|---|
| **#** | **Functional design requirements** |
| **1** | The metamodels should describe and visualize describe the value proposition. |
| **2** | The metamodels should describe and visualize describe the value interface through which the value proposition is delivered. |
| **3** | The metamodels should describe and visualize the service platform upon which the actors interact which each other. |
| **4** | The metamodels should describe and visualize the organizing model which defines how the networked enterprises will organize themselves to effectively and efficiently deliver the value proposition. |
| **5** | The metamodels should describe and visualize the sharing of costs and revenues amongst the networked enterprises. |
| **6** | The metamodels should describe and visualize the exchanges of values (in terms of products/services and resources and capabilities), data objects and information objects. |
| **7** | The metamodels should describe and visualize the creation (or processing) of values (in terms of products/services and resources and capabilities), data, information and knowledge objects in value activities and business processes performed by actors. |
| **8** | The metamodels should describe and visualize which actor has access to what value, information, data and knowledge objects. |
| **9** | The metamodels should be used in a step-by-step modelling procedure, starting from the value propositions, where it from there on helps to define all the required business model implementation concepts to realize the networked value proposition. |
| **10** | The metamodels should describe and visualize risk and compliance related restrictions. |
| **#** | **Non-functional design requirements** |
| **1** | The metamodels should formally define the relations between business model concepts and enterprise architecture concepts, by formally integrating similar business model and enterprise architecture concepts. |
| **2** | The metamodels should be compatible with UML-modelling standards based on MOF. |
| **3** | Relationships between concepts should be defined according to the ArchiMate meta relationships (such as 'assignment' or 'realization' relationships). |
| **4** | The metamodels should be comprehensible – i.e. the ease with which an artefact can be understood or comprehended by business oriented stakeholders and IT oriented stakeholders. |

