Ontological Foundations for Strategic Business Modeling: The Case of Value, Risk and Competition

Doctoral Thesis

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Abstract

To cope with increasingly dynamic and competitive markets, enterprises need carefully formulated strategies in order to improve their processes, develop sustainable business models and offer more attractive products and services to their customers. To help them make sense of this complex environment, enterprises resort to an array of strategic business analysis tools and techniques, such as SWOT and the Business Model Canvas. Most of the tools, however, are derived from informally defined social and economic concepts, which hinders their reuse by practitioners. In this thesis, we address this limitation by means of in-depth ontological analyses conducted under the principles of the Unified Foundational Ontology (UFO). In particular, we focus on the notions of value, risk and competition, as these are recurrently employed by many techniques and yet, still suffer conceptual and definitional shortcomings. One main contribution of this thesis is the Common Ontology of Value and Risk (COVER), a reference conceptual model that disentangle and clarifies several perspectives on value and risk, while demonstrating that they are ultimately two ends of the same spectrum. We demonstrate the usability and relevance of COVER by means of two applications in ArchiMate, an international standard for enterprise architecture representation. A second contribution is the Ontology of Competition, which formally characterizes competitive relationships and defines the nature of several competitive relationships arising in business markets.

Keywords. Strategic Business Modeling, Enterprise Modeling, Business Informatics, Strategic Analysis, Value Modeling, Risk Modeling, Business Ontology, Formal Ontology, OntoUML, Unified Foundational Ontology.

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List of Acronyms

AHP Analytic Hierarchy Process.

ARIS Architecture of Integrated Information Systems.

BFO Basic Formal Ontology.

BIM Business Intelligence Model.

BMC Business Model Canvas.

BMO Business Model Ontology.

BPMN Business Process Modeling Notation.

BVP Business Value Proposition.

COSO Committee of Sponsoring Organizations of the Treadway Commission.

COVER Common Ontology of Value and Risk.

DOLCE Descriptive Ontology for Linguistic and Cognitive Engineering.

EA Enterprise Architecture.

EO Enterprise Ontology.

ER Entity–Relationship Model.

GFO General Formal Ontology.

IRM Institute of Risk Management.

ISO International Organization for Standardization.

ISSRM Information System Security Risk Management.

ODP Ontology Design Pattern.

OPL Ontology Pattern Language.

OVP Offering Value Proposition.

OWL Web Ontology Language.

RDF Resource Description Framework.

RiskML Risk Modeling Language.

RM-ODP Reference Model of Open Distributed Processing.

RSO ArchiMate's Risk and Security Overlay.

SABSA Sherwood Applied Business Security Architecture.

SE Software Engineering.

STAMP Systems-Theoretic Accident Model and Processes.

SWOT Strengths, Weaknesses, Opportunities, and Threats.

TOGAF The Open Group Architecture Framework.

UFO Unified Foundational Ontology.

UML Unified Modeling Language.

VAC Value Ascription Component.

VAO Value Ascription Ontology.

VDML Value Delivery Modeling Language.

VP Value Proposition.

VPL Value Pattern Language.

Chapter 1

Introduction

1.1 Context and Motivation

Business markets are nowadays much more complex and dynamic than they used to be. We can see that in the widespread digitization of services, which drastically reduced market barriers and led to a significant increase in competition, in the accelerated advancement of technology, which keeps pushing enterprises to change their business models (Cavalcante, 2013), and due to customers becoming more demanding and value conscious (Sweeney and Soutar, 2001). In order to survive and thrive in this new environment, enterprises need more and more carefully formulated strategies in order to improve their processes, develop more sustainable business models, and offer products and services that are more attractive to their customers. This is no easy task, as the amount of information they have to process is enormous, uncertainties are everywhere, and there are no right answers to be given *a priori*.

To help them make sense of this complex environment so that they can develop successful strategies, enterprises resort to an array of strategic business analysis tools and techniques (Wright et al., 2013). These serve a variety of purposes, such as to drive the generation of strategically relevant information, to support the representation and analysis of complex problems, to make useful connections with different types of information, and to facilitate communication between their stakeholders (Frost, 2003). The list of available tools is long, as each focuses on a particular aspect of enterprises or their economic environments, such as competitive advantage, value chains, and market segments. Examples include SWOT analysis (Pickton and Wright, 1998), which guides enterprises in assessing internal and external factors that may influence strategic decisions, Porter's Five Force Analysis (Porter, 2008b), which evaluates the competitive landscape of industries, and the Business Model Canvas (Osterwalder and Pigneur, 2010), which provides a generic frame for enterprises to describe and communicate their business models.

The vast majority of the tools and techniques, however, share a common limitation: they are built on top of informally defined theories about the economic and social reality. This means that they put forth a number of concepts without accurately characterizing them. Thus, practitioners have to make their own interpretations about the key concepts proposed in such tools, which may result in distorted usage, and subsequently, them not obtaining the expected results (Jarzabkowski and Wilson, 2006). This issue, in fact, is pervasive in the field of management sciences, as evinced by the sheer number of publications discussing conceptual and definitional issues regarding many important notions (e.g. strategy (Mintzberg et al., 2005), strategy practice (Jarzabkowski and Paul Spee, 2009), business model (Osterwalder and Pigneur, 2004; Timmers, 1998), competitive advantage (Powell, 2001), risk (Aven et al., 2011; Kjellmer, 2007), value and value co-creation (Bowman and Ambrosini, 2000; Boztepe, 2007; Sánchez-Fernández and Iniesta-Bonillo, 2006), competition (Gur and Greckhamer, 2018), brand (Grassi, 1998), personas (Junior and Almeida, 2018), customer loyalty (Dick and Basu, 1994), market and industry (Nightingale, 1978), service (Nardi et al., 2015)). In most cases, the story is roughly the same. A new concept is proposed without being properly characterized. It nonetheless becomes popular among researchers and practitioners, who then start to argue about what the concept really means and how it should be used. This leads to a number of (often conflicting) definitions, which end up hindering communication and adoption of the proposed concept in practice.

To make strategic theories and techniques more concrete and directly applicable in practice, a more recent stream of research has focused in the development of modeling languages and methods, which gave rise to the field of strategic business modeling. The general approach has been to define a (semi) formal language that reflects concepts and relations pertaining to a particular aspect of an enterprise and/or its environment, so that models built using the language could assist strategy workers in performing manual or automated analysis. Well known examples include i* (Yu et al., 2011), Business Intelligence Model (BIM) (Horkoff, Barone, et al., 2014), and *e*^{3}*value* (Gordijn and Akkermans, 2003). It has been demonstrated that these strategic business modeling languages have a lot of potential in supporting strategy workers (Annosi et al., 2008; Barone et al., 2012; Derks et al., 2018; Gordijn, De Leenheer, et al., 2011). They, however, still suffer from the same problem as the classical strategic and business analysis techniques–they lack sound and rigorously defined conceptual foundations about the domains they represent.

In this thesis, we focus exactly on this issue. However, instead of investigating the conceptual foundations of a particular language or technique, we focus on three domains that crosscut several of them, namely those of value, risk and competition. The reason why we choose these domains is two-fold. First, because of their ubiquitous presence. The notion of value appears in many contexts, such as value chains (Porter, 2001), value propositions (Osterwalder and Pigneur, 2010), value co-creation (Vargo et al., 2008). The number of risk management techniques, guides and standards just keeps growing (American Institute of Chemical Engineers and Energy Institute, 2018; COSO, 2004; IRM, 2002; ISO, 2018; Lund et al., 2010; Sadgrove, 2016; Siena et al., 2014). Competitor identification is still an issue for many companies (Krzyżanowska and Tkaczyk, 2013; Ng et al., 2009) and scholars still debate on the nature and types of competitors (DeSarbo et al., 2006; Peteraf and Bergen, 2003). Second, because they are particularly complex and have been the source of much debate in recent years (Aven et al., 2011; Bowman and Ambrosini, 2000; Boztepe, 2007; Gur and Greckhamer, 2018; Kjellmer, 2007; Sánchez-Fernández and Iniesta-Bonillo, 2006), which reinforces the need for in-depth conceptual analysis.

1.2 Research Objectives

In order to address the aforementioned research challenges, we define the general objective (GO) of this thesis as *to define sound conceptual foundations for the modeling of strategic business information, particularly that which is related to value, risk and competition, in order to support organizations in formally representing and reasoning with it.* From this general objective, we define the following specific objectives (SO):

- SO.1 Define sound conceptual foundations for value modeling that can explain which, how, and why things have value, such that it can be used to characterize the notion of value propositions.

SO.2 Define sound conceptual foundations for risk modeling that can disentangle and harmonize different perspectives on risk found in the literature.

SO.3 Define sound conceptual foundations for modeling business competition, such that it supports competitor identification and classification.

SO.4 Apply the reference ontologies to an existing modeling framework in order to (i) reveal potential semantic limitations, and (ii) improve its modeling power regarding the representation of strategically relevant information.

1.3 Methodological Aspects

Our main goal in this thesis is to develop well-founded ontological accounts for socially constructed concepts. To achieve that, we adopt the methodology discussed below.

1.3.1 Ontological Analysis Process

Over the years, a significant number of ontology engineering methodologies has been proposed, yet none has evolved into a *de facto* standard in the field (Corcho et al., 2003; Sure et al., 2006). Most of these methodologies, such as NeOn (Suárez-Figueroa et al., 2012) and Ontology 101 (Noy and McGuinness, 2001), view ontologies as mere data models for linking data on the web and performing rule-based reasoning, and thus, propose processes to develop and metrics to evaluate only this kind of artifact. This, however, is not the what we want to develop in this thesis. Our goal is to develop ontologies in the sense of reference conceptual models, which are meant to primarily support humans in tasks such as meaning negotiation and consensus establishment (Guizzardi, 2007).

The only methodology that recognizes this distinction between an ontology as a data model and an ontology as a reference conceptual model is SABiO (Falbo, 2014). In fact, it proposes a process that starts with the development of a reference conceptual model, which is then used to develop a data model. In this thesis, we follow a customized version of SABiO. We adhere to the general steps proposed in the methodology (up to the point of developing a reference ontology), but we execute them following strategies that are better suited to our particular context and needs.

These general steps are depicted in Figure 1.1. The process starts with the specification of the purpose of the ontology and then enters an iterative loop of knowledge acquisition, ontology formalization, and ontology evaluation. In the following subsections, we elaborate on each step by discussing its goals, expected outputs and the strategies we adopted to perform them.

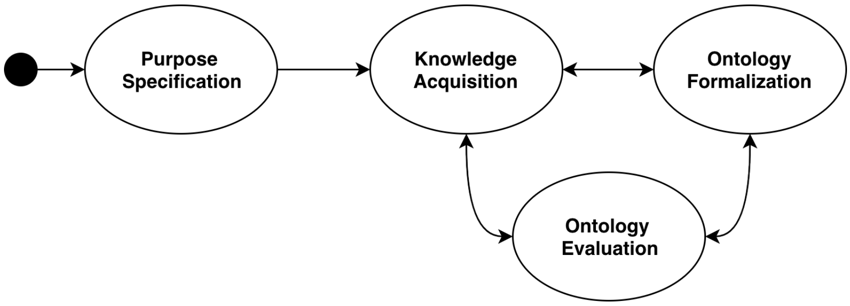

Figure 1.1: Overview of the ontology development method.

Purpose Specification

The first step in the ontology development process is to specify why the ontology is being built. In the beginning, the answer to this question is usually a general statement that roughly delimits the domain of interest and identifies the main goals driving the development of the ontology. An example would be “We want to develop an ontology about business models to support entrepreneurs in representing the business logic of their enterprises, so that these models can more easily be communicated and properly evaluated”.

In the case of core ontologies, i.e., those that describe general domains (e.g. service, value) that crosscut several others, one can identify recurrent goals that motivate their development. These include disentangling and harmonizing multiple meanings ascribed to a term or serving as a conceptual foundation to facilitate the development of ontologies on more specific domains (e.g. public services, medical services, value proposition, value co-creation).

Motivation statements should be explored to elicit a number of problems the ontology is meant to help users solve, i.e. actual valuable ways in which the ontology can support its intended users. In the business model example, such problems could be assessing if a business model is sustainable, analyzing its scalability, or understanding how easy others can replicate it. In a way, these problems resemble the motivating scenarios proposed by Grüninger and Fox (1995), one of the first methodological proposals made in the field and that heavily influenced those that followed it.

Note that we do not further refine ontology requirements into "competency questions", as usually proposed in most methodologies. A competency question is a query that an ontology, seen a populated database, should be able to answer (Grüninger and Fox, 1995). Since no granularity level is specified, in practice, these questions end up being extensive lists of look up queries that have little use to actually delimiting the scope of an ontology. Take for instance, some prototypical examples of competency question: "What is the market segment associated to the value proposition x?", "How many channels are defined for business model y?", and "Which key partners are included in this business model?". We choose not to list these questions because: (i) it is impossible to come up with them without already committing to a particular view on the domain (e.g. that a market segment is associated to a value proposition), which is something that we either cannot or do not want to do at the beginning of an ontological analysis; and (ii) actually listing all these questions is basically describing the ontology in natural language and thus, nothing is achieved by doing it.

Knowledge Acquisition

The second step in the ontology development process is to acquire knowledge about the domain. This means understanding how domain experts would solve the problems previously elicited, identifying the most prominent theories on the domain, uncovering the most important terms and their respective definitions, and so on.

One way in which this can be done is by surveying relevant literature on the topic. There are three types of publications that are particularly useful in this context. First, there are those that propose theories (sometimes called "conceptual frameworks") to describe the domain of interest. This type of publication usually introduces a number of concepts and definitions that can provide a lot of insight into how experts understand the domain[1]. For the business model domain, an example is the paper by Timmers (1998), in which the author defines a

[1]When searching for conceptual works, it is worthy to explore different fields in which a particular concept might be used. Take for instance the notion of competition. Even if our goal would be to explore it from a business perspective, investigating relevant literature from other fields (e.g. ecology and psychology) might provide further insights into its ontological nature.

business model as “an architecture for the product, service and information flows, including a description of the various business actors and their roles” and then proposes a taxonomy to classify different types of business models. A second type of publication is one that introduces a proper ontology to conceptualize the domain (or a closely related one). These are obviously extremely useful, but they are not always available. For the business models domain, a famous example is the Business Model Ontology (Osterwalder and Pigneur, 2004). Lastly, a third type of publication is one that proposes modeling languages to represent the domain of interest. Since every modeling language makes an ontological commitment (even if not explicitly), they can also help one to identify relevant concepts and relations.

When encountering a domain term that seems to convey multiple meanings, a useful strategy is to look for linguistic evidence that exemplify their usage. To demonstrate what we mean, let us consider an example discussed by Dölling (2018). If we can say that “The book is full of coffee stains”, it means that *book* can refer to a physical object, as only physical things can have coffee stains. Nonetheless, if we can also say that “The book turned out to be very uninteresting”, *book* can also refer to an information object encoded in the physical thing.

A third strategy (and undoubtedly the fastest) is to interact with domain experts, such as researchers and practitioners. By conducting interviews and exploring cases, knowledge about a domain can be obtained much quicker.

Note that the knowledge acquisition step does not necessarily yield a concrete artifact as an output, as the main goal at this stage is to learn about the phenomena of interest. Nonetheless, it might be useful to assemble a list of concepts recurrently encountered across multiple sources or to sketch a simple mind map connecting them.

Ontology Formalization

The ontology formalization step consists in using a formal language to model domain concepts, along with their interrelations and properties, such that they form an ontology that can support the intended uses elicited in the beginning of the process. In this thesis, our ontology representation language of choice is OntoUML (for more details, see subsection 1.3.2).

Choosing OntoUML as a modeling language means that we follow a foundational approach for ontology representation. In this type of approach, domain concepts are defined in terms of broader concepts specified in a foundational ontology, either by specializing or instantiating them. A foundational ontology, as defined by Borgo and Masolo (2009), is one that: (i) has a large scope, (ii) is highly reusable across different modeling scenarios, (iii) is philosophically and conceptually well-founded, and (iv) is semantically transparent and richly axiomatized. Examples include the Unified Foundational Ontology (UFO) (Guizzardi, Wagner, Almeida, et al., 2015), from which OntoUML is derived, but also the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) (Borgo and Masolo, 2009), the General Formal Ontology (GFO) (Herre, 2010), and the Basic Formal Ontology (BFO) (Arp et al., 2015).

As argued and demonstrated in the literature, grounding a domain ontology in a foundational one has a number of advantages (Arp et al., 2015; Guizzardi, 2006; Guizzardi, Baião, et al., 2010; Keet, 2011; Schulz, 2018), including increase in quality, precision and expressiveness. One particularly important advantage is that it provides a conceptual basis from where to start the domain analysis. For instance, when developing an ontology about football, one can reuse the notion of event to define a match, and that of an endurant to define a stadium. In addition to these generic concepts, foundational ontologies define a number of meta-properties one can go through to investigate the ontological nature of a domain concept, such as rigidity and dependency. For instance, the concept of football player is anti-rigid, as it only contingently characterizes its instances–a person can become a football player given a relational context and can cease to be so while maintaining her identity.

Notice that it is natural that, while building the ontology, a number of questions about the domain arise. Thus, the ontology formalization step often simultaneously occurs with that of knowledge acquisition.

Ontology Evaluation

Ontologies can be evaluated according to multiple criteria, each of which can be assessed using a particular set of methods and tools (Vrandečić, 2009). Three of them are particularly relevant for this thesis, namely accuracy, precision, and completeness. Accuracy regards whether an ontology appropriately covers the domain of interest by providing enough concepts to distinguish between desired and undesired state-of-affairs. For an ontology to be accurate, it does not need to contain every imaginable concept of a domain, but those that are necessary for the ontology to fulfill its purpose. To exemplify, let us consider an ontology of genealogy. Such an ontology will have accuracy issues if the only relation it contains is *ancestor-of*, as one would not be able to differentiate parents from grandparents. The last two metrics, precision and completeness, regard how well an ontology actually captures the domain of interest. In a maximally precise ontology, every instantiation (logical model) corresponds to an intended domain structure, whilst in a maximally complete ontology, every intended domain structure is a model of the ontology. In the genealogy case, an ontology would not be precise if it allows a person to be its own ancestor, while it would be incomplete if it does not describe state-of-affairs in which a person has multiple offspring.

There are several ways in which each of these three criteria can be assessed. In this thesis, we measure accuracy by means of cases we want to ontology to be able to handle. For a genealogy ontology, for instance, we would use a number of differently structure families as cases. To assess precision and completeness, we can leverage a number of engineering tools to help us. Particularly for OntoUML, we use visual model simulation and ontological anti-patterns. *Visual model simulation* is an approach to automatically generated possible instances of an ontology in order to expose the consequences of modeling decisions (Benevides et al., 2010). By generating the allowed instances of our ontologies, we can confront them with the desired states-of-affairs, ruling out undesired instances. We can also intentionally request examples of instantiations we expect the ontology to allow. *Ontological anti-patterns* are recurrent modeling structures that, albeit produce syntactically valid models, are prone to be the source of domain misrepresentations (Sales and Guizzardi, 2015). A support for visual model simulation and a library of ontological anti-patterns are available in the Menthor Editor (Moreira et al., 2016), an open-source platform for designing, evaluating and implementing ontologies using OntoUML.

1.3.2 Ontology Representation Language

As we previously mentioned, we choose OntoUML as the ontology representation language in this thesis. OntoUML is a general purpose ontology-driven conceptual modelling language designed to comply with the ontological distinctions with the Unified Foundational Ontology (UFO) (Guizzardi, 2005).