## Appendix B VISOR metamodel

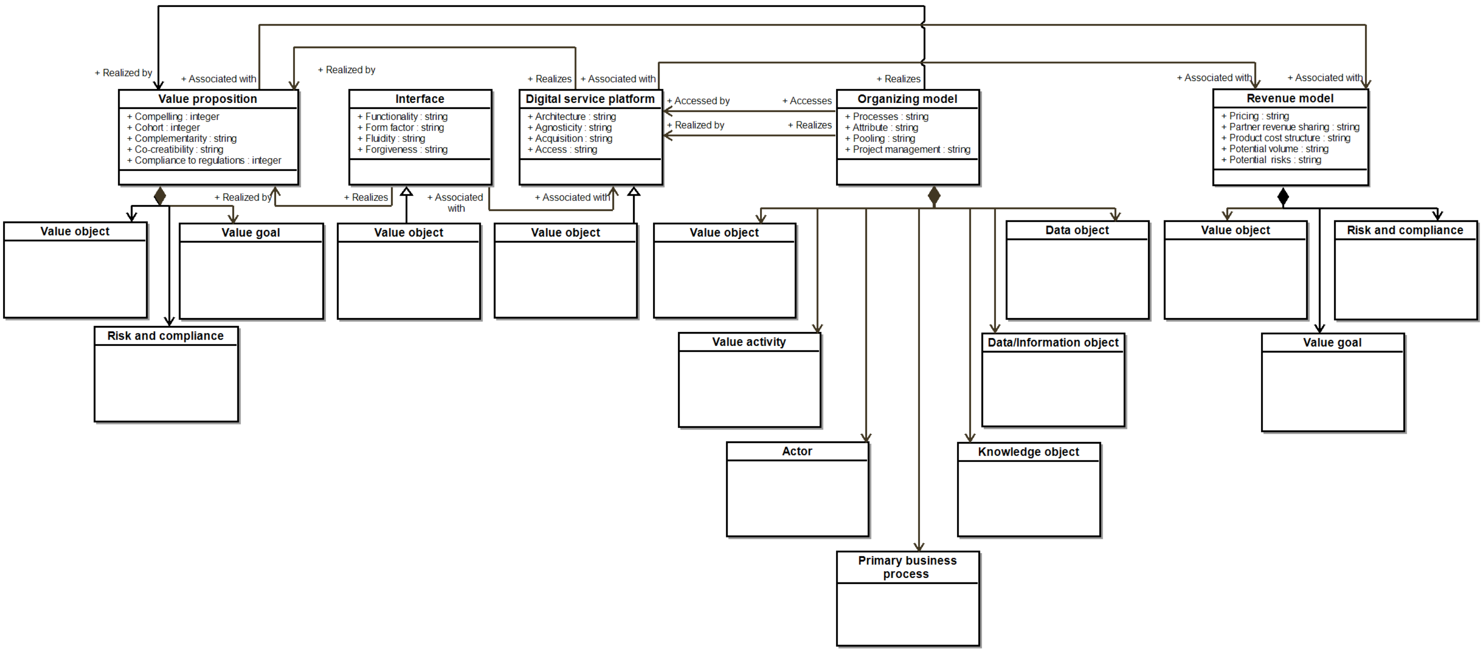


## Appendix C Concept of the VIP metamodel

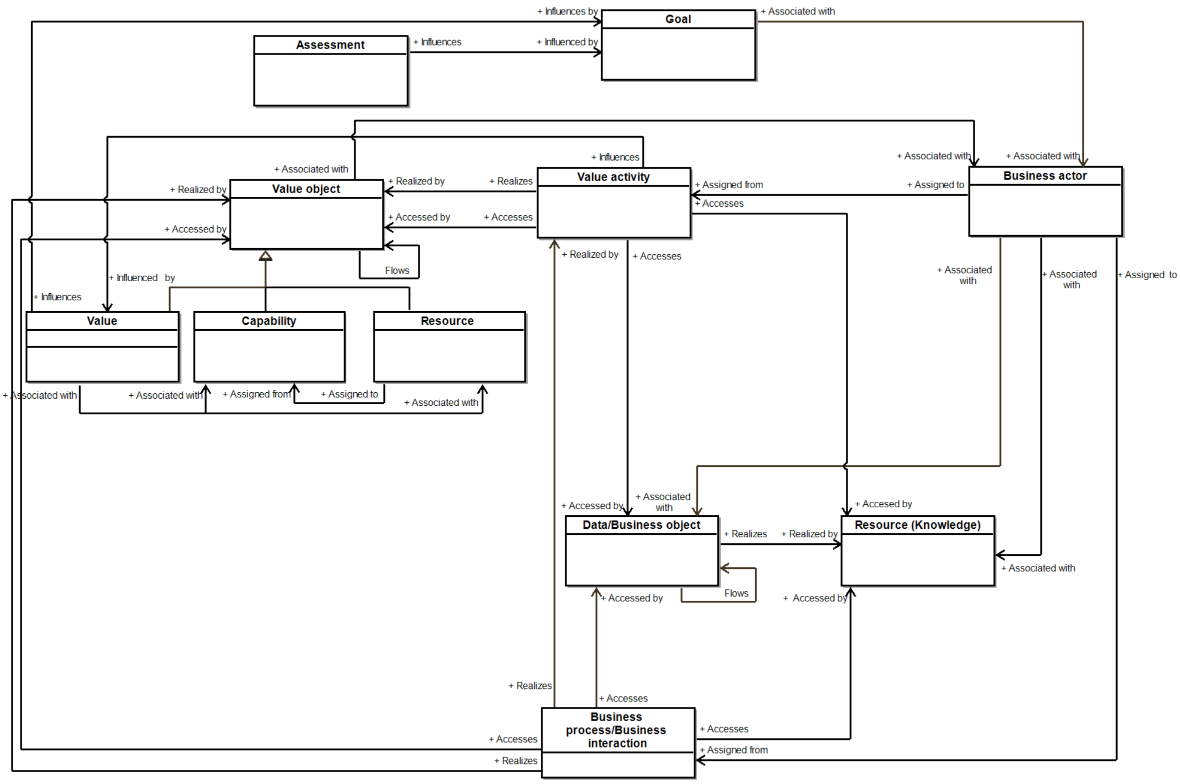
Table C Concepts of the VIP-metamodel specification