Our motivation for choosing OntoUML is three-fold. First, we choose OntoUML for its expressivity. As argued in (Guizzardi, 2007), when building a reference ontology, one needs a language that commits to a rich foundational ontology so that one can create strongly axiomatized ontologies that approximate as well as possible to the ideal ontology of the domain. This expressivity is preferred over computational tractability, since reference ontologies are meant to be used by humans and not machines. As demonstrated in the literature, UFO and OntoUML provide enough constructs to accurately describe complex social domains, while supporting the clarification and disambiguation of overloaded terms. Examples include ontologies for services (Nardi et al., 2015), legal relations (Griffo et al., 2018), resources and capabilities (Azevedo, Iacob, et al., 2015), organizational structures (Pereira and Almeida, 2014), requirements (Guizzardi, Li, et al., 2014), and communities (Almeida and Guizzardi, 2013). Second, because OntoUML is a visual language, as it has been originally designed as a profile of the Unified Modeling Language (UML). This facilitates communication about the concepts defined in an ontology with domain experts, which is particularly relevant when developing the ontology, but also with potential users. Third, because the "OntoUML Toolkit" contains a number set of tools to facilitate the ontology engineering process, such as ontological design patterns (Guizzardi, Graças, et al., 2011) and anti-patterns (Sales and Guizzardi, 2015), visual model simulation (Benevides et al., 2010), and transformations for codification technologies (Barcelos et al., 2013; Rybola and Pergl, 2016).

1.4 Structure of the Dissertation

This thesis is organized in a *paper-based structure*, i.e. the core of this thesis (chapters 2-6) consists of a collection of research papers written by the author and that are published in international peer-reviewed venues. Chapters 2, 3 and 6 present ontological analysis on the domains of value, risk and competition, whilst chapters 4 and 5 present their application in ArchiMate.

Chapter 1. Introduction

In the introductory chapter, we contextualize and motivate our research project. We describe the research questions that guided its development, discuss the methodology we followed and list the works published while the author was conducting his doctoral research.

Chapter 2. An Ontological Analysis of Value Propositions

In this chapter, we focus on one of the core aspects of a business model: its value proposition. We present an ontological analysis that starts from the general notion of (use) value ascription and is incrementally developed to characterize the concept of value proposition. We discuss the extensive literature on the topic, from the introduction of the concept of value proposition by Lanning and Michaels in the late 1980s, to the work that mostly popularize its adoption in the entrepreneurial world–the Business Model Canvas–and its application in enterprise modeling frameworks. In our analysis, we argue that value is relative, experiential and contextual, and that it can only be assessed by referring to goals. The result of this analysis is formalized in an OntoUML reference model, whose use we demonstrate by means of an illustrative case study in the domain of on-demand video streaming services.

This chapter was published in the proceedings of the *21st IEEE International Enterprise Distributed Object Computing Conference (EDOC'17)* (Sales, Guarino, et al., 2017a), in which it received the Best Student Paper Award and an invitation for an extended version to be published in a special issue of the Information Systems journal.

Chapter 3. The Common Ontology of Value and Risk

In this chapter, we extend our initial analysis on value to explain risk, arguing that risk ascription is a particular case of value ascription. Our argument is based on a number of similarities between the two notions, such as their experiential and contextual nature, their grounding on goals, and the role played by uncertainty in their definition. From this analysis, we introduce the Common Ontology of Value and Risk (COVER), in which we disentangle and formally characterize three perspectives on risk, that of an event, a quality, and a relationship. We also discuss a number of implications from viewing value and risk as two ends of the same spectrum, the most relevant one being that many of the developments made for risk modeling frameworks could be leveraged in those for value modeling.

This chapter was published in the proceedings of the *37th International Conference on Conceptual Modeling (ER'18)* (Sales, Baião, et al., 2018).

Chapter 4. A Pattern Language for Value Modeling in ArchiMate

This chapter introduces the Value Pattern Language (VPL) for ArchiMate. It addresses the well-recognized inadequate support for value modeling in ArchiMate by proposing a pattern language derived from the Common Ontology of Value and Risk. VPL is designed in conformance with the ArchiMate 3.0.1, the latest version of the standard, meaning it does not introduce any new construct to the language, but only specializes existing ones when necessary. As a pattern language, VPL introduces a catalogue of patterns and a process on how to combine them. The use of VPL is demonstrated by means of an illustrative case that models how customers of a low-cost airline perceive value by traveling with such a company.

This chapter has been accepted in the *31st International Conference on Advanced Information Systems Engineering (CAiSE'19)* (Sales, Roelens, et al., 2019).

Chapter 5. Ontological Analysis and Redesign of Risk Modeling in ArchiMate

This chapter investigates the real-world semantics underlying the risk modeling fragment of ArchiMate's Risk and Security Overlay (RSO). This is done by means of an ontological analysis that leverages the Common Ontology of Value and Risk, in which we reveal a number of semantic limitations in the current state of the overlay, including cases of ambiguous and missing constructs. Building on this analysis, we propose a redesign of the overlay that is more expressive and precise to model risks in the context of enterprise architecture, demonstrating these improvements using the examples proposed in the original overlay.

This chapter was published in the proceedings of the *22nd IEEE International Enterprise Distributed Object Computing Conference (EDOC'18)* (Sales, Almeida, et al., 2018).

Chapter 6. Ontological Foundations of Competition

In this chapter, we focus on the third strategic aspect covered in this thesis: competition. We address the conceptual complexity and semantic overload involving this notion through an ontological analysis that leverages theories from marketing, strategic management, ecology, psychology and cognitive sciences. This analysis, the very first of its kind in the literature, yields a well-founded reference ontology of competition specified in OntoUML. We then apply this general ontology to formally characterize three types of competitive relationships that arise in business environments, namely market-level, firm-level and potential competition.

This chapter was published in the proceedings of the *10th International Conference of Formal Ontology and Information Systems (FOIS)* (Sales, Porello, et al., 2018). It received an invitation for an extended version to be published in a special issue of the Applied Ontology journal.

Chapter 7. Conclusions

In the concluding chapter, we summarize the contributions of this thesis, while arguing how they satisfy the goals we established for this doctoral research project. We also discuss why and how these contributions are relevant for both researchers and practitioners working in the fields of enterprise modeling, enterprise architecture and business informatics. We finalize the chapter by revisiting the general limitations of our work and elaborating on future research perspectives.

1.5 Publications

In this section, we list all the works published by the author during his doctoral research. In the Core Publications section, we list those that directly contribute to this thesis, whilst in the Additional Publications section, those that do not.

1.5.1 Core Publications

In Peer-Reviewed International Conference Proceedings

- T. P. Sales, N. Guarino, G. Guizzardi, and J. Mylopoulos (2017a). "An Ontological Analysis of Value Propositions". In: *21st IEEE International Enterprise Distributed Object Computing Conference (EDOC)*. ed. by S. Hallé, R. Villemaire, and R. Lagerström. IEEE, pp. 184–193. DOI: `https://doi.org/10.1109/EDOC.2017.32`
- T. P. Sales, F. Baião, G. Guizzardi, N. Guarino, and J. Mylopoulos (2018). "The Common Ontology of Value and Risk". In: *37th International Conference on Conceptual Modeling (ER)*. ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 121–135. DOI: `https://doi.org/10.1007/978-3-030-00847-5_11`

- T. P. Sales, D. Porello, N. Guarino, G. Guizzardi, and J. Mylopoulos (2018). "Ontological foundations of competition". In: *10th International Conference on Formal Ontology in Information Systems (FOIS)*. vol. 306. IOS Press, pp. 96–109. DOI: http://doi.org/10.3233/978-1-61499-910-2-96
- T. P. Sales, J. P. A. Almeida, S. Santini, F. Baião, and G. Guizzardi (2018). "Ontological Analysis and Redesign of Risk Modeling in ArchiMate". In: *22nd IEEE International Enterprise Distributed Object Computing Conference (EDOC)*. IEEE, pp. 154–163. URL: http://doi.org/10.1109/EDOC.2018.00028
- (To be published) T. P. Sales, B. Roelens, G. Poels, G. Guizzardi, N. Guarino, and J. Mylopoulos (2019). "A Pattern Language for Value Modeling in ArchiMate". In: *31st International Conference on Advanced Information Systems Engineering (CAiSE)*. Springer

In Peer-Reviewed International Workshops

- T. P. Sales, N. Guarino, G. Guizzardi, and J. Mylopoulos (2017b). "Towards an Ontological Analysis of Value Propositions". In: *11th International Workshop on Value Modeling and Business Ontologies (VMBO)*. CEUR-WS.org
- T. P. Sales, N. Guarino, G. Guizzardi, and J. Mylopoulos (2018). "Towards an Ontology of Competition". In: *12th International Workshop on Value Modeling and Business Ontologies (VMBO)*. ed. by J. Gordijn and E. Proper. CEUR-WS.org, pp. 64–73

1.5.2 Additional Publications

In Peer-Reviewed International Conference Proceedings

- T. P. Sales and G. Guizzardi (2017). ""Is It a Fleet or a Collection of Ships?": Ontological Anti-patterns in the Modeling of Part-Whole Relations". In: *21st European Conference on Advances in Databases and Information Systems (ADBIS)*. ed. by M. Kirikova, K. Nørvåg, and G. A. Papadopoulos. Springer, pp. 28–41. DOI: https://doi.org/10.1007/978-3-319-66917-5_3
- G. Guizzardi, C. M. Fonseca, A. B. Benevides, J. P. A. Almeida, D. Porello, and T. P. Sales (2018). "Endurant Types in Ontology-Driven Conceptual Modeling: Towards OntoUML 2.0". In: *37th International Conference on*

Conceptual Modeling (ER). ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 136–150. DOI: https://doi.org/10.1007/978-3-030-00847-5_12

- N. Guarino, T. P. Sales, and G. Guizzardi (2018). "Reification and Truthmaking Patterns". In: *37th International Conference on Conceptual Modeling (ER)*. ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 151–165. DOI: https://doi.org/10.1007/978-3-030-00847-5_13

In Peer-Reviewed International Workshops

- J. L. R. Moreira, T. P. Sales, J. Guerson, B. F. B. Braga, F. Brasileiro, and V. Sobral (2016). "Menthor Editor: An Ontology-Driven Conceptual Modeling Platform". In: *2nd Joint Ontology Workshops (JOWO)*. ed. by O. Kutz and S. de Cesare. Vol. 1660. CEUR-WS.org
- G. Guizzardi and T. P. Sales (2017). ""As Simple as Possible but not Simpler": Towards an Ontology Model Canvas". In: *3rd Joint Ontology Workshops (JOWO)*. ed. by S. Borgo, O. Kutz, F. Loebe, and F. Neuhaus. Vol. 2050. CEUR-WS.org
- N. Guarino, G. Guizzardi, and T. P. Sales (2018). "On the Ontological Nature of REA Core Relations". In: *12th International Workshop on Value Modeling and Business Ontologies (VMBO)*. ed. by J. Gordijn and E. Proper. CEUR-WS.org, pp. 89–98
- M. Verdonck, T. P. Sales, and F. Gailly (2018). "A Comparative Illustration of Foundational Ontologies: BORO and UFO". in: *6th International Workshop on Ontologies and Conceptual Modeling (Onto.Com)*. Ed. by Gailly, F. et al. Vol. 2205. CEUR-WS.org

In Book Chapters

- T. P. Sales and G. Guizzardi (2016). "Anti-patterns in Ontology-driven Conceptual Modeling: The Case of Role Modeling in OntoUML". in: *Ontology Engineering with Ontology Design Patterns: Foundations and Applications*. Ed. by A. Gangemi, P. Hizler, K. Janowicz, A. Krisnadhi, and V. Presutti. Studies on the Semantic Web. IOS Press. Chap. 8, pp. 161–187. DOI: https://doi.org/10.3233/978-1-61499-676-7-161

Chapter 2

An Ontological Analysis of Value Propositions

In competitive markets, companies need well-designed business strategies if they seek to grow and obtain sustainable competitive advantage. At the core of a successful business strategy there is a carefully crafted value proposition, which ultimately defines what a company delivers to its customers. Despite their widely recognized importance, there is however little agreement on what exactly value propositions are. This lack of conceptual clarity harms the communication among stakeholders and the harmonization of current business strategy theories and strategy support frameworks. Furthermore, it hinders the development of systematic methodologies for crafting value propositions, as well as adequate support for representing and analyzing them. In this paper, we present an ontological analysis of value propositions based on a review of most relevant business and marketing theories and on previous work on value ascription, grounded in the Unified Foundational Ontology (UFO). Our investigation clarifies how value propositions are different from value presentations, and shows the difference between value propositions at the business level from those related to specific offerings.

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2.1 Introduction

In competitive markets, companies need well-designed business strategies if they seek to grow and obtain sustainable competitive advantage. Crafting a business strategy, however, is a complex and laborious activity, since one must consider various internal and external factors and make important decisions that will define how the company operates in its market. This strategic process includes understanding what customers need, designing the value to be delivered, choosing revenue models, among other decisions.

There are various theories and frameworks for supporting strategic and business analysis. These include simple strategic models (e.g. SWOT), generic strategic frameworks (Treacy and Wiersema, 1993), and tools and methodologies for designing business models (Osterwalder and Pigneur, 2010) and value propositions (Barnes et al., 2009). Most proposals, however, put forth concepts without properly defining them. Such informality hinders the use of these proposals in practice, for some concepts can be interpreted in different, and potentially contradicting, ways. It also compromises the development of computational tools to support strategic and business analysis, for these require a precise semantics for the notions being represented.

In this paper, we analyze the nature of a crucial component of a business strategy, the value proposition (VP). The conceptual confusion and semantic overloading of the *term* VP is clearly recognized in the literature (Anderson and Narus, 2006; Ballantyne, Frow, et al., 2011; Barnes et al., 2009), as well as its importance and increasing adoption in practice (Frow and Payne, 2008). The intuition behind a value proposition is that it describes what a company delivers to its customers. In other words, it is the ultimate answer for why customers choose to hire their services or buy their products. Carefully crafting a value proposition aids companies in understanding their customers, positioning themselves in the market, and identifying relevant competition.

The main contribution of this paper is to provide an ontological analysis and conceptual clarification of the notion of value proposition. This project is carried out by employing a foundational ontology, namely, the Unified Foundational Ontology (UFO) (Guizzardi, 2005), which we briefly present in section 2.2. The analysis uses, as theoretical reference for domain knowledge, various contributions to the study of value propositions from strategic management, marketing science, and e-business modeling. We discuss these contributions in section 2.3.

Our analysis builds upon previous ontological work on the process of value ascription (Andersson, Guarino, et al., 2016), which we revisit and extend in section 2.4. In the ontological analysis *per se*, described in section 2.5, we differentiate value propositions from offerings and value presentations, and also distinguish between the value proposition of a whole business and the value proposition of a single offering. Such distinctions are used then to characterize different quality requirements for value propositions found in the literature, such as profitability and clarity. In section 2.6, to validate and demonstrate the contribution of our value proposition ontology to the modeling practice, we apply it to model the value propositions of a well-known service provider (Netflix). We finalize the paper in section 2.7 with some final considerations and directions for future works.

2.2 Ontological Foundations

UFO is an axiomatic formal theory based on theories from analytic metaphysics, philosophical logics, cognitive psychology and linguistics, which is a result of an integration and re-visitation of previous foundational approaches such as OntoClean (Guarino and Welty, 2009), DOLCE (Borgo and Masolo, 2009) and GFO (Herre, 2010). UFO is the theoretical basis of OntoUML, a language for ontology-driven conceptual modeling that has been successfully employed in a number of industrial projects in several different domains, such as petroleum and gas, complex digital media management, off-shore software engineering, telecommunications, retail product recommendation, and government (Guizzardi, Wagner, Almeida, et al., 2015). A recent study shows that UFO is the second-most used foundational ontology in conceptual modeling and the one with the fastest adoption rate (Verdonck and Gailly, 2016). Moreover, the study also shows OntoUML is among the most used languages in ontology-driven conceptual modeling, together with UML, (E)ER, OWL (W3C, 2012) and BPMN (OMG, 2011). Finally, the study shows that UFO is perceived by modelers as particularly useful when analyzing notions pertaining to social and intentional aspects of reality.

UFO has been successfully employed to analyze, (re)design and integrate several different modeling languages and standards (Guizzardi, Wagner, Almeida, et al., 2015). In particular, in the area of enterprise modeling, it has been used to analyze the ontological nature of basic notions such as those of *organizational* *role*, *motivation*, *capacity* and *service* in Archimate, *business process* and *organizational structure* in ARIS (Scheer, 2000), and other aspects of enterprise modeling languages and standards ranging from BPMN to RM-ODP (ISO/ITU-T, 1995). Moreover, UFO and OntoUML have been employed to promote conceptual clarification and develop core ontologies in domains such as services (Nardi et al., 2015) and micro-economics (Andersson, Guarino, et al., 2016). Therefore, we shall adopt UFO and OntoUML in this paper.

We start our overview of UFO with a very fundamental distinction made by the ontology, the separation of universals and individuals. Universals represent types of things (e.g. Company, Employee), whilst individuals represent particular things (e.g. Netflix, Mary). Universals are characterized by means of the OntoClean meta-properties, such as those concerning *rigidity*. Rigid universals are those that are necessarily (in the modal sense) instantiated by their instances. Examples include the universals person, dog, and car (e.g., no person can cease to be a person and keep existing). Anti-rigid universals, on the other hand, are those whose instances contingently instantiate them, such as student, employee, and customer (e.g., students can cease and become students while still existing as people). A third type of universals is what is termed semi-rigid universals. Semi-rigidity characterizes universals that are necessarily instantiated by some of its instances and contingently instantiated by others. A typical example is musical artist, which necessarily characterize music groups and contingently characterizes persons.

The metamodel of the OntoUML language was designed to reflect the ontological distinctions put forth by UFO. For this reason, the distinctions of the latter are reflected as modeling primitives (mostly stereotyped classes and relations) of the former. In OntoUML, the stereotypes «phase» and «roleMixin» represent the respective ontological types of anti-rigid universals: phases are anti-rigid universals with an associated intrinsic contingent instantiation condition (e.g., being a teenager is being a person who contingently is in a certain age range); roles are anti-rigid universals with an associated relation contingent instantiation condition (e.g., being a husband is being a person who contingently participates in a marriage relation). Furthermore, the stereotype «mixin» is used to represent semi-rigid universals. Finally, the stereotype «category» is used to represent rigid universals.

A second important distinction in UFO is the one between two fundamentally different types of individuals: endurants and perdurants. The basic intuition is that endurants, commonly referred to as objects, are wholly present whenever they are present (e.g. a person, a company). Perdurants (or events), on the other hand, are not present in time, but occur in time (e.g. a wedding, a lunch, a business process).

Endurants in UFO can be either substantial individuals or aspects (also termed moments). Substantials are individuals that can exist by themselves, i.e., they do not ontologically dependent on other individuals in order to exist. Aspects, in contrast, are individuals that can only exist by inhering in other individuals. Think on how the marriage between Marshall and Lily can only exist if both Marshall and Lily exist, or how Robin's headache can only exist if Robin exists. Aspects can be *intrinsic* when they existentially depend on a single individual (e.g., Robin's headache; Barney's Dengue Fever) or *relational*, when they existentially depend on a multitude of individuals (e.g., Marshall and Lily's marriage; Barney's employment at Goliath National Bank; Ted's enrollment at Wesleyan University).

In particular, we shall rely on a recent re-visitation of the notion of *relationship* (Guarino and Guizzardi, 2016), which plays a fundamental role in our analysis. In UFO, most relationships (the so-called *descriptive* ones) are *reified*, that is, they are considered as elements of the domain of discourse, modeled as clusters of relational aspects termed *relators*. A relationship is considered as the truth-maker of a relation, i.e., a relation holds because a relationship exists. Take for instance the relation between a student and an university. Why is it true that a particular students studies at a particular university? Because there is an enrollment relationship (a relator) that sustains this relation. An important consequence of relationships reification in an ontology is the possibility to describe how they can change through time. Reified relationships have been shown to be fundamental for modeling social and enterprise phenomena such as services (Nardi et al., 2015), contracts (Griffo et al., 2016) and value ascription (Andersson, Guarino, et al., 2016; Gailly et al., 2016).

In UFO, intrinsic aspects are further classified into qualities and modes. The former account for those aspects whose descriptions require the association with values in a conceptual space, such as the weight of a person, or the color of a car. The latter refer to those that do not need such structure, such as the desire of a person or disease of an animal. These concepts are represented in OntoUML by means of the stereotypes «Quality» and «Mode», which stand respectively for quality kinds and mode kinds.

Finally, a clarification is needed concerning the use of stereotypes in OntoUML. The semantics of a stereotype is that of a metaclass, so if a class has the stereotype «Role» it means that such a class is an instance of the role metaclass. So, a particular class of relators should have «Relator *Kind*» as a stereotype, and, similarly, classes of modes, qualities, and events should have «Mode *Kind*» as a stereotype, and so on. However, in OntoUML the term *kind* is omitted for reasons of visual compactness.

2.3 Previous Work on Value Proposition

The concept of value proposition (hanceforth VP) was proposed by Lanning and Michaels (1988), who defined it as a promise a company makes to a customer segment to deliver some value, which in turn is understood as benefits minus price. They exemplified the concept using Domino's, an American pizza restaurant chain. Domino's value proposition was made towards convenience-oriented pizza lovers (the customer segment) and consisted in a guaranteed speedy deliver of consistently good-tasting pizzas (the benefits), whose price would be 10-20% more than that of their competitors.

Value propositions are the ultimate answer for why customers engage in a business relationship with one company as opposed to another—customers choose offerings for which they perceive a higher value. This claim suggests that market leaders gain their position not just by having a better product or a superior marketing strategy, but by delivering a superior value proposition.

Consciously choosing a VP was not the only thing defended by Lanning and Michaels in their seminal work. They also emphasized the importance of echoing it throughout the company. By making the proposed value clear and communicating it to the company, top management could understand what contributed or harmed the creation of value, including business processes, sales channels, and service/product features. This discovery would help the company redesign itself and its offerings to maximize the value being created to their customers.

Since its creation, the concept of VP has been extended and analyzed by several researchers. An insightful contribution was made by Kambil et al. (1996), who extended the original idea by further detailing the main parts of a VP, namely benefits, costs, and customers.

As a first contribution, the authors proposed two additional dimensions of value-reducing factors besides price, namely *risk* and *effort*. To exemplify why risk reduces value, suppose two online retailers offer the same clothes at the same price. One of them allows you to return purchased items in case you are not happy when you try them on, while the other does not. The first company offers a superior value because it reduces the risk of customers ending up with unwanted clothes. To illustrate why effort reduces value, consider two companies that sell the same phones at the same price. The first is an e-commerce company that allows customers to purchase from the comfort of their homes; the second a physical store that requires customers to reach it in order to buy something. For busy people, the low effort of buying from the e-commerce company increases the value of its offering.

As a second contribution, Kambil et al. (1996) classified product/service attributes according to the way they match customers' needs. This resulted in four categories. *Basic attributes* are those necessary to satisfy the basic customer's needs (e.g., for a restaurant, serving food). *Expected attributes* are those that typically the competition offers (e.g., for a restaurant, allowing reservations). *Desired attributes* are those the customer would want to have, but are incompatible with the desired price range (e.g., imported wine at a cheap price). Finally, *unanticipated attributes* are those customers would appreciate but are not typically aware of.

As a third contribution, the authors distinguished between four roles played by customers. The *buyer role* is the one played by an actor responsible for determining needs, assessing alternatives and making the purchase; the *user role* is played by the actor that will actually use the product/service; the *co-creator role* is played by those actors that collaborate with suppliers to actually produce the value; finally, the *transferer role* is played when products are disposed of, including actions such as discarding, recycling and reselling. These roles could be played by the same actor (e.g. a person buying a jacket for herself) or by different ones (e.g. a mother buying a happy meal for her kids). The usefulness of distinguishing these roles lies on accounting how customers playing these different roles might ascribe different values to the same product/service.

This revisited view on value propositions influenced the development of the Business Model Ontology (BMO) (Osterwalder and Pigneur, 2004), which is the conceptual basis for the popular Business Model Canvas (BMC) (Osterwalder and Pigneur, 2010). Nonetheless, BMO provides its own informal definition, which states that a value proposition is "*an overall view of a firm's bundle of products and services that together represent a value for a specific customer segment*". 'Value proposition' is one of the core classes of BMO, being related to 'Offering', 'Target customer', (customer) 'Relationship', 'Revenue model', 'Distribution channel', 'Capability', and 'Partnership'.

In BMO, however, the core properties of a VP are only the target customer, a set of offerings, and a set of capabilities. Offerings describe how a product, service, or features thereof, create value for the target customers (although no explicit representation of products and services are included in the ontology). This is meant to enable a company to compare its VP to the one of its competitors. BMO characterizes an offering by the following properties: a *reasoning*, which describes the belief of why an offering creates value (e.g., Amazon's delivery service reduces the effort of purchasing); a *life cycle*, which identifies when in the value life cycle the offering actually creates value (e.g., Netflix's online streaming services creates value during consumption); a *value level*, which identifies how valuable the offering is believed to be (e.g., a camera in a smartphone might be considered as very valuable); and a *price level*, which positions the price of the offering w.r.t. to the competition (e.g., an iPhone is a high-end smartphone).

Although the refinement of VPs into offerings in BMO was meant to allow for a finer grained representation of this notion, it resulted in conflating too many notions (services, products, features, economic offerings). As a consequence, this hinders the understandability and reuse of the ontology. Furthermore, it does not account for the additional types of costs proposed by Kambil et al. (1996), nor for the aggregated value of the entire proposition.

Historically, VPs were mostly thought of as being oriented towards customers. However, the idea is generalizable towards other types of target audiences. In particular, Ballantyne, Frow, et al. (2011) discuss the design of VPs for current and potential employees of the firm, suppliers and partners, influencers, and shareholders.

Another line of investigation introduced *reciprocal value propositions* (Ballantyne and Varey, 2006). From this perspective, a VP should not only state the benefits and costs for the target audience, but also for the company that makes the proposition. This view is particularly useful when considering VPs for audiences other than customers. For instance, a VP for a business partner would not only state how a partner benefits from engaging with the company, but also what the company gets in return.

It is important to highlight that all the aforementioned contributions attempted to further clarify the meaning of VPs. Still, there are also works in the literature that go in another direction by attempting to radically simplify its definition. An example is the paper by Bagchi and Tulskie (2000), who reduce a VP to a list of benefits offered to a customer.

2.3.1 Patterns of Value Propositions

In parallel with the advancements discussed in the previous section, other academics investigated the use of VPs in order to discover emerging patterns. In general, the goal was to discover commonalities among successful VPs and how these could guide the design and presentation of new ones.

An example of such a contribution is that made by Treacy and Wiersema (1993), who propose a generic approach for designing value propositions[1]. They argue that there are ultimately only three types of "winning" value propositions; thus, companies should choose one of them. The first, *operational excellence*, means offering lower prices and a high convenience. The second is *customer intimacy*, which means carefully segmenting the market and designing very specific propositions. Third, there is *product leadership*, which means offering the best product among the competition.

An alternative classification was later proposed by Rintamäki et al. (2007) to guide companies in crafting VPs for retailing. This approach uses the most prominent aspect of a VP to classify it within the following four categories:

- *Economic value propositions* regard low prices as the most important aspect of a proposition;
- *Functional value propositions* are aimed at customers who prefer convenience over price;
- *Emotional value propositions* highlight the experience of buying and using the products; and
- *Symbolic value propositions* are those where the benefits arise through self-expression.

[1] In their work, Treacy and Wiersema use the term value discipline, but meaning the same thing as a value proposition

A third classification is presented by Anderson and Narus (2006), who discuss generics strategies to present a VP. They describe three ways in which a VP can be framed:

- *Benefits only*, when companies describe only the benefits they believe customers will receive from their offerings;
- *Favorable points of difference*, when the VP contains all the favorable points in comparison to the competitors' offerings; and
- *Resonating focus*, when only the most relevant favorable points are presented, accompanied by points of parity with alternative VPs.

2.3.2 Value Propositions in Enterprise Modeling

Despite the core role of value propositions in strategic analysis, few enterprise modeling approaches include them as first-class citizens in their underlying ontologies. Those that do include VPs or closely-related concepts, still fall short on providing a clear definition of the term.

One of such languages is *e³value* (Gordijn and Akkermans, 2001), which aims at the representation and analysis of value networks. In *e³value*, the concept most similar to that of value proposition is that of value offering, which is intended as what an actor offers or requests from a network. This concept, however, assumes a very objective view on value, in terms of what is exchanged in the network–the value objects, and it does not account for *why* and *when* agents may value things.

Another language that includes value-related concepts is Archimate (The Open Group, 2017). Even though it does not have an explicit representation of value propositions, some of the concepts in the language, namely *actor*, *value*, *business product*, *business service*, and *goal* could be used to describe some aspects of them. Archimate lacks, however, an explicit distinction between *costs* and *benefits*, which are essential components of value.

Lastly, the Value Delivery Modeling Language (VDML) (OMG, 2018) is a standardization effort aimed at describing and analyzing the operations of an organization with an emphasis on how value is created and exchanged. VDML describes value propositions as the aggregation of values that emerge from measurable characteristics of deliverables. VPs are represented from the point of view of their recipient, capturing the recipient's overall level of satisfaction with an exchange. Although VDML provides a detailed account for value propositions, it still adopts a very objective view of value, disregarding why things may be valuable for a particular audience. In addition, VDML does not account for the use of value propositions in a more abstract way – when they are used to describe a whole business addressing a market segment (see the discussion in subsection 2.5.2).

2.4 Revisiting the Value Ascription Ontology

In order to provide a clear and sound theory of value propositions, we must first understand the nature of (economic) value, which "things" can have value, and how the process of *ascribing value* works. In particular, we shall focus on *use* value (henceforth just 'value'), as opposed to *exchange* (or *market*) value, since this seems to be what counts most in a value proposition. To address these issues, we shall build upon the Value Ascription Ontology (VAO) (Andersson, Guarino, et al., 2016), refining and extending it when necessary.

A first observation at the basis of the VAO is that nothing is intrinsically valuable. Value only exists because people ascribe it to things, and thus, value is, to a great extent, subjective. Teenagers might ascribe a high value to video-game consoles, whilst their grand parents are unlikely to do so. This is because value depends on mental aspects of the value-ascribing stakeholders (henceforth value beholders), such as desires, goals, needs, and preferences.

A further observation is that value is not a synonym of benefit. Value arises from weighing benefits and sacrifices. The value of an airline service is not taking passengers to a location within a short time, but doing so minus paying the respective ticket. For instance, consider owning a car that has a market price of five thousand euros. When we say that such a car has a certain value for a particular person, we do not refer to this amount, but the resultant of the benefits and sacrifices of owning it.

Claiming that value depends on the beholder (and its mental aspects) does not mean, however, that the intrinsic aspects of an object (or its parts) do not influence the value people ascribe to it. We do ascribe a high value to a safe car or a comfortable bed. Note that such intrinsic aspects include qualities (e.g. the softness of a mattress), but also dispositions and capabilities (Azevedo, Iacob, et al., 2013). In fact, value is perceived when particular properties of an object match particular mental aspects of a value beholder. For instance, one may ascribe a higher value to a car with an airbag because it matches the goal of *protecting* *oneself from accidents*.

A valuation is also affected by the *context* in which it is made. Consider, for example, being at a restaurant and wanting a bottle of water. Being charged two euros for it seems fair (meaning drinking the water has a value compatible with the money paid for it), while being charged twenty euros does not. Now consider a radically different scenario, being very thirsty in a desert. In this case, a bottle of water is much more likely to be worth those twenty euros. So, ascribed value depends on whatever happens and whatever is present in the specific spatio-temporal region where the valuation occurs, which in the VAO is generically labeled as *context*.

Despite its useful clarifications, the VAO does not provide all the necessary conceptual primitives to describe value propositions. A first reason is that proposing value requires an agent to assume that somebody *else* values something. This suggests that a valuation judgment involves two roles, the *value beholder*, who actually ascribes the value, and the *value beneficiary*, who is supposed to "enjoy" the value. To exemplify the distinction between these two roles, consider the situation where a father is deciding what to give his daughter for lunch. Eventually, he decides to cook a meal, which he knows will be healthy for her, instead of buying a sandwich from a fast food chain, which he knows she would prefer. In this picture, the father (the value beholder) ascribes a higher value to a home-cooked meal for his daughter (the value beneficiary), while she ascribes a higher value to the sandwich for herself (in this case she plays both the role of value beholder and that of beneficiary). Based on this distinction between beholder and beneficiary, we classify value ascription in two types:

- *Value perception*: when the value beholder and the value beneficiary are the same agent;
- *Value assertion*: when the value beholder is different from the value beneficiary;

Another clarification we need to make regards the *value bearers*, i.e., the "things" which people attach value to. The VAO does not make any claim regarding the nature of these entities, which may be goods, services, actions, or economic offerings. In this paper, we take a stronger position, namely that, as depicted in Figure 2.1[2], a value bearer can be either a *value experience* or *value objects*, but any

[2]In all diagrams, we represent classes of events in yellow, classes of substantials in pink, classes of

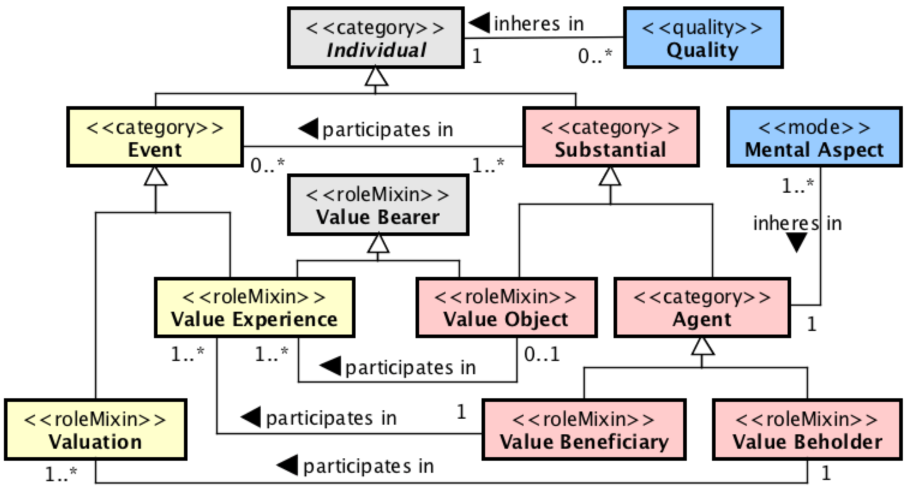

Figure 2.1: VAO revisited (fragment): value bearers, experiences and objects.

value ascription presupposes an *value experience*. This means that, in accordance with the notion of use value, value is always relative to one or more (envisioned, actual or past) experiences, and therefore results from the valuation of such experiences, which are the ultimate bearers of value. Typically, such experiences, which always involve the beneficiary, are direct experiences of a value object, such as owning/controlling/using (or just having the right to use) a good, enjoying a service, performing an action, or obeying to the conditions of an offering. Adopting a term largely used in marketing science (Woodruff, 1997), we shall call them *value experiences*. Note that, in ontological terms, we consider value objects as *substantials* in UFO (i.e., entities that keep their identity in time), while value experiences are considered as events, in the non-standard sense to be explained in the sequel.

A first important aspect of events, in the way we understand them in this paper, is that each of them includes a *context* (i.e., whatever it happens meanwhile, that is, a *scene* according to (Guarino and Guizzardi, 2016)), which contributes to the valuation judgment. For example, the noise coming from the neighbors would be part of the value experience of living in a house, while the behavior of the tenant would be part of the value experience of renting a house. Similarly, while deciding whether buying a car or relying on a car-sharing service, one would consider the

relators in green, classes of intrinsic aspects in blue, and classes whose instances might be of different ontological nature in gray.

actual experiential context, including one's working needs, the actual family needs, the car-sharing service request convenience, and so on.

There is however another modeling challenge concerning events that we need to face if we anchor value judgment in experiences. This seems an obvious and natural choice for *ex post* evaluations, made after the experience took place, but how to deal with *ex ante* evaluations, made before the experience actually occurred, or did actually finish? The traditional ontological view of events assumes that they are static entities "frozen in time", so that we can only refer to them in the past (Guizzardi, Guarino, et al., 2016). Still *ex ante* evaluations seem to be unavoidable for any serious theory of value, and definitely fundamental for an account of value propositions, which are intrinsically bound to future expectations. This means that we need to refer to envisioned events, whose expected temporal properties are not completely fixed (so that they may change in time before the event occurs), but still are considered as first-class citizens in our domain of discourse. We are aware that this is a bold assumption (discussed in detail by Guarino (2017)), but we think it is unavoidable, especially given the explanatory purposes of our paper – indeed, explaining value proposition without any reference to the future would sound as an oxymoron to us. So, in this paper we shall talk of expected events as if they were regular entities of our domain, not differently from, say, a planned air trip in a flight reservation system.

Our position on value objects and value experiences has a consequence on the original formulation of value ascription w.r.t how qualities influence the valuation. In the original VAO's formulation, the relevant qualities are those that inhere in the value object. In our position, they are the qualities that either inhere in the value experience or in the objects that participate in it (possibly including a value object). Consider, for example, that a student claims to value a course on ontologies more than another on patent law because the professor (a participant of the event) is more eloquent (a quality of the participant), and the course (the experience) has a shorter duration (a quality of the event).

In conclusion, we model a value ascription as a judgment relationship between an agent (the VALUE BEHOLDER) and a VALUE BEARER that the beholder judges as having VALUE for someone (the VALUE BENEFICIARY), as shown in Figure 2.2. A VALUE BEARER can either be a VALUE EXPERIENCE or a VALUE OBJECT, in which case a set of relevant experiences enabled by the VALUE OBJECT are also evaluated. Moreover, we represent a VALUE ASCRIPTION as an aggregation

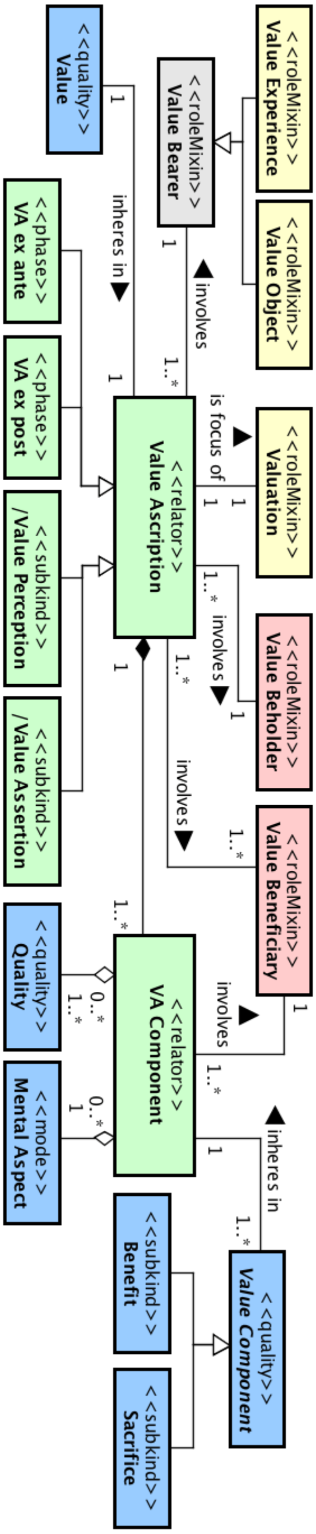

Figure 2.2: VAO revisited (fragment): value ascription relationship.

of "smaller" judgments, namely the VALUE ASCRIPTION COMPONENTS. Each component focuses on an experience of the beneficiary under the perspective of one of its MENTAL ASPECTS, which considers relevant QUALITIES of the experience or of its participants to identify a set of BENEFITS and SACRIFICES.

2.5 Understanding Value Propositions

In this section, we use the aforementioned theory of value ascription to characterize value propositions, while confronting them with closely related concepts and alternative interpretations found in the literature. In particular, we discuss the differences between VPs and offerings, between business VPs and offering VPs, and between VPs and their presentations. Lastly, we show how these distinctions can be used to characterize different *quality requirements* for value propositions.