| Concept | Definition | Source |
|---|---|---|
| **Actor** | An independent economic (and often legal) entity. By carrying out value activities, an actor makes a profit or increases its utility | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |
| **Information Exchange** | Information exchanges represent the interactions in networked enterprises through exchanges of data and information between networked enterprises. To ensure consistency with the value exchange concept, the name of the concept is slightly modified to information exchange. | Adapted from (De Marco, 1979)(J. Gordijn et al., 2000) and interviewee E/6 |
| **Information, Data, Knowledge Objects** | **Data.** Numbers, characters, images, or other method or recording, in a form that can be assessed by a human or (especially) input into a computer, stored and processed there, or transmitted on some digital channel. Data on its own has no meaning, only when interpreted by some kind of data processing system does it take on meaning and become information. An example is a database of automatically stored users' behaviour.<br>**Information.** The result of applying data processing to data, giving it context and meaning. Some examples are contracts, product specifications, or interpreted data of users' behaviour.<br>**Knowledge.** The appropriate collection of information, such that is intent is to be useful. Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference. If information is data plus meaning, then knowledge is information plus processing. Examples are experts' tacit knowledge and expert information systems. | Adapted from (Ackoff, 1989; Alavi & Leidner, 2001; Bellinger, Castro, & Mills, 2004; Howe, 2010) |
| **Primary Business Processes** | Primary physical activities that are required to enable the physical or virtual creation of the product or service, within or across the borders of the company (e.g., in/outbound logistics, operations, marketing and sales, delivery, after sale servicing). | Adapted from (Mooney, Gurbaxani, & Kraemer, 1996; Porter, 1985) |
| **Risk and compliance** | Financial and operational risks and compliance to regulations that restrict the value proposition design or endanger revenues. | Adapted from the risk concept of the STOF model (Bouwman et al., 2008) and risk concept as added to the STOF model by (Hastenteufel, 2015) |
| **Value object** | Tangible resources (e.g., goods, contract, money) and intangible capabilities (e.g., service, credit, authority), valuable to one or more actors within the network. | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |
| **Value activity** | Actions or tasks an actor performs to create, provide and/or capture value for and from other actors within or outside the network. By carrying out value activities, an actor or collaboration of actors makes a profit or increases it utility for its own benefit as well as for other actors in the networking, including, partners, providers, and customers. | Adapted from (J. Gordijn et al., 2000; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |
| **Value exchange** | Value exchange represent the interactions for networked enterprises through exchange of value objects. Adapted from the 'value exchange' concept of the e3 value model (J. Gordijn et al., 2000) and 'deliverableflow' (OMG, 2015) concept of VDML. Added since VIP itself does not provide a concrete concept to express the exchange of objects. According to E/2, VIP itself is all about exchanges of objects. However, to be able to model VIP in UML and to be able to express this exchange, a class that explicitly expresses this exchange is necessary. This was also suggested by interviewee E/6. | Adapted from (J. Gordijn, 2003; OMG, 2015; Rasiwasia, 2012) and interview with E/6 |
| **Value goal** | Values that an actor or a network of actors intend(s) to create, offer, capture and/or sustain. | Adapted from (Bouwman et al., 2008; El Sawy & Pereira, 2013; Osterwalder, 2004; S. Solaimani, 2014; Sam Solaimani & Bouwman, 2012) |

## Appendix D VISOR-VIP target metamodel




## Appendix E VIP-ArchiMate target metamodel



## Appendix F Modelling procedure