2.5.1 Value Propositions *versus* Offerings

Value propositions and offerings are closely related concepts that are often confused with one another, since both concepts convey the intuition of what a company "offers" to its customers. This confusion can be quickly revealed through an online search for examples of value proposition, in which one can find various VPs that merely describe the services offered by a company.

An attempt to distinguish between these two concepts was made by Osterwalder in the Business Model Ontology (BMO) (Osterwalder and Pigneur, 2004), who claimed that value propositions are particular types of composite offerings that target a specific market segment. We argue that this is not the case. As we discuss in the following paragraphs, we also believe that value propositions and offerings are directly related, but not through a subsumption relationship.

Following Massin and Tieffenbach (2016), we define an *offering* as a promise with a conditional content, made by an agent, the *offeror*, towards a group of agents, the *eligible market*. An offering (which by itself is a particular kind of *speech act*) is described by an *offering description*, which is composed by two parts, the content description and the condition description. The content description describes the actions to be performed by the offeror, such as transferring the ownership of a car, or allowing the right to use a streaming service. The condition description, on the other hand, describes the expected actions (usually some sort of payment) the offerees must perform if they want to take advantage of the offering's content. The following statements exemplify offerings: "John offers Mary to sell her his car for 5.000 euros", "Netflix offers video streaming services in Italy for 9,99 euros per month".

We emphasize that an offering may contain different types of promises. As discussed by Griffo et al. (2016), they may be commitments to perform particular actions (e.g. Amazon promises to deliver the goods you purchased at your home) or not to perform actions (e.g. Netflix commits *not* to embed commercials in their content). Moreover, these promises may contain restrictions on how the action will be performed. For instance, Amazon Prime's 1-Day delivery service contains a commitment to deliver an order within 24 hours.

Moreover, offerings typically specify the channels through which they are accessible or even restrictions on who can accept them. Netflix's offerings, for example, are accessible through their web portal and mobile applications. Yet note that Netflix has different offers for each country, thus, Netflix's Italian standard plan can only be hired by those who are in Italy. Our account of offerings is depicted in Figure 2.3.

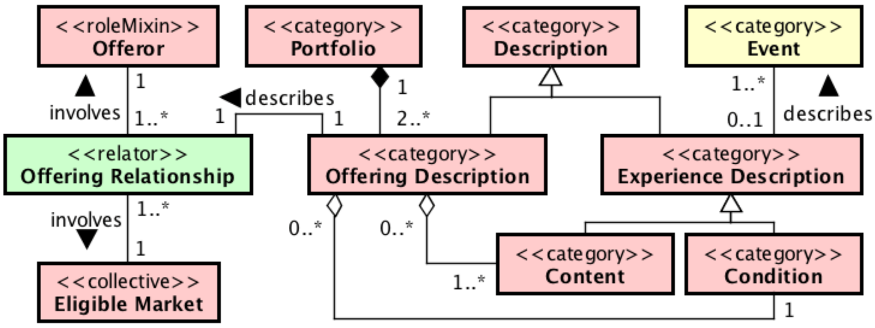

Figure 2.3: Modeling offerings and their properties.

Let us now consider the notion of value proposition. Differently from an offering, this is not a promise, but rather an assertion of the value resulting from a trade-off between the benefits and sacrifices one gets from taking an offering. As depicted in Figure 2.4, we define a VALUE PROPOSITION as a VALUE ASSERTION a company makes (as the VALUE BEHOLDER) that a given MARKET SEGMENT (the beneficiaries) will ascribe a particular value to the experiences enabled by an OFFERING (the VALUE OBJECT). To make such an assertion, a company must presuppose that the members of a segment share the same types of goals, as well as that they value the experiences in the same way. Simply put, the difference between Value Propositions and Offerings is that the former answer *what* customer value and why, whilst the latter describes *how* value is delivered by the company.

Note that value propositions depend on specific offerings, but not the other way around. To see why, consider a pharmaceutical company that developed a new drug for treating patients with fever. It makes an offering to sell this drug for two euros a packet. On top of this offering, the company crafts a value proposition that claims a shorter time for the drug to work than the alternatives. Now, suppose that the company discovers that the same drug might be used in a preventive treatment for heart attacks. It could keep the same offering (two euros a packet) and craft an additional value proposition focused on another market segment, patients with heart conditions. However, if the company decides to sell the same drug for fifty euros a packet, this definitely implies a different value proposition, since the sacrifice embedded in the offering changed.

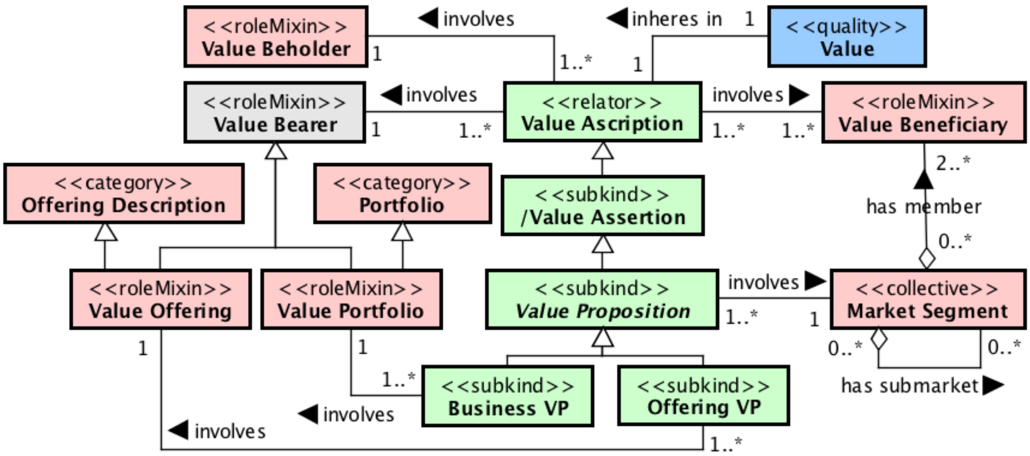

Figure 2.4: Value proposition as a type of value ascription.

A further difference between VPs and offerings concerns their targets. On one hand, the target of a VP (its market segment) includes those whom the proposition is designed for. On the other hand, the target of an offering (its eligible customers) includes those who are allowed to take the offering. Yet note that if a VP is crafted for an offering, it is reasonable to assert that its market segment is a subset of the eligible customers. Consider, for instance, a company that rents cars. Its target community includes every person that is legally allowed to drive a car. Its VP, however, aims at travelers who prefer the flexibility and comfort of a car over public transportation, besides being legally allowed to drive.

Finally, note that the notion of value proposition, in the way we defined it, is at the core of a particular type of strategic analysis, namely, choosing the offering that delivers the best VP. This scenario can be interpreted as an optimization problem, in which one describes multiple possible configurations of an offering and the problem is to find the configuration that optimizes the value the offering delivers.[3]

2.5.2 Business VPs *versus* Offering VPs

Explaining value propositions only through offerings, however, is not enough. Consider Netflix, a popular company that offers online video streaming services. It seems reasonable to state that Netflix has just one value proposition: to help their customers relax and entertain themselves by means of online video content (e.g. series, movies) that can be accessed anywhere at anytime, at the price of a low monthly fee. If we take a closer look, however, we find that Netflix offers three subscription plans: Basic, Standard, and Premium. Each plan offers different levels of service, such as number of simultaneous devices, at different costs. Yet, offering different benefits at different costs means offering different values, thus different value propositions. This may suggest that Netflix has three value propositions, and not just one.

This contradiction occurs due to the use of VPs at very different levels of abstraction. On one hand, there are value propositions described at the *business level*, which provide an abstract idea of the value offered by the company through all of its offerings for a specific market segment, measuring benefits and costs with a coarse granularity. On the other hand, there are value propositions described at the *offering level*, which are very accurate in terms of benefits and costs. The former notion, which we name Business Value Proposition (BVP), conveys the idea of what the company delivers to its customers by means of its Portfolio (the set of offerings made toward the same market segment), while the latter, named Offering Value Proposition (OVP), specifies the actual value embedded in each offering, which conforms to the former. Besides making the benefits and costs concrete, OVPs may focus on specific sub-segments or on specific additional benefits. This distinction between value propositions is depicted in Figure 2.4.

[3]Note that we are focusing on optimizing *customer* value here. A dual reasoning can be done from the company's perspective.

Differentiating between business- and offering value propositions is useful when we consider changes that offerings may undergo. Suppose, for instance, that Uber increased its price by 10 cents per km traveled. By increasing the cost customers have to pay, Uber is reducing the value it delivers. However, at the business level, a price increase of just 10 cents it does not make sense to say that Uber is changing its value proposition. In this scenario, Uber changed its offering value proposition, but not its business value proposition.

Note that the existence of multiple offerings might even be a value-creating factor for the BVP. For instance, if a restaurant has only one dish in its menu, its BVP is probably lower than that of another restaurant offering a variety of dishes to choose from. Note also that companies may have more than one BVP, typically one for each macro customer segment in their business model. Uber, for instance, has a general BVP for passengers, which includes a short waiting time and low effort to request vehicles, associated to its portfolio of offerings to passengers (e.g. UberBlack, UberPOOL). It has another BVP for drivers, which includes flexibility on working hours and access to customers through their mobile app. Also note that there might be no intersection between the BVPs of a company for different segments (e.g. Uber's BVP for passengers and Uber's BVP for drivers), but whenever these are refined into OVPs, the latter should not violate assumptions of the former.

We are aware that this distinction suggests that VPs could be organized in a hierarchy (in line of what is discussed by Barnes et al. (2009)), accounting for more than the two levels discussed so far. A situation in which such a hierarchy would be useful is when companies have product lines and customized products. Apple, for example, owns the iPhone line, which in turn has various models (e.g. iPhone 7), which are sold with different configurations (e.g. iPhone 7 128GB Black). We could try to craft different VPs for each of these levels. We refrain from such a refinement for now, since the two levels of VP we discussed seem to be more commonly used in practice.

2.5.3 Value Propositions *versus* Value Presentations

The importance of *communicating* a value proposition has been emphasized in the literature since Lanning and Michaels (1988) coined the term. It helps customers understand why they should hire the company, explain to the employees why the company exists, or convince investors that the business idea is worth their investment.

Nonetheless, a VP presentation should not be confused with the VP itself. As we previously argued, a VP is a judgment made by a company that a particular set of customers value its offering in a particular context, assuming that such an offering fulfills their goals. A *value proposition presentation* is the communication of such a VP for a particular audience, not necessarily the audience it is made towards. A VP may be presented to employees, investors, partners, influencers, and, obviously, to the customers.

When presenting a VP, companies might focus on specific aspects they believe will serve their communication's purpose. When used in marketing campaigns, companies might decide to highlight the core benefits of the proposition in order to attract customers. When used as an input for strategic planning, all aspects might be described. In competitive analysis, the focus might be on the comparison with competing VPs. What is fundamental is that making a different presentation does not imply making a new value proposition.

To exemplify how different presentations may be coined for the same VP, consider Turo (`http://www.turo.com`), an American company that offers an online marketplace where travelers can rent cars from local owners. One can describe their business value proposition through a simple analogy with Airbnb: "Turo is the Airbnb for cars". This suggests that one can ascribe the same type of value expected from Airbnb to Turo. Another statement could be: "Turo enables travelers to rent unique cars at a cheaper price than car rental chains". This statement identifies the customer segment (travelers), highlights one benefit (uniqueness of the cars), and provides a comparative notion of the price (cheaper than rental chains).

2.5.4 Quality Requirements for Value Propositions

In the literature, several requirements have been proposed to qualify a good VP, including clarity and persuasiveness (Anderson and Narus, 2006; Barnes et al., 2009), profitability (Barnes et al., 2009), competitiveness (Rintamäki et al., 2007) and uniqueness (Kambil et al., 1996). In this section, we use the VP-related notions we have described to better understand what these requirements are about.

Clarity and persuasiveness refer to *value proposition presentations*. Clarity describes how easy it is for someone to understand the most important aspects of a VP from its presentation. The same VP can be described in a very clear or a very confusing and imprecise way. In fact, the same presentation might be clear for a particular audience and unclear for another. The important point is that crafting different statements does not imply crafting different VPs. Persuasiveness refers to how convincing and believable the VP presentation is to its target audience. When Anderson and Narus (2006) suggested that VPs should only contain the most important benefits and points of parity with their alternatives, they do not mean that VPs do not have the remaining properties, but that they are more persuasive when presented in such a way.

Profitability, in turn, is a quality of an *offering*, not of a value proposition. It means that the company must be able to fulfill the promise within an offering and still make a profit. Since multiple VPs can be made on top of the same offering, profitability cannot be a direct property of a VP.

The last two requirements, competitiveness and uniqueness, are the only two that actually concern value proposition as we conceptualized it. A VP is competitive if it is perceived as superior by at least a subset of the market segment. Finally, a VP may be unique for different reasons. It might target an ignored audience or offer a benefit no one else does. Ultimately, uniqueness is about avoiding the commoditization trap (Kambil et al., 1996), namely the situation in which the value propositions made by all the competitors in a market are so similar that customers only consider price when choosing amongst them–a scenario that might significantly harm profit margins.

2.6 Use Case Illustration: Netflix

Netflix aims at addressing a very simple desire people have – to relax and entertain themselves. It does that by offering its customers the experience of watching a wide range of video contents, such as movies, series and documentaries, in exchange for monthly payments. This general idea is in fact Netflix's business value proposition.

Netflix offers propose to entertain their customers by means of three service modalities (composing its offering portfolio), namely the Basic, Standard and Premium subscription plans. Each plan has a specific price and promises an experience of a certain quality level. For instance, the Standard plan costs 9.99 euros/month and enables customers to watch movies in high-definition (HD).

We depict a prototypical watching experience enabled by the Standard plan in Figure 2.5. Note that such an experience involves various elements, including the viewer (as the value beneficiary), but also the movie being watched, the Netflix App, the device used for streaming (e.g. a computer, a table), and even the internet connection required for accessing the service. In order to describe how this experience creates value, we also identify some relevant qualities of these participants, such as the entertainability and the resolution of the movie, and the speed of the Internet connection.

In its value proposition, the Standard plan aims at a subsegment of the mass market targeted by Netflix business value proposition. This sub-market includes those customers that prefer to pay a slightly higher price to be able to watch movies in HD. As shown in Figure 2.6, to identify the benefits and sacrifices that compose the value of the standard plan, we decompose the value proposition in three Value Ascription Components (VAC): the Entertainment VAC, the Video Quality VAC, and the Payment VAC.

The Entertainment VAC "matches" the customers' goal of relaxing with the entertainability capacity of a movie being watched, thus yielding a relaxing *benefit*. Moreover, the Video Quality VAC explains why videos in HD produce a benefit, by assuming that (i) customers believe sharper images improve the watching experience; (ii) they will use the service with an Internet connection that is fast enough (> 5 Mbps) to stream the video without interruptions; and (iii) the streaming device supports HD resolutions.

Note, however, that this benefit might be accompanied by a *sacrifice*, namely the increased data traffic in the network, if customers have a limited Internet contract. Lastly, the Payment VAC identifies the main sacrifice of the Standard plan, i.e., paying for the service. Such a sacrifice exists due to the assumption that, in general, customers want to expend as little as possible.

The fact that Netflix offers a viewing experience that is not disturbed by commercials is often described as part of the value proposition. But if we analyze the whole experience closely, there is not a single property of the experience that creates such a value. The "no commercials" part of Netflix's usual presentation of their value arises from a comparison with alternatives propositions of competitors, in particular with regular television channels and Youtube, offerings that do include commercials and thus, have value diminishing elements (i.e. sacrifices) in their value experiences. If for instance, Youtube and television channels would cease to include advertising in their services, this factor would likely not be included to describe Netflix's value proposition.

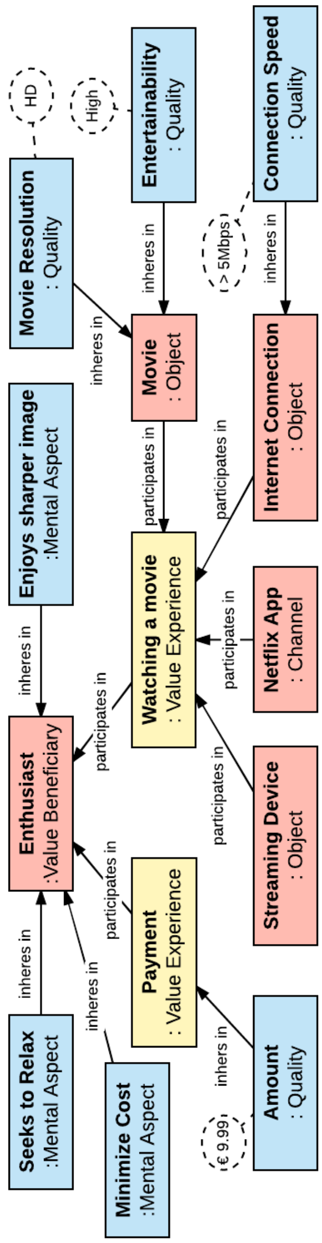

Figure 2.5: A value experiences of the Netflix service.

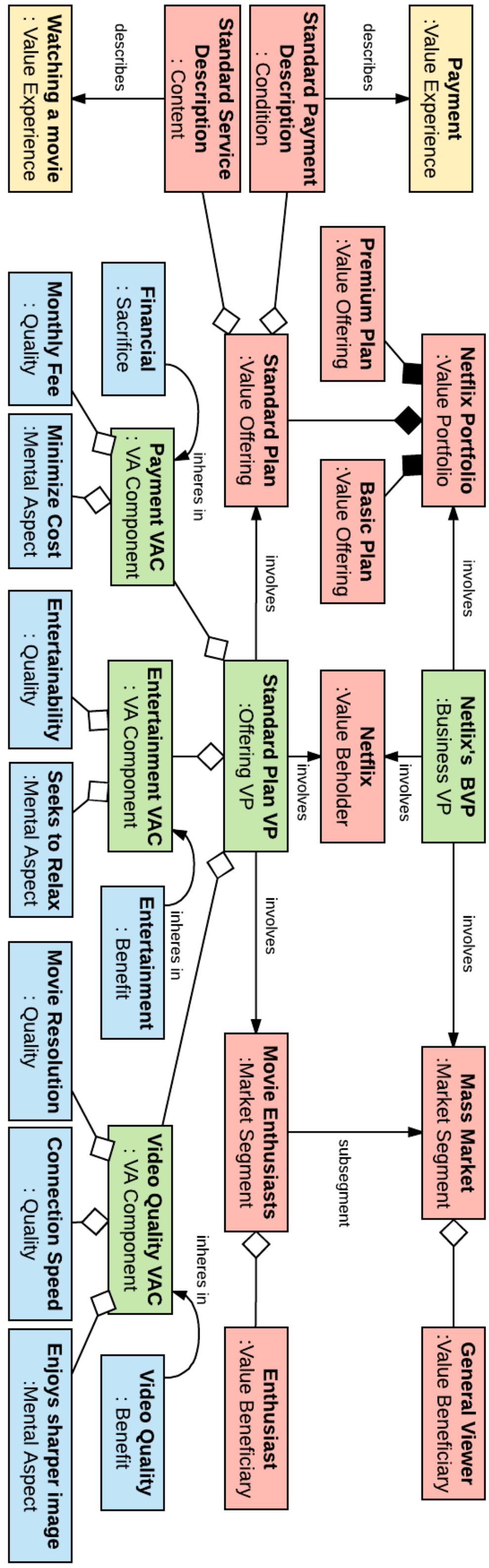

Figure 2.6: Overview of Netflix's value propositions.

2.7 Final Remarks

In this paper, we clarified the notion of value proposition through an ontological analysis based on UFO and on the previous work on the ontology of value ascription. We explained value propositions as a particular type of value ascription and distinguished them from offerings and value proposition statements. Moreover, we discussed how VPs can be conceived for offerings and offerings portfolios (i.e., at the business level). We are aware that further clarifications might still be required, however we argue that the discussion regarding VP quality requirements in combination with the Netflix case study exemplified how the distinctions we made contribute to a better understanding, communication and use of VPs in research and practice.

We plan to follow two main directions in future investigations. First, we intend to use the presented ontology to analyze and redesign existing modelling languages (e.g. Archimate) to enable them to consistently describe value propositions. Second, we plan to connect the present ontology to complementary domains that are relevant for strategic analysis. In particular, the domain of markets and competition, to account for external factors that affect strategy, and the domain of capabilities and business processes, to further clarify how value propositions are actually delivered.

Chapter 3

The Common Ontology of Value and Risk

Risk analysis is traditionally accepted as a complex and critical activity in various contexts, such as strategic planning and software development. Given its complexity, several modeling approaches have been proposed to help analysts in representing and analyzing risks. Naturally, having a clear understanding of the nature of risk is fundamental for such an activity. Yet, risk is still a heavily overloaded and conceptually unclear notion, despite the wide number of efforts to properly characterize it, including a series of international standards. In this paper, we address this issue by means of an in-depth ontological analysis of the notion of risk. In particular, this analysis shows a surprising and important result, namely, that the notion of risk is irreducibly intertwined with the notion of value and, more specifically, that risk assessment is a particular case of value ascription. As a result, we propose a concrete artifact, namely, the Common Ontology of Value and Risk (COVER), which we employ to harmonize different conceptions of risk existing in the literature.

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3.1 Introduction

Risk analysis is traditionally accepted as a complex and critical activity in various contexts, such as strategic and project planning, finance, engineering of complex systems, and software development. It offers techniques and tools for systematically identifying potential issues, analyzing their impact and designing and evaluating mitigation strategies.

Given the complexity of risk analysis, several modeling approaches have been proposed to help analysts in representing and analyzing risks in different contexts. Examples include the Goal-Risk framework (Asnar et al., 2011), an approach designed to support risk analysis in the context of requirements engineering; RiskML (Siena et al., 2014), an i*-based modeling language tailored for dealing with risks inherent to the adoption of open source software; the CORAS method (Lund et al., 2010), a model-driven approach focused on the protection of enterprise assets; and Archimate (Band et al., 2017), in which risks are analyzed in the context of enterprise architecture models.

Naturally, having a clear understanding of the ontological nature of risk is fundamental for performing risk analysis, and even more for developing modeling languages to support it. Yet, risk is still a heavily overloaded and conceptually unclear notion (Aven et al., 2011; Renn, 1998), despite the wide number of efforts to properly characterize it (Aven, 2010; Boholm and Corvellec, 2011; Rosa, 1998)– including several standardization efforts (COSO, 2004; IRM, 2002; ISO, 2009; 2018).

In this paper, we address this issue by means of an in-depth ontological analysis, conducted under the principles of the Unified Foundational Ontology (UFO) (Guizzardi, 2005). As we shall see, our analysis shows an important result: the notion of *risk* is irreducibly intertwined with the notion of *value* and, more specifically, the process of assessing risk is a particular case of that of ascribing value. Indeed, we are not the first to relate value and risk. For example, Boholm and Corvellec (2011) defended, in their relational theory of risk, that "*for an object to be considered 'at risk', it must be ascribed some kind of value*", and Rosa (1998) defined risk as "*a situation or event where something of human value [...] has been put at stake*". Our analysis, however, is (to the best of our knowledge) the first to show and formally characterize the process of ascribing risk as a particular case of the process of ascribing value (in the sense of use value, as we shall discuss in section 3.2). This opens the possibility of applying methodologies and techniques developed in marketing and economics for value analysis to the case of risk analysis, and vice versa, linking together two historically disconnected bodies of research. As a result of our analysis, we propose a concrete artifact, namely the Common Ontology of Value and Risk (COVER), formalized in OntoUML (Guizzardi, 2005).

The remainder of this paper is organized as follows. First, in sections 3.2 and 3.3 we start with separate characterizations of the concepts of value and risk, contrasting their different interpretations found in the literature. Then, in section 3.4 we compare the two concepts and discuss how several characteristics, historically ascribed to value, also apply to risk and vice versa. In section 3.5 we present the common ontology of value and risk resulting from our analysis, and finally we discuss the implications of our findings on the practice of conceptual modeling of risk and value in section 3.6, adding some further remarks in section 3.7.

3.2 On Value and Value Ascription

The term 'value' is heavily overloaded, standing for various meanings in different fields. Thus, it is paramount to this paper to clarify what we mean (and what we do not mean) by value. There is one sense in which value stands for *ethical value* (Rokeach, 1973), as in "the values of our company are passion, integrity and diversity". In this sense, a value can be some sort of high-level and long term goal an agent is committed to pursuing or a sort of constraint that guides the behavior of an agent. This notion of value is important in the study of Ethics and human behavior, but it is not what we mean here.

Another common meaning for value is that of *exchange value* (Vargo et al., 2008), an interpretation that is widely adopted in economics. This meaning of value is exemplified in sentences such as "the value of my bicycle is 100 €" and "the value of my house is equivalent to that of two cars". Exchange value captures how much people are willing to pay for something or, more broadly, the worth of one good or service expressed in terms of the worth of another. This meaning of value is fundamental for economics and has been used in modeling approaches such as *e³value* (Gordijn and Akkermans, 2003), but still, it is not the interpretation we adopt in this paper.

Moreover, value may stand for *use value* (Andersson, Guarino, et al., 2016; Sales, Guarino, et al., 2017a; Vargo et al., 2008), as in "my bicycle is valuable to me because I ride it to the office every day" and "the heating system of my car is of little value to me because I live in a city that is warm all year round". In this sense, the value of a thing emerges from how well its affordances match the goals/needs of a given agent in a given context. The notion of use value (or value-in-use) is mostly used in the business literature, in particular in marketing and strategy research, as it is a core part of understanding relevant phenomena such as what motivates customers to buy a particular product, why they choose one offering over another, and how companies differentiate themselves from their competitors. *Use value is the interpretation of value we adopt in this paper.*

In recent works (Andersson, Guarino, et al., 2016; Sales, Guarino, et al., 2017a), some of us have investigated the ontological nature of use value, aiming at understanding foundational questions such as: "What do we ascribe value to?" and "Which factors influence value?". In these works, we were able to identify and formalize various characteristics of use value. Its first characteristic is *goal-dependency*, i.e. things have value to people because they allow them to achieve their goals. This means that value is not intrinsic to anything, and the same object may have different values to different agents, or even according to different goals of the same agent. For example, a winter jacket has value on a cold night because, by wearing it, one is protected from the cold.

A second characteristic of use value is that, ultimately, it is ascribed to experiences, not objects. This may sound counter intuitive at first, as we have mentioned several examples of value seemly being attributed to objects. To clarify this point, let us go back to the winter jacket example. To ascribe some value to a jacket, we need to consider the situations in which we envision ourselves using such a jacket. It could be a snowy day while we go to work, a winter hike on the Italian Dolomites, or a rainy evening when we go to a dinner. In each of these situations, we will have different goals that we expect the jacket to help us fulfill, such as staying warm and dry, looking fashionable, keeping our belongings and so on. The value that we ascribe to the jacket, thus, will be "calculated" from the value ascribed in these envisioned experiences.

Despite its subjective nature and the fact that value is ultimately grounded on experiences, value is directly affected by the intrinsic properties of the objects that participate in these experiences. For instance, if a jacket is worn during a hike, it will be more or less valuable depending on its weight (an intrinsic quality that inheres in the jacket), as lighter jackets facilitate exercise. The same applies for a jacket's waterproof capability on a rainy day: the more it can repel water, the more it satisfies its wearer's goal of staying dry.

By considering the whole experience in which objects are used, we are able to explain that not only intrinsic properties of things affect their value, but also the properties of other objects and of the experience itself. This is useful, for instance, to explain that the value experienced by a user of a movie streaming service is affected by the speed of the internet connection used to access it, as well as the screen resolution of the streaming device.

Note that the conceptualization of value we proposed in our previous works (Andersson, Guarino, et al., 2016; Sales, Guarino, et al., 2017a) is not restricted to the positive dimensions of experiences. As extensively discussed in the literature (Kambil et al., 1996; Lanning and Michaels, 1988), value is a composition of benefits, which emerge from goal satisfaction, and sacrifices, which emerge from goal dissatisfaction. Thus, the value of an airline service is not only taking passengers from one place to another, but doing so minus the price one has to pay for the respective flight ticket, the effort to arrive to the point of departure, and so on.

The types of sacrifices that affect customer value have even been classified in the literature. Kambil et al. (1996), for instance, propose to distinguish between three types of sacrifices, namely price, risk and effort. Note that the explicit representation of risk as a value reducing factor already suggests the process of ascribing value is strongly related to the process of assessing risk.

3.3 On Risk and Risk Assessment

The notion of risk has been systematically investigated for over 50 years (Renn, 1998). Throughout this time, a wide number of definitions have been proposed and, although much progress has been made to clarify the nature of risk, the term remains overloaded and conceptually unclear (Aven, 2011; Aven et al., 2011; Renn, 1998; Rosa, 1998).

One of the definitions that gained significant traction over the years in the risk community was proposed by the sociologist Rosa (1998), who defined risk as "*a situation or event where something of human value (including humans themselves) has been put at stake and where the outcome is uncertain*". Rosa argues that his definition contains the three necessary and sufficient conditions to characterize risk. First, risk relates to some possible state of reality that affects someone's *interest*, either positively or negatively. Second, risk involves *uncertainty* about whether or not such a state will hold in the future; thus, if an event is certain to happen (such as the sun rising tomorrow), one cannot ascribe a risk to it. Third, risk is about a *possible* state of reality (thus ruling out the possibility of talking about the risk of someone turning into a werewolf).

Note that, intentionally, Rosa's definition does not exclude the case of "positive risks", i.e., risks related to events that can exclusively affect one's interests in a positive way. This idea that risks are not necessarily "bad", however, is in fact much older, dating back to at least the 1960's, when the distinction of speculative and pure risks was already being discussed (Williams, 1966). In this context, pure risk stands for uncertain events that exclusively lead to negative outcomes (such as the risk of being in a car accident or the risk of being robbed), while speculative risk stands for the possibility of getting either a positive or a negative outcome, such as when investing in a company or playing the lottery.

More recently, Boholm and Corvellec (2011) proposed the so-called *relational theory of risk*, which defines risk as a triple composed of a *risk object*, an *object at risk*, and a *risk relationship* connecting the former two. In this theory, *risk objects* are said to be the source of risks, such as a drunk driver that poses a threat to the wellbeing of pedestrians, or a blizzard that puts car drivers in risk of an accident. Note that, even though the authors use the term *object*, they also include events and states as possible risk "objects". *Objects at risk* are the things of value[1] that are at stake because of a risk object. In the former examples, the objects at risk could be the pedestrians, the car, the driver and so on. The *risk relationship* is what connects risk objects to objects at risk. The authors adopt a cognitive approach towards the nature of risk, arguing that these relationships do not just occur, but instead they must be crafted or imagined by some agent. What follows from this position is that being a risk object or an object at risk is neither an intrinsic nor a necessary property of anything. Thus, an object may be a risk object to one person and an object at risk to another.

Aven et al. (2011) compared eleven definitions of risk from different sources, categorizing them in three groups, each capturing a particular sense in which risk is used. A first group refers to risk as a quantitative concept "attached" to an event. This interpretation is fundamental to make sense of sentences such as "it is

[1] Boholm and Corvellec (2011) do not explicitly state which notion of value they use, but, through their argumentation and examples, we inferred that they mean use value.

riskier to drive when it is snowing than when it is not". The second group refers to risks as if they were the actual events, defined in terms of a chain of causality leading to consequences to some agent. This perspective is fundamental to explain what we assess risk for, and where risk comes from. The last group refers to risks as people's perceptions, equating objective risk to assessed risk. In this sense, risk is not just "out there", but, as argued in the relational theory of risk, it must be necessarily assessed by someone.

This plethora of risk definitions led to a number of standardization efforts (COSO, 2004; IRM, 2002; ISO, 2009; 2018) that aimed to provide an ultimate definition for those working on risk management. One of these efforts resulted in the ISO 3100:2018 (ISO, 2018) standard, which defines risk as the *"effect of uncertainty on objectives"*. This very abstract and concise definition is further explained in the standard by a number of commentaries, including that risks might refer to positive or negative impact on objectives, in line with what Rosa (1998) proposed, and that risks are often explained in terms of events, consequences and likelihood.

In summary, what can be extracted from these different definitions is that to conceptualize risk, one must refer to:

- agents and their goals;
- events, their triggers and impact on goals; and
- uncertainty.

3.4 Similarities Between Value and Risk

In this section, we elaborate on the evidences that motivated our pursue of a common ontology of value and risk. In particular, we explore the role of goals, context, uncertainty and impact in the conceptualization of both risk and value.

3.4.1 Goal Dependency

The first similarity between value and risk is that they are both goal-dependent notions, in the sense that nothing is intrinsically valuable and nothing is intrinsically at risk. Things do not just have value, they have value *for* someone, and in case their *affordances* enable certain happenings that positively contribute to the achievement of one's goals. Analogously, things are only at risk from one's perspective, in case their *vulnerabilities* enable happenings that hurt one's goals. Just as "beauty is in the eye of the beholder", so are value and risk.

Take a pack of cigarettes, for instance. It has a high positive value for a smoker, as it enables him to satisfy his addiction. The same pack of cigarettes, however, would have arguably no value for a non-smoker, as its affordances would not help such a person to make any progress towards her goals. Similarly, if one drops her wallet on the street, we would claim that the wallet is at risk of being stolen, as it is unattended and the owner probably wants to keep her money and documents. However, from the perspective of an alert thief, such an unattended wallet is not at risk, but an opportunity for an easy theft.

Note that even though risk and value are subjective, they still depend on the intrinsic properties of things or, to put it more precisely, on their *dispositions* (or dispositional properties). Note that when dispositions are perceived as beneficial, i.e., they enable the manifestation of events desired by an agent, they are usually labeled as *capabilities*(Osterwalder and Pigneur, 2010), as in the capability of a smartphone to make calls. Conversely, when dispositions enable undesired events, as in "the fragility of my phone's screen material makes it susceptible to breaking", they are referred to as *vulnerabilities* (Band et al., 2017). That is why conceptualizations of value, which usually focus on positive outcomes, refer to capabilities, and those of risk, which usually focus on negative outcomes, refer to vulnerabilities.

Still, some argue that risks can be absolute in some situations (Aven et al., 2011), such as in the risk of dying. This argument is built upon the claim that some things, such as human lives, are universally valuable, thus any death is an event that necessarily "destroys" value. We argue against this position because, from an utilitarian perspective, value always emerges from goal achievement, which makes it necessarily relative. Take for instance the extreme case of suicidal terrorist attacks. From the perspective of the attacker, his death does not destroy value, but creates it for his terrorist organization.

3.4.2 Context Dependency

Another similarity between value and risk comes from the process we follow to "calculate" them. The value/risk ascribed to an object is always derived from the value/risk ascribed to events (or experiences) "enabled" by their dispositions, regardless if these events are intentional or not, and if they affect one's goals positively or negatively. Ascribing value to a notebook, for instance, means ascribing value to a number of different experiences enabled by the notebook, such as streaming a movie, giving a presentation, using a social media platform, working on a paper while traveling for a conference in another country, or playing a computer game. The ascribed value could be even high for some of these cases and low for others. Nonetheless, *the value of the notebook* cannot be computed without considering the different scenarios in which it will be used. Analogously, ascribing risk to an object means ascribing risks to different events involving this object. For instance, the risk of a car being stolen is ascribed based on the risk of it being stolen when parked on a private garage, when parked on the street, when being driven in a city with high criminality rates, and so on.

Stating that risk and value are contextually dependent means that they emerge not only from intrinsic properties of an object, but also from contextual properties. The value of watching a film on Netflix indeed depends on the properties of the Netflix service, but it also depends on the properties of the other objects involved in the experience, such as the resolution of the streaming device and the speed of the internet connection. In an analogous manner, the risk of being involved in a car accident when driving on a highway is certainly affected by the car's properties, such as how reliable the breaking system is, but it is also affected by the properties of the other participants of the driving event, including the highway's physical conditions and the traffic intensity.

3.4.3 Uncertainty and Impact

Another similarity between the conceptualization of risk and value is the role played by uncertainty and impact. According to the popular risk equation, risk is equal to the likelihood of an event times its impact.

To understand why impact is positively correlated with risk, consider the following example. Two business angels invested in the same startup. One invested a hundred thousand euros and the other a million. If everything else but the invested amount is the same, the bigger investment is said to be riskier, since the impact of an eventual bankruptcy of the startup would be ten times worse. But what about value? Is the value ascribed to an experience also positively correlated with its impact? As we have previously discussed, value emerges from achieving goals. Thus, the more an event makes progress towards achieving one, the more valuable it is. For instance, imagine that a traveler wants to fly from Rome to

Brussels and that there are only two flights available. If the only significant difference between them is that one takes two hours and the other takes four hours, the shorter flight would be more valuable to the traveler, assuming that she has the goal of minimizing the duration of her trip.

The other parameter in the risk equation is likelihood, often referred to as probability or frequency, which states that the more likely an event is to happen, the riskier it is. To understand this correlation, consider two trips. The first takes place in a highway during a bright sunny day, whilst the second takes place during a snowstorm. The risk of an accident in the latter scenario is greater simply because an accident is more likely to happen in conditions of reduced visibility and adhesion of the car tires to the road. Note that the likelihood parameter also applies to value. To see how, let us consider a mobile app that works as a compass. It is very unlikely that urban smartphone users would ever need such an app for guidance. Thus, having it in their phones is of very little value to them, even though it could be useful in a theoretical scenario. If we then compare it to other apps, such as a calendar, a camera, or an alarm, the value of the compass app seems to be even lower, as these other apps are often used in a daily basis.

In summary, the computation of the likelihood of an event times its impact on one's objectives and preferences fits the quantitative analysis of both risk and value. The differences between them rely on the kind of event one usually analyzes (unwanted for risks, expected and desired for value) and the nature of the expected impact on goals (negative for risks and positive for value).

3.5 The Common Ontology of Value and Risk

In this section, we present a well-founded ontology that formalizes the assumptions on value and risk discussed in the previous sections. Given the polysemic nature of these terms (Kjellmer, 2007; Vargo et al., 2008), we aim to disentangle three perspectives:

- an *experiential perspective*, which describes value and risk in terms of chains of events structured by means of causal relations and impacts on agents's goals;
- a *relational perspective*, which accounts for the subjective nature of value and risk by recognizing the need for an agent to ascribe/assess them; and

- a *quantitative perspective*, which assumes that value and risk can be measured and their magnitude projected on scales of choice.

In the OntoUML diagrams depicting this ontology, we adopt the following color coding: events are represented in yellow, objects in pink, qualities and modes in blue, relators in green, situations in orange, and powertypes in white. Additionally, in the models represented in these diagrams, we use the semantics of non-sortals proposed by Guizzardi, Fonseca, et al. (2018).

The *experiential perspective* is depicted in figures 3.1 and 3.2. As argued in the previous section, value and risk can be ascribed to both objects and events. Still, whenever they are ascribed to an object, one must always consider all the relevant events involving it, which will ultimately ground value and risk. These events, named VALUE and RISK EXPERIENCE, have some agents as key participants, deemed VALUE and RISK SUBJECT respectively. These identify the perspective from which the judgment is made and whose INTENTIONS are considered.

Note that, as argued by Sales, Guarino, et al. (2017a), value can be ascribed to past, actual or envisioned experiences. Risk, however, is only ascribed to envisioned experiences that may (but are not certain to) happen. We are aware that there is a controversy concerning the ontological nature of future events. The classical view of events assumes that they are immutable entities and that only past events truly exist as genuine perdurants (occurrences) (Diekemper, 2014). However, accounting for future events (which is the case for envisioned experiences) seems to be unavoidable for any theory of risk, as uncertainty and possibility are core aspects of this concept. This means that we need to refer to future events – whose expected temporal properties are not completely fixed – as first-class citizens in our domain of discourse. As bold as this assumption may seem (see Guarino (2017) for details), conceptualizing risk with no reference to the future would sound as an oxymoron to us, given the explanatory purposes of our paper. So, we shall talk of expected events as regular entities of our domain, not differently from, say, a planned air trip in a flight reservation system. In order to use this non-classical notion of events in our analysis while maintaining its ontological rigour, we employ the formulation of events as proposed by Guarino (2017), which was already successfully employed in our work on value propositions (Sales, Guarino, et al., 2017a).

VALUE and RISK EXPERIENCES are commonly decomposed into "smaller" events to clarify their internal structure and how they affect multiple goals. One

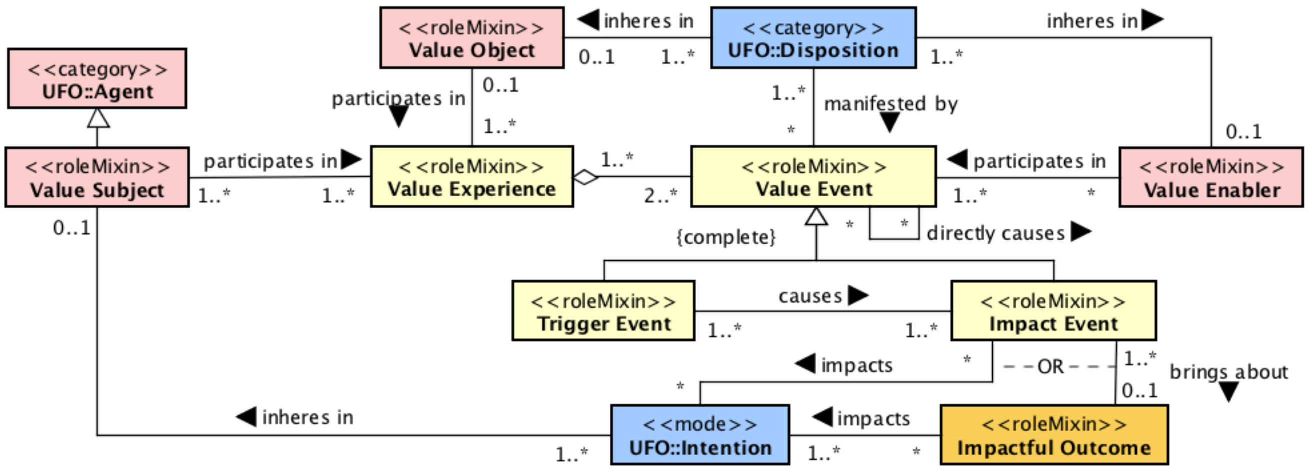

Figure 3.1: Value experiences, their parts and participants.

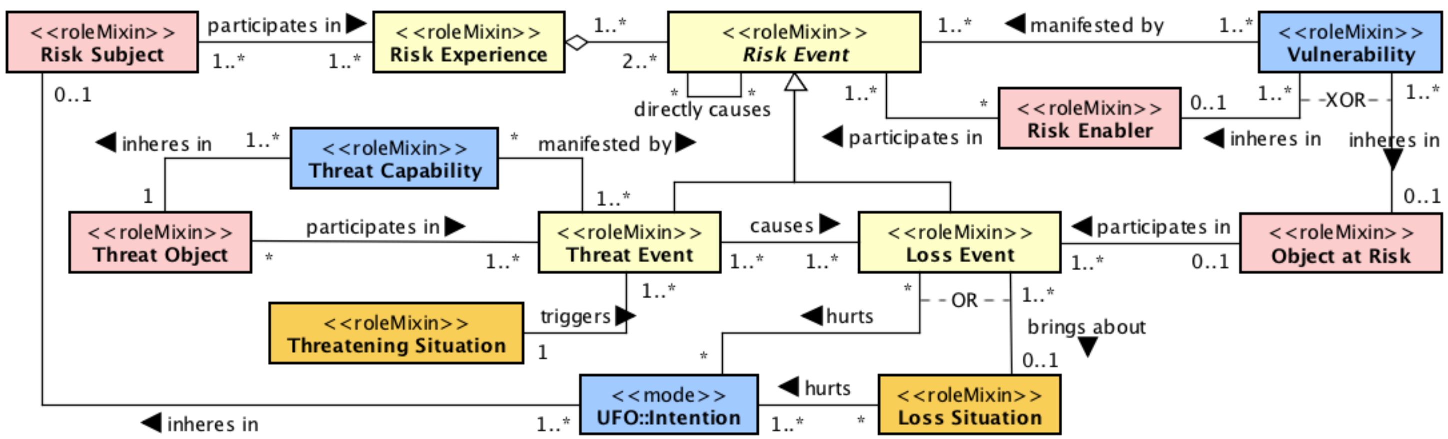

Figure 3.2: Risk experiences, their parts and participants.

component type of a VALUE EXPERIENCE is a TRIGGER EVENT, which is defined by causing, directly or indirectly, events of gain or loss. A second component type is an IMPACT EVENT, which is defined by its impact on INTENTIONS. Note that such an impact might be direct or indirect, and positive or negative. An example of an event with a *direct positive* impact is that of eating which directly satisfies a goal of being fed, while an example of an event with a *direct negative* impact is that of being robbed, which directly hurts the goal of feeling safe. An example an event with an *indirect positive* impact is that of taking a bus, which, upon its completion, will satisfy the goal of arriving at a destination. Lastly, an event with an *indirect negative* impact would be that of having your phone stolen, which puts one in a phone-less situation, which in turn hurts one's goals of contacting people. The difference for RISK EXPERIENCES is that the focus is on unwanted events that have the potential of causing losses. Thus, its components are restricted to THREAT and LOSS EVENTS. A THREAT EVENT is one with the potential of causing a loss, which might be intentional, such as a hacker attack, or unintentional, such as an accidental liquid spill on a computer. LOSS EVENTS are simply *Impact Events* that necessarily impact intentions in a negative way.

In the ontology, we differentiate between several roles played by objects in VALUE and RISK EXPERIENCES. In the value case, we distinguish between VALUE OBJECTS and VALUE ENABLERS. These are the objects whose dispositions "enable" the occurrence of a VALUE EXPERIENCE (or of one of its parts). Their difference is that the former is the focus of a given value ascription (e.g. a car, a music streaming service), whilst the latter plays an ancillary role in VALUE EXPERIENCES (e.g. the fuel in car, the device used for streaming). In the risk case, we distinguish between three roles:

- the THREAT OBJECT, as that which causes a threat;
- the OBJECT AT RISK, as that which is exposed to potential damage; and
- the RISK ENABLER, as that which plays an ancillary role in RISK EXPERIENCES

To exemplify this latter distinction, consider a situation in which a factory worker gets hurt while operating a machine. In this case, the worker is both the THREAT OBJECT and the OBJECT AT RISK, but she only got hurt because her equipment, the RISK ENABLER, was not sturdy enough. Analogously to the value case, the dispositions of all these objects are manifested in risk experiences. Those of Threat Objects, however, are labeled Threat Capabilities (e.g. the skill of a pick-pocketer to swiftly grab a wallet), whilst those of Objects at Risk and Risk Enablers are labeled Vulnerabilities (e.g. the flammability of a house manifested in a fire, a security flaw in an information system which allows hackers to steal sensitive data).

The *relational perspective* is depicted in figures 3.3 and 3.4. We capture it by means of objectified relationships labeled Value Ascription and Risk Assessment, which involve:

- an agent responsible for the judgment, deemed the Value and Risk Assessor respectively; and
- the target of a judgment, either an object or an event.

Judgments made for objects are labeled Object Value Ascription and Object Risk Assessment and involve, respectively, exactly one Value Object and one Object at Risk. Judgments on events are deemed Experience Value Ascription and Experience Risk Assessment, and involve, respectively, one Value Experience and one Risk Experience.

The *quantitative perspective* is also depicted in Figure 3.3 and 3.4. We represent it by means of the Value and Risk qualities inhering in the aforementioned relationships. In UFO, a quality is an objectification of a property that can be directly evaluated (projected) into certain value spaces (Guizzardi, 2005). Common examples include a person's weight, which can be measured in kilograms or pounds, and the color of a flower, which can be specified in RGB or HSV. Thus, representing value and risk as qualities means that they can also be measured according to a given scale, such as a simple discrete scale, such as $< Low, Medium, High >$, or a continuous numeric scale, such as $< 0.0 - 100.0 >$.

Lastly, as discussed in section 3.4, conceptualizing value and risk requires accounting for the likelihood of events, which is typically expressed by probability measures. However, as noted by Aven et al. (2011), there are two conflicting interpretations on the ontological nature of probability:

- the *frequentist* interpretation, in which the probability of an event is the fraction of times an event of that *type* occurs. For example, the likelihood of the Brazil beating Germany in the 2018 World Cup may be calculated based on the number of times it happened in the past; and

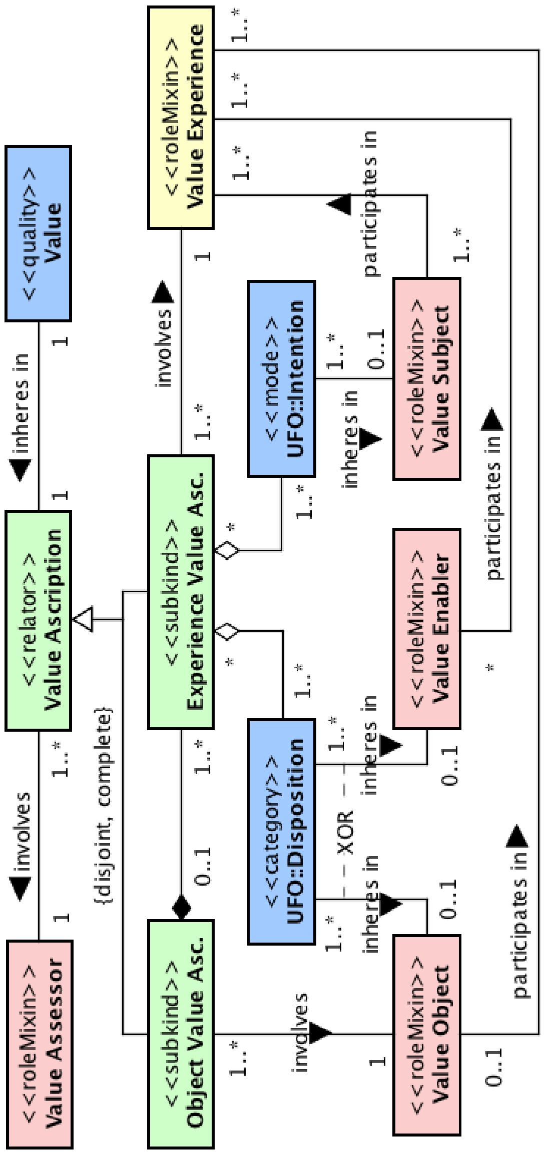

Figure 3.3: Modeling value ascriptions.

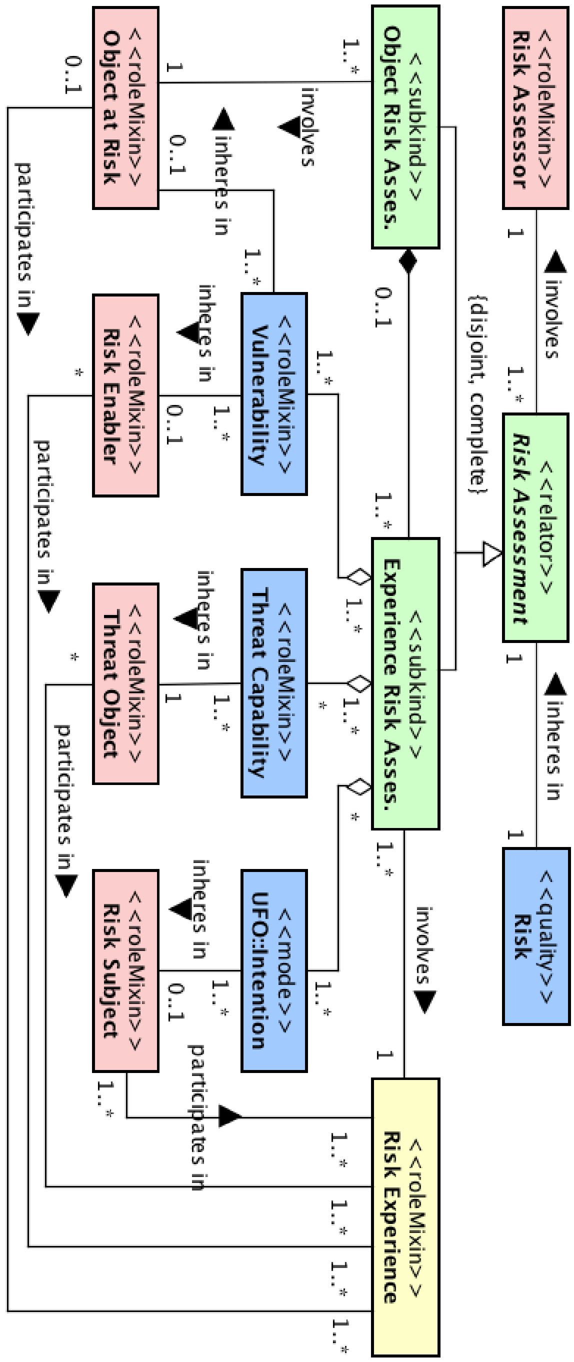

Figure 3.4: Modeling risk assessments.

- the *subjective* interpretation, in which the probability of an event expresses the assessor's uncertainty (degree of belief) of an event to occur, conditioned on some background knowledge. In the World Cup example, the likelihood of a Brazilian victory for a sports analyst depends on her knowledge about the physical conditions of players, the teams' tactics, etc.

Discussing the ontological nature of probability is out of the scope of this paper. For us, it suffices that, in both perspectives, likelihood is a quantitative concept that inheres in *types*, not in individuals. Thus, we need to include types of events and situations in our domain of discourse. We do that by employing the notion of *powertype* incorporated into OntoUML. This means taking its ontological interpretation as proposed by Guizzardi, Almeida, et al. (2015) and following the modeling guidelines proposed by Carvalho et al. (2017). In particular, following the latter, we employ the relation of *categorization* between a *powertype* t and its base type t' such that: a type t categorizes a type t' iff all instances of t are proper specializations of t'.

Figure 3.5 illustrates the excerpt of our ontology w.r.t. the concept of likelihood. We distinguish between a Triggering and Causal Likelihood. The former inheres in a Situation Type and represents how likely a Situation Type will trigger an Event Type once a situation of this type becomes a fact. The latter inheres in an Event Type and captures that, given the occurrence of an event e and a certain Event Type t, how likely e will – directly or indirectly – cause another event of type t to occur. In the value case, how likely a Trigger Event of a Value Experience will cause an Impact Event, whilst on the risk case, how likely a Threat Event of a Risk Experience will cause a Loss Event.

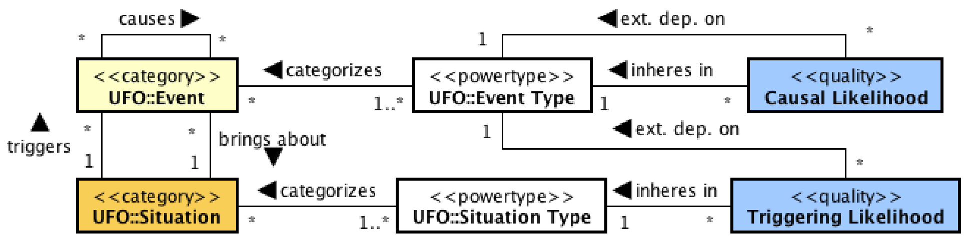

Figure 3.5: Representing likelihood in UFO.

3.6 Implications for Conceptual Modeling

The ontology we proposed in this paper has a number of implications for research on the conceptual modeling of value and risk. First, the ontology can provide well-founded real world semantics for existing risk modeling languages, such as CORAS (Lund et al., 2010), RiskML (Siena et al., 2014), Goal-Risk Framework (Asnar et al., 2011) and Archimate (Band et al., 2017).

Second, following existing methods for ontology-based language evaluation and redesign (Guizzardi, 2005; Rosemann et al., 2004), our proposal can serve as a reference model to assess how well these modeling approaches stand w.r.t to the risk domain in terms of *domain appropriateness* and *comprehensibility appropriateness* (Guizzardi, 2005). More concretely, these methods can be systematically employed for the identification of a number of types of deficiencies that can occur in language design (e.g., *construct deficit* - when there is concept in the domain that does not have a representation in terms of a construct of the language, and *construct overload* - when a construct in the language represents more than a domain concept). For example, such an analysis of RiskML (Siena et al., 2014) would identify a construct deficit with respect to the representation of vulnerabilities, whilst one in the CORAS approach (Lund et al., 2010) would identify a construct deficit regarding the explicit representation of goals. A case of construct overload is also found in ArchiMate (Band et al., 2017), in which the RISK construct collapses: (i) a complex event, (ii) the overall risk an asset is exposed to, and (iii) an assessment regarding what to do about an identified risk.

Third, the ontology we propose allows for the comparison and integration of risk modeling approaches by means of semantic interpretation of the languages' constructs–after all, language integration is a semantic interoperability problem. For instance, the constructs of Threat Scenario and Unwanted Event in CORAS seem to be equivalent to those of Threat Event and Loss Event in Archimate (Band et al., 2017), respectively, which in turn, are all specializations of RiskML's Event.

Languages for modeling use value are much less developed than those for risk. Thus, a relevant impact of this work is to demonstrate that a lot of the effort that has been done on risk modeling could be fruitfully leveraged in developing tools for value modeling. This is a noteworthy impact, given that value modeling approaches are in high demand, as evinced by the increasing popularity of tools such as the Business Model Canvas (Osterwalder and Pigneur, 2010) and the Value

Proposition Canvas (Osterwalder, Pigneur, et al., 2014).

3.7 Final Remarks

In this paper, we have presented an ontological analysis of risk which explicits the deep connections between the concepts of value and risk. The ontology that resulted from this analysis formally characterizes and integrates three different perspectives on risk:

- risk as a *quantitative notion*, which we labeled simply as Risk in our ontology;
- risk as a *chain of events that impacts on an agent's goals*, which we labeled as Risk Experience; and
- risk as a *relationship of ascribing quantitative risk*, which we labeled as Risk Assessment.

Moreover, this paper further extends the ontological analysis on use value initiated by Andersson, Guarino, et al. (2016) and revisited by Sales, Guarino, et al. (2017a), improving them by:

- discussing how likelihood influences value;
- refining the internal structure of value experiences and their participants;
- clarifying the role of dispositions in value creation; and
- distinguishing between value objects and value enablers.

We are aware, however, that the current ontology does not fully describe the domain of risk management, as it lacks security-related concepts such as *mitigation* and *control strategies*. These are recurrently found in risk modeling languages (Band et al., 2017; Lund et al., 2010), as analysts do not just need to identify and model risks, but also decide on how to address them. As future work, we plan to extend and further validate our ontology with risk analysis experts from different domains, such as finance and software development. We also plan to validate it by means of systematic comparisons with other theories and formalizations of risk. Then, we can leverage it to analyze the domain adequacy of existing risk modeling languages and, if needed, redesign them so that they are clearer and more expressive to model risks.

Chapter 4

A Pattern Language for Value Modeling in ArchiMate

In recent years, there has been a growing interest in modeling value in the context of Enterprise Architecture, which has been driven by a need to align the vision and strategic goals of an enterprise with its business architecture. Nevertheless, the current literature shows that the concept of value is conceptually complex and still causes a lot of confusion. For example, we can find in the literature the concept of value being taken as equivalent to notions as disparate as goals, events, objects and capabilities. As a result, there is still a lack of proper support for modeling all aspects of value as well as its relations to these aforementioned notions. To address this issue, we propose in this paper a pattern language for value modeling in ArchiMate, which is based on the Common Ontology of Value and Risk, a well-founded reference ontology developed following the principles of the Unified Foundation Ontology. This enables us to delineate a clear ontological foundation, which addresses the ambiguous use of the value concept. The design of the Value Pattern Language will be guided by the Design Science Research Methodology. More specifically, a first iteration of the build-and-evaluate loop is presented, which includes the development of the pattern language and its demonstration by means of a case study of a low-cost airline.

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4.1 Introduction

In the last decades, several value modeling languages have been introduced, such as *e³value* (Gordijn and Akkermans, 2003) and VDML (OMG, 2018). However, it is only recently that there is an interest in modeling value in the context of Enterprise Architecture (EA) (Svee and Zdravkovic, 2015). This integration is important as the concept of value enables to bridge the gap that exists between the goals that an organization wants to achieve and the processes that are needed to achieve these goals (Andersson, Johannesson, et al., 2009). In other words, the notion of value enables the alignment of the Architecture Vision with the Business Architecture of an organization (Svee and Zdravkovic, 2015), which is needed for a company to deliver a positive end-to-end experience to their customers (Kalbach, 2016).

Despite this growing interest, it is largely recognized that value is a polysemic *term* (Boztepe, 2007; Vargo et al., 2008) that might refer to several conceptually complex phenomena for which there has not been shared agreement. This issue is evinced in the current proposals to model value in ArchiMate (The Open Group, 2017). For instance, value has been described as:

- a *goal*, such as “Being insured” (Aldea et al., 2015), “Anonymity” (Feltus et al., 2018), “Security”(Meertens et al., 2012);
- a *value object*, as in “Warehouse Space” (Singh et al., 2014);
- an *event*, such as “Payment” (Aldea et al., 2015); and
- a *capability*, such as “Computer Skills” (Singh et al., 2014).

To address this ambiguity, a value modeling approach for ArchiMate should be based on a proper ontological theory, which provides adequate real-world and formal semantics for such a language’s vocabulary (Guizzardi, 2005). In particular, we make use of the concepts and relations defined in the Common Ontology of Value and Risk (COVER) (Sales, Baião, et al., 2018), a novel well-founded reference ontology that explains value and risk as two ends of the same spectrum. As we elaborate in subsection 4.2.2, COVER is grounded on several theories from marketing, service science, strategy and risk management, and it is specified in OntoUML (Guizzardi, 2005), thus being compliant with the meta-ontological commitments of the Unified Foundational Ontology (Guizzardi, 2005).

Based on COVER, we propose a Value Pattern Language (VPL) for ArchiMate that consists of a set of interrelated modeling patterns. ArchiMate was chosen as it is a widely used modeling standard in the EA field, which is also aligned to the TOGAF standard (The Open Group, 2018). The advantage of a pattern language (Buschmann et al., 2007) is that it offers a context in which related patterns can be combined, thus, reducing the space of design choices and design constraints (Falbo et al., 2016).

We designed VPL according to a first cycle of Design Science Research (Hevner et al., 2008). As a first step in the design, a set of requirements is identified for the language (subsection 4.3.1). These requirements ensure that the contribution of this paper is clear and verifiable, and they are needed for a formal evaluation of the language (Hevner et al., 2008). Afterwards the individual modeling patterns that compose VPL are presented (subsection 4.3.3), as well as method for combining them (subsection 4.3.4). We demonstrate how the VPL can be used using the case example of a low-cost airline (section 4.4). The actual evaluation of the VPL is outside the scope of this paper, but it will be addressed by future research.

4.2 Research Baseline

4.2.1 ArchiMate

ArchiMate is a modeling standard to describe the architecture of enterprises (The Open Group, 2017). The language is organized in six layers, namely Strategy, Business, Application, Technology, Physical, and Implementation & Migration (The Open Group, 2017). For this paper, only elements of the Strategy and Business layers are particularly relevant. Each element is classified in the language according to its nature, referred to as "aspect" in ArchiMate: a Behavior Element represents *a unit of activity performed by one or more active structure elements*, an Active Structure Element represents *an entity that is capable of performing behavior*, a Passive Structure Element represents *a structural element that cannot perform behavior*, a Motivation Element is one that *provides the context of or reason behind the architecture of an enterprise*, and a Composite Element is simply one that aggregates other elements.

Table 4.1 lists the most relevant ArchiMate elements and relations for the VPL. The underlying logic for the relevance of each concept in this paper can be found in subsection 4.3.2. We refer the reader to the ArchiMate specification for a detailed definition of the concepts (The Open Group, 2017), while their concrete syntax can be inferred from the patterns in subsection 4.3.3.

Table 4.1: Overview of the relevant ArchiMate concepts for the VPL.

Type	**Elements**
	Concepts
Motivation	Stakeholder, Driver, Assessment, Goal, Value
Structure	Resource
Behavior	Capability, Business Process, Business Interaction, Business Event
Composite	Grouping
	Relations
Structure	Composition, Realization
Dependency	Influence
Dynamic	Triggering
Other	Association

4.2.2 COVER: Common Ontology of ValuE and Risk

The Common Ontology of Value and Risk (COVER) (Sales, Baião, et al., 2018) formalizes a particular sense in which the term value is used, namely that of *use value*. Briefly put, use value is the quality that summarizes a utility assessment of an object or experience from the perspective of a given subject. This is the meaning of value in sentences such as “A waterproof jacket is valuable when in a rainy city” and “A messenger app that no one uses is of no value to anyone”. The notion of use value should not be confused with those of exchange and ethical value, which are also frequently used in daily life. The former refers to the worth of something in the context of an exchange and is usually measured in monetary terms (e.g. a startup valuated at €1.000.000). The latter refers to a high-level constraint that guides the behavior of individuals, as in “one of Google’s core values is that Democracy on the web works”.

COVER makes the following ontological commitments on the nature of value:

- **Value emerges from goal satisfaction.** Value emerges from events that affect the degree of satisfaction of one or more goals of an agent. For example, sunscreen is valuable to a tourist in a hot summer day at the beach, as it allows to achieve the goal of protection from ultraviolet radiation–and thus premature aging.

- **Value is neither "good" or "bad".** Even though people intuitively assume a positive connotation for the term value, use value emerges from events that impact goals either positively or negatively. For instance, consider an event in which Vittoria drops and breaks her new phone. Assuming she had the goal of keeping it intact so she could text her friends, the break event has hurt her goal, and thus has a negative value for her.
- **Value is relative.** The same object or experience may be valuable to a person and of no value to another. For instance, a cigarette has value for a smoker and virtually no value for a non-smoker.
- **Value is experiential.** Even though value can be ascribed to objects, it is ultimately grounded on experiences. For instance, in order to explain the value of a smartphone, one must refer to the experiences enabled by it. These could include sending a text message, watching a video, or paying a bill via a banking app. Then, by valuating each experience and aggregating them according to a given function, one can "compute" the smartphone's value.
- **Value is contextual.** The value of an object can vary depending on the context in which it is used. Consider a winter jacket, for instance. If worn in a cold evening in the Italian Dolomites, it creates value by protecting one from the cold. Conversely, if worn on a warm day, it is of little use.

The aforementioned ontological commitments are captured in the COVER diagrams presented in figures 4.1 and 4.2. The former is centered around the experiences that create value. It depicts the VALUE SUBJECT class as the role played by an AGENT from whose perspective a value ascription is made. If the target of such an ascription is an object, it is said to play the role of a VALUE OBJECT. Conversely, if the target is an event, it is said to play the role of a VALUE EXPERIENCE. Naturally, a VALUE EXPERIENCE involves VALUE SUBJECTS and VALUE OBJECTS as participants. Additionally, it can also involve other objects, which are labelled VALUE ENABLERS. These allow the ontology to represent participants which contribute to or are necessary for an experience, but are not the focal targets of a given valuation. Examples include a browser application, which someone needs to navigate on the internet using a computer, or a road, on which

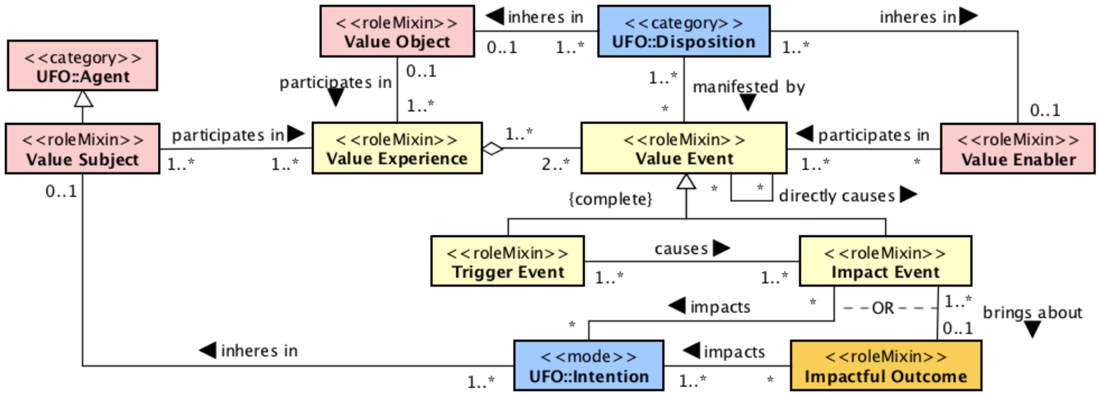

Figure 4.1: A fragment of COVER on value experiences, their parts and participants.

someone drives a car. COVER breaks down Value Experiences into "smaller" events, dubbed Value Events. These are classified into Impact and Trigger Events. The former are those that directly impact a goal or bring about a situation (named Impactful Outcome) that impacts a goal. On contrast, Trigger Events are simply parts of an experience that are identified as causing Impact Events, directly or indirectly. To formalize goals, COVER reuses the concept of Intention from UFO (Guizzardi, Falbo, et al., 2008), as a type of mental state that describes a class of state-of-affairs that an agent, the Value Subject in our case, is committed to bring about.

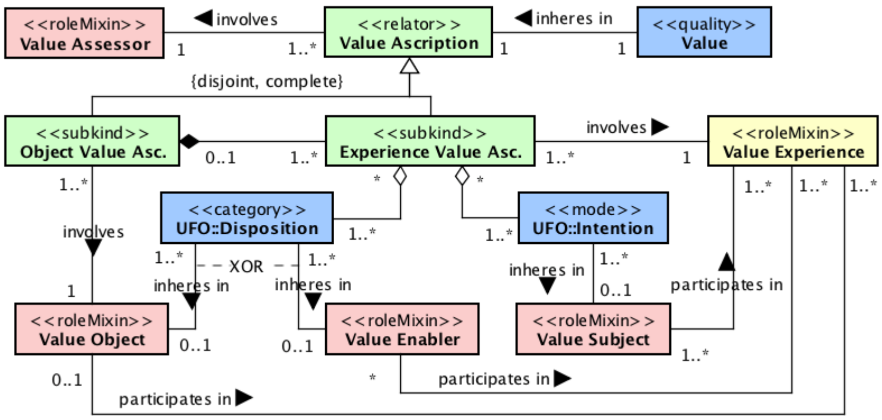

Figure 4.2: A COVER fragment formalizing relationships of value ascription.

The diagram in Figure 4.2 is centered around the Value Ascription relationship, which represents an assessment made by an Agent, the Value Assessor, that "attaches" a quality VALUE to a given VALUE OBJECT or EXPERIENCE from the perspective of a VALUE SUBJECT. As COVER commits to grounding value on experiences, it distinguishes between OBJECT- and EXPERIENCE VALUE ASCRIPTION relationships, with the former being composed by the latter.

4.2.3 Patterns and Pattern Languages

A *modeling pattern* describes a situation-independent well-proven solution to a recurring modeling problem. Its use favors the reuse of encoded experiences and good practices. As discussed in depth by Falbo et al. (2016), a particular modeling pattern of interest is an Ontology Design Pattern (ODP). The authors demonstrate that ODPs can be systematically extracted from so-called core ontologies, i.e., ontologies that capture phenomena that are recurrent in a number of domains.

As pointed out by Alexander et al. (1977), each pattern can exist only to the extent that it is supported by other patterns. According to Schmidt et al. (2000), in Software Engineering (SE), the trend is defining pattern languages, rather than stand-alone patterns. The term "pattern language" in SE refers to a network of interrelated patterns that defines a process for systematically solving coarse-grained software development problems (Schmidt et al., 2000). Falbo et al. (2016), make a case demonstrating the viability and benefits of this approach for conceptual model engineering. As shown there, from a core ontology, one can systematically extract a set of ODPs as well as their ties (comprising relations of aggregation, precedence, dependence, mutual exclusion, etc.). Languages that prescribe how ODPs extracted from the same core ontology can be used together are termed Ontology Pattern Languages (OPLs). The method proposed by Falbo et al. (2016) has been successfully employed to construct OPLs for the modeling of Enterprises, Services, Software Processes, among others. Following this method, in next section, we propose a Pattern Language for Value Modeling.

4.3 A Pattern Language for Value Modeling

4.3.1 Language Requirements

In the context of modeling language design, it is useful to identify two types of requirements. The first, named an *analysis requirement*, refers to what the models produced with the language should help users to achieve, either by means of automated or manual analysis. The second, named an *ontological requirement*, refers to the concepts and relations the language should have in order to accurately represent its domain of interest and thus support its intended uses. Let us consider a case for ArchiMate to exemplify these notions. By allowing the representation of how the various elements of an architecture are related, such as services being realized by business processes, which in turn are supported by applications (an ontological requirement), ArchiMate allows users to perform an impact-of-change analysis (an analysis requirement) (Lankhorst, M. et al., 2013).

For the VPL, we established the following *analysis requirements*:

R1. *Design-time value analysis*: An enterprise should be able to understand how it creates value for a given stakeholder, as well as identify opportunities to improve its offerings so that it can maximize value creation.

R2. *Run-time value analysis*: An enterprise should be able to identify which indicators it needs to monitor value creation for a given stakeholder, so that it can detect deviations from planned experiences, as well as identify opportunities for innovation.

R3. *Competitive analysis*: By modeling the value experiences an enterprise offers to its customers and those of its competitors, an enterprise should be able to identify its competitive advantages.

Given that we are leveraging COVER for the design of the VPL, its ontological requirements are fairly straightforward, i.e., they consist of an isomorphic representation of all concepts and relations defined in the ontology (Guizzardi, 2005). In addition to the aforementioned requirements, we assumed the following *constraints* for the VPL:

R4. It should rely exclusively on constructs available in ArchiMate 3.0.1(The Open Group, 2017). This is to avoid adding to the complexity of the language.

R5. It should map value-related concepts into ArchiMate constructs maintaining, as much as possible, their original meaning as described in the standard. Stereotypes should only be used if strictly necessary to refine the meaning of particular constructs.

4.3.2 Mapping

Table 4.2 shows the mapping of COVER concepts into ArchiMate elements.

Table 4.2: Representation of value-related concepts in ArchiMate.

Concept	**Representation in ArchiMate**
Value Subject	Stakeholder
Value Object	Structure Element connected to a «ValueExperience»
Value Enabler	Structure Element connected to a Value Event
Value Experience	«ValueExperience» Grouping
Value Event	Business Process, Business Interaction, Business Event
Disposition	Capability
Quality	«Quality» Driver
Intention	«QualityGoal» Goal, «FunctionalGoal» Goal
Value	Value
Value Assessor	Stakeholder connected to a «Valuation»
Obj. Value Ascription	«Valuation» Assessment connected to a Value Object
Exp. Value Ascription	«Valuation» Assessment connected to a «ValueExperience»
Triggering Likelihood	«Likelihood» Assessment connected to a triggering association
Occurrence Likelihood	«Likelihood» Assessment connected to a «ValueExperience»

4.3.3 Value Modelling Patterns

Value Object

This pattern allows modelers to express which object will be the focus of a valuation, as well as which kind of experiences enabled by the object are being considered to deduce its value. Its generic structure is depicted in Figure 4.3. It consists of a Structure Element–the Value Object–connected to a «ValueExperience» Grouping that realizes a «FunctionalGoal» Goal and for which there is a «Likelihood» Assessment. The likelihood element allows modelers to represent how frequent an experience involving the value object will occur. This assessment serves as a "weight" to the overall use value of an object.

We suggest that modelers represent one experience per type of goal that someone can accomplish with a given value object. For instance, if the value object under analysis is a car, the experiences could include driving it to work, to travel, or to buy groceries. If relevant, modelers can also represent multiple experiences that fulfill the same goal, but that take place in different contexts, such as travelling by car through highways or through dirt roads in the countryside.

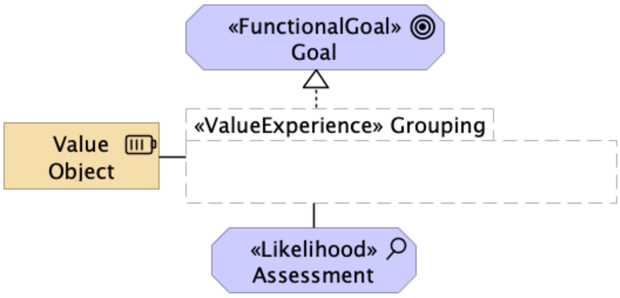

Figure 4.3: Generic structures of the Value Object pattern.

Value Experience

This pattern refines the former w.r.t detailing value experiences. As depicted in Figure 4.4, it consists of «ValueExperience» Grouping connected to a Stakeholder acting as the value subject, and its decomposition into value events, which can be represented using Business Processes, Business Events and/or Business Interactions.

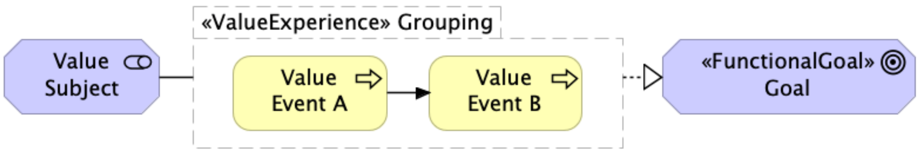

Figure 4.4: Generic structures of the Value Experience pattern.

This pattern is neutral with regard to the level of detail at which an experience is modelled. For instance, let us consider the experience of a football fan watching a match at a stadium. It could simply include the events of going to the stadium, watching the match, and then going home. Alternatively, it could be further detailed to account for the ticket purchase, the movement within the stadium to find one's designated seat, and the consumption of food and drinks. Still, note that the more an experience is detailed, the more accurate is the value creation description, and thereby, more insights can be obtained.

Value Subject

In order to account for what creates value for a given stakeholder, we introduce the Value Subject Pattern, as depicted in Figure 4.5. It allows one to represent every relevant GOAL of a STAKEHOLDER, as well as to specify their importance by means of a numeric REWARD attribute (represented in the figure between brackets for clarity). Adding "weights" to goals is a modeling strategy that has shown to be very useful for analyzing models, such as the optimization algorithms proposed by Nguyen et al. (2018). Moreover, to represent the various goals of a value subject in a more compact manner, we propose to represent them within a «Motivation» GROUPING associated to their owner. This modeling strategy is directly inspired by those proposed in goal modeling languages, such as i* (Yu et al., 2011).

Note that we differentiate between functional and quality goals, following the semantics proposed by Guizzardi, Li, et al. (2014). Simply put, functional goals refer to what change in the state-of-affairs an agent wants to bring about, while a quality goal refers to how this change should occur. For instance, traveling to a destination is a functional goal, while doing so in less then two hours is a quality goal. One should note that this distinction is not equivalent to that of hard and soft goals. This second classification refers to how clearly a goal is defined, and thus, is orthogonal to the former. Our previous example of traveling under two hours is considered a hard goal, whilst traveling quickly is a soft goal.

Figure 4.5: Generic structure of the Value Subject Pattern.

We are aware that providing concrete values for rewards given by goals is challenging. Such numbers may feel artificially chosen and contradictions may quickly arise. Nonetheless, it is fundamental to be able to articulate the motivations driving different stakeholders. To explain why, let us consider customers of low-cost and regular airlines. All of them want to reach their destination, have a comfortable trip, and minimize their financial efforts. However, customers of low-cost airlines prefer to minimize their financial efforts over having a comfortable trip, i.e. they ascribe a higher reward to the former goal than to the latter. To help modelers define these rewards, we suggest the use of prioritization techniques, such as the Analytic Hierarchy Process (AHP) (Roelens et al., 2017).

Value Event

Given that we described the motivation driving a value subject, we go back to the description of value experiences. In order to account for how parts of an experience affect goals, and thus, increase or reduce its value, we propose the Value Event Pattern. Its three variants are presented in Figure 4.6.

The first variant, depicted in Figure 4.6a, has a very simple structure, consisting of a value event associated to a «FunctionalGoal» GOAL by means of a REALIZATION relation. One could use this variant to represent that the event of watching a movie realizes the goal of being entertained.

The second variant, depicted in Figure 4.6b, has a more complex structure. It consists of a value event, a «QualityGoal» GOAL, a «Quality» DRIVER and a quality ASSESSMENT. The value event INFLUENCES the GOAL (either positively or negatively) because the magnitude of one of its qualities is directly related to the satisfaction of the goal. For instance, consider the event of waiting in line at the post office. Since most people want to minimize the time they waste doing chores, its satisfaction is directly related to the duration of the waiting event.

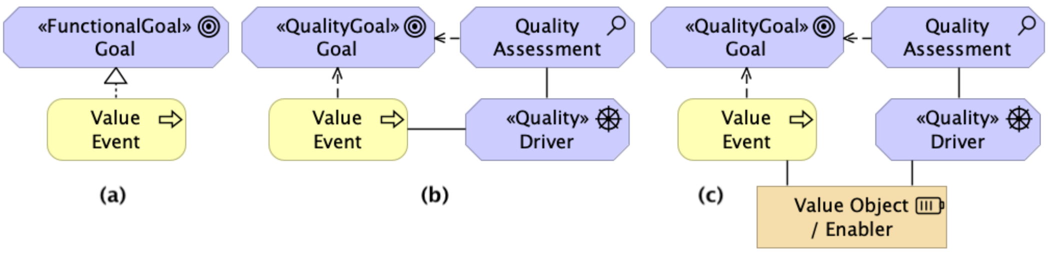

Figure 4.6: The three variants of the Value Event pattern.

In the third variant, depicted in Figure 4.6c, the quality related to the satisfaction of a goal does not inhere in the event, but in one of its participants. Let us consider again the post office case. One's value perception of such an experience is also influenced by qualities like the politeness of the post office attendants, the number of seats available in the waiting room, and the number of complaints being made by other customers.

Lastly, notice that none of the value event pattern variants include the participation of the value subject. That is simply because it would render the model too verbose. Instead, we propose generalize the participation of the value subject to the value experience (as presented in the Value Experience Pattern).

Disposition

This pattern further characterizes value events, in the sense of accounting for what allows them to happen (ontologically, events are always manifestations of dispositions). As shown in Figure 4.7, it consists on modelling the dispositions (i.e., CAPABILITIES in ArchiMate) whose manifestations are the value events, as well as the value objects or enablers, in which these dispositions inhere. This pattern allows one to represent that a banking app has capabilities to enable customers to check their balance and make payments. It also allows the representation of dispositions that are manifested as unwanted value events, such as a car that has a disposition to overheat.

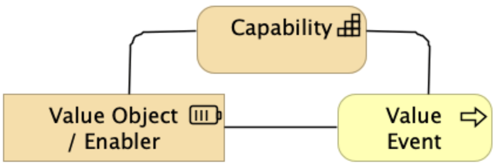

Figure 4.7: Generic structure of the Disposition pattern.

Causality

This pattern connects value events that composed a value experience to allow its characterization as an ordered sequence of steps. Its general structure, depicted in Figure 4.8, consists of two value events connected by a TRIGGERING relation, for which a «Likelihood» ASSESSMENT is made. This means that a value event has a probability to cause (or be followed by) another value event. To exemplify this pattern, let us consider the experience of using an on-demand video streaming service. A modeler could use this pattern to represent that after choosing a movie on the platform library, a viewer actually watches it, or that while watching, there is a chance that the viewer dislikes it and then proceeds to search for an alternative content to watch.

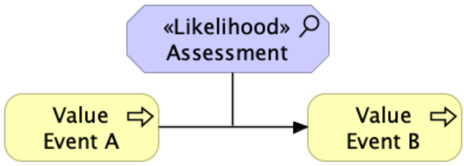

Figure 4.8: Generic structure of the Causality pattern.

Experience Valuation

This pattern allows modelers to describe value judgments made towards experiences. As shown in Figure 4.9, it consists of a «Valuation» ASSESSMENT made by a STAKEHOLDER that a «ValueExperience» GROUPING creates VALUE for another STAKEHOLDER. Note that the actual VALUE element here is not described in textual terms, but rather as an entry in a scale chosen by the modeler. Just as we are used to see in risk management methodologies, value can be described using a simple discrete scale, such as $< Low, Medium, High >$, or using a continuous numeric scale, as in <from 0.00 to 100.00>.

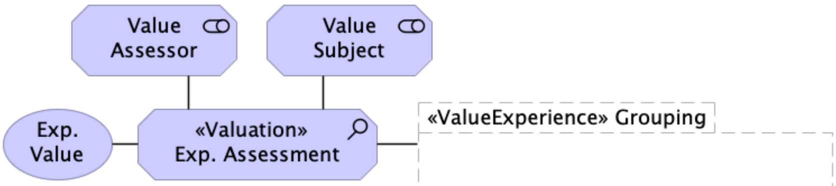

Figure 4.9: Generic structure of the Experience Valuation pattern.

Object Valuation

The last VPL pattern is very similar to the previous one, as it also represents a value judgment. The difference is that the judgment is made towards a value object, as seen in Figure 4.10. As we previously discussed, the value ascribed to objects is computed from the experiences they afford. Thus, a «Valuation» ASSESSMENT associated to a value object is composed by «Valuation» ASSESSMENTS associated to «ValueExperience» GROUPINGS that are associated to the focal value object. We also represent a derived INFLUENCE association between the VALUE attached to each ASSESSMENT, so that we can clearly see the process of value aggregation.

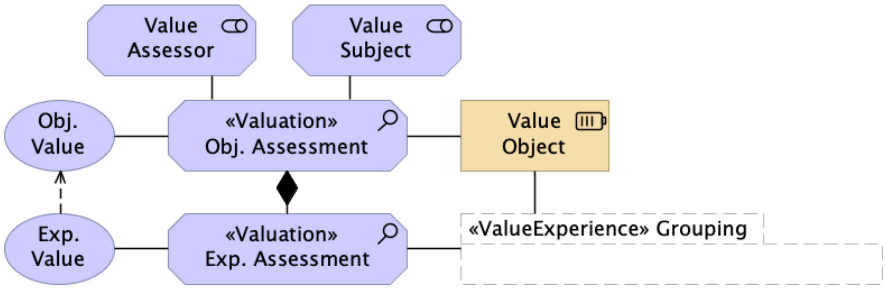

Figure 4.10: Generic structure of the Object Valuation pattern.

4.3.4 Combining the Patterns

As proposed by Falbo et al. (2016), there might be multiple entry points for one to start using a pattern language. In the case of VPL, as depicted in figures 4.11 and 4.12, a modeler may start with the application of:

1. the Value Object pattern, if the valuation focus is an object (e.g. a product offered by the enterprise or a resource owned by it);
2. the Value Experience pattern, if the valuation focus is an experience (e.g. a service provided by the enterprise); or
3. the Value Subject pattern, if the focus is the value perceived by a stakeholder in multiple contexts (e.g. as a partner and as a provider).

When starting with a Value Object pattern, a user may iteratively apply it to account for the relevant ways in which an object can create value, as well as in which contexts it may do so. Each application should be followed by that of the Value Experience. Then, for every experience, the user should iteratively apply the three patterns that detail the inner structure of a value experience: the Value Event, Disposition, and Causality patterns.

For each detailed experience, the modeler should apply the Experience Valuation pattern in order to represent its value for the chosen value subject. If one is valuating an object, the Object Valuation pattern should be used to group the experience valuations, and thus derive the aggregate value of the object.

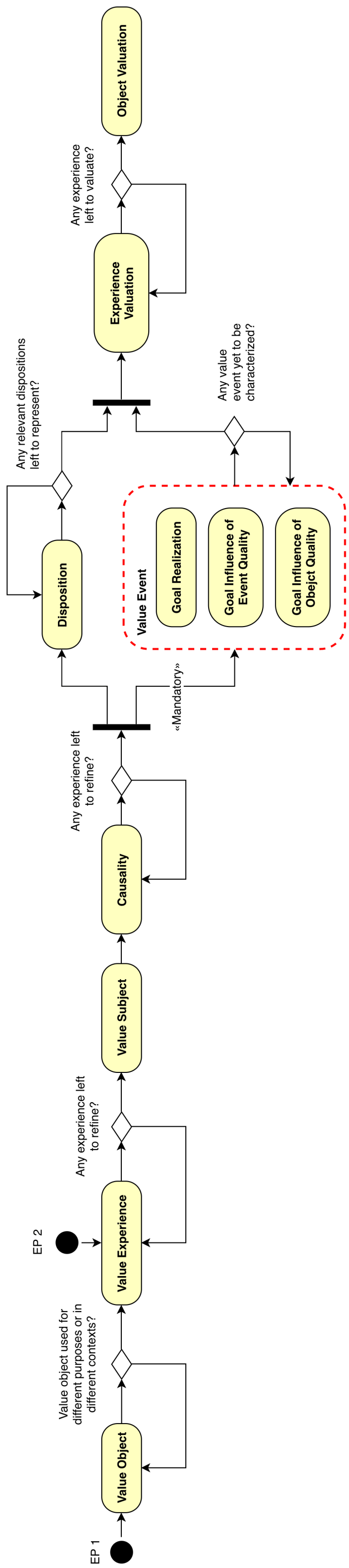

Figure 4.11: VPL application process from entry points 1 and 2.

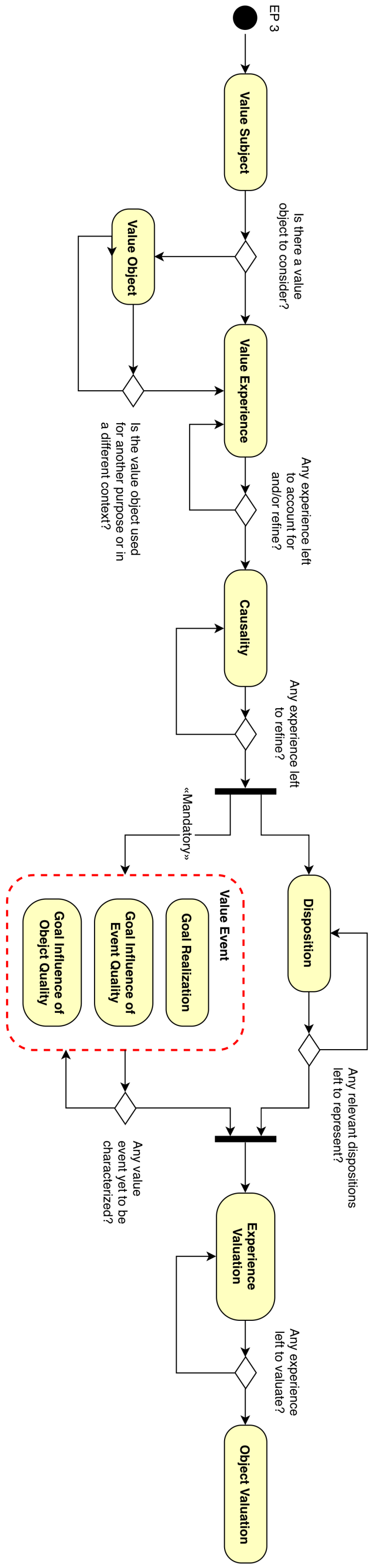

Figure 4.12: VPL application process from entry point 3.

4.4 Case Study

We now present a realistic case study in which we use the VPL to describe how a low-cost airline creates value for its customers. In particular, we model the experience of flying with such a company following a customer journey mapping approach (Kalbach, 2016), a marketing framework that proposes to map, evaluate and redesign customers' experiences when engaging with companies. Given the limited space available, we only present relevant fragments of the resulting model. The complete case study is available at `https://github.com/ontouml/vpl`.

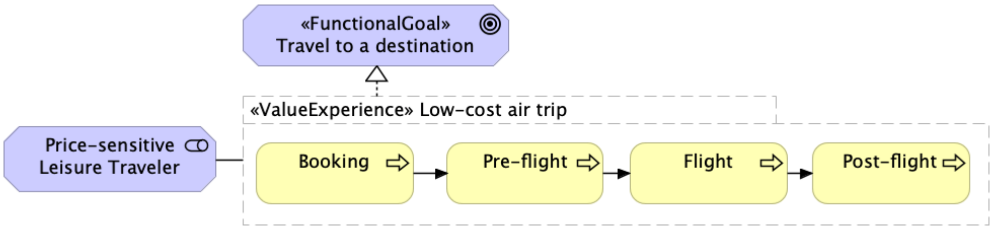

Figure 4.13: Usage of the Value Experience pattern.

Since our case focuses on an experience, rather than a product, we start with the application of the Value Experience pattern, as shown in Figure 4.13. As the value subject, we use a persona that exemplifies the prototypical customer of a low-cost airline, here named PRICE SENSITIVE LEISURE TRAVELER. Naturally, the main functional goal of air travelling is to TRAVEL TO A DESTINATION, and thus, we represent it as the goal the experience realizes. We also decompose the experience into 4 main steps: BOOKING, PRE-FLIGHT, FLIGHT and POST-FLIGHT.

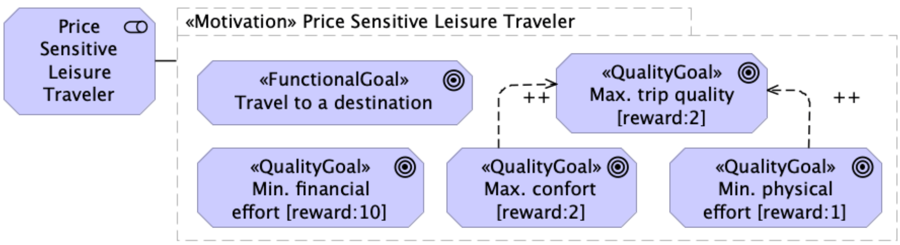

Figure 4.14: Application of the Value Subject pattern.

In order to describe how our subject perceives value, we apply the Value Subject pattern, as depicted in Figure 4.14. In addition to the travelling goal, we assume that the subject wants to minimize her efforts, both monetary and non-monetary.

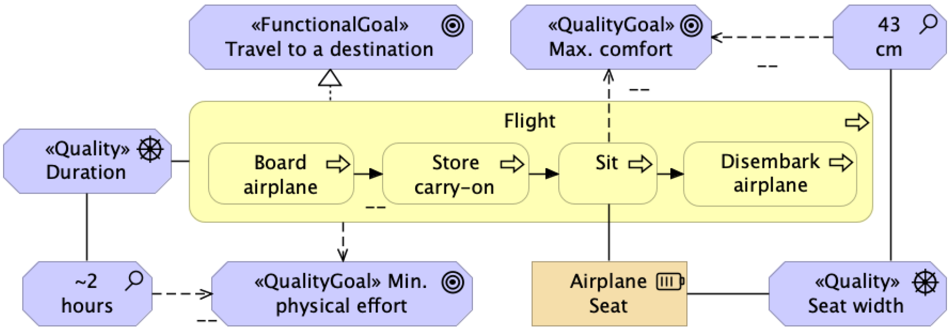

Figure 4.15: Application of all three variants of the Value Event pattern.

The former refers to how much she pays to book a flight, choose a seat, and dispatch her luggage, whilst the latter refers to any physical, emotional, cognitive or time effort (Clark and Bryan, 2013) she has to endure throughout her experience. To each goal, we ascribe a reward between 1 and 10, which reflects their importance to the subject. This prioritization evinces that the subject rather prefers to minimize her financial effort than to enjoy a high quality trip.

We now further detail the travelling experience by applying the Value Event pattern three times, as depicted in Figure 4.15. We first use the pattern to represent that the Flight process realizes the traveling goal. Then, we apply it to express that the Duration of the flight is inversely related to the satisfaction of the goal of minimizing physical effort. Lastly, we apply it to represent that, the width of the Airplane Seat negatively impacts the subject's comfort goal.

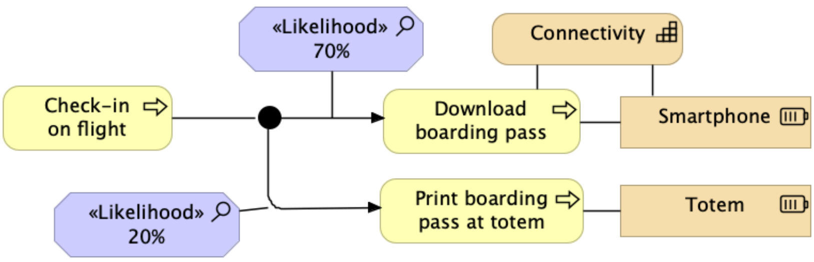

Figure 4.16: Usage of the Causality and of the Disposition pattern.

Using the Causality pattern, we represent alternative paths the air traveling experience can take. In Figure 4.16, we present a refinement of the Pre-Flight step that captures a choice the subject can make after checking in on the flight. She can either download her boarding pass on a smartphone or print it at a totem the airline provides at the airport. Moreover, we use the Disposition pattern to model that the Download boarding pass process depends on the Smartphone, a value enabler, having a Connectivity disposition to access the internet.

Lastly, we demonstrate the application of the Experience Valuation pattern in Figure 4.17. With it, we express that a Customer Experience Analyst, an employee of the low-cost airline, judges that our subject, the Price Sensitive Leisure Traveler ascribes a High value to the low-cost traveling experience.

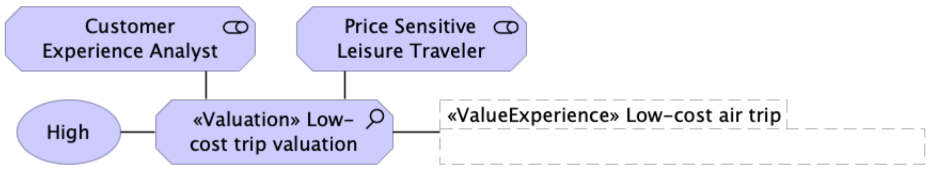

Figure 4.17: Application of the Experience Valuation pattern.

4.5 Related Work

In the last 10 years, several works aimed to incorporate value modeling in ArchiMate, evincing a clear recognition by the research community that the language's does not properly handle this domain. The first of these works was put forth by Iacob et al. (2012), who proposed to extend ArchiMate 2.0 so that it could model strategy- and value-related constructs. As we did, the authors also argue for a relative perspective on value, although it is not clear if they mean taking the perspective of the value subject or the assessor. They also explicitly relate value and risk, although they do not elaborate on the relation itself. Nonetheless, compared to this paper, an interesting aspect of their proposal is to model value from a quantitative perspective, one that is often neglected in the literature.

A second extension was proposed by Aldea et al. (2015). In their work, the authors are clearly concerned with properly grasping the nature of value, as they recognize the difference between use and exchange value. They account for the relative notion of use value by representing it as being perceived by a stakeholder, as well as the relation between value and goals. Nonetheless, the lack of clearly defined ontological foundations hinders the clarity of their proposal, as the authors seem to contradict themselves by using the value element in the sense of a goal ("Being insured") and in the sense of a value creating event ("Payment").

More recently, Feltus et al. (2018) introduced a value co-creation extension for ArchiMate. They grounded their proposal on the Value Co-creation Ontology, a reference ontology designed from a Service-dominant Logic perspective that formalizes the concept of use value. Despite their more narrow focus on co-creation, the authors also assume a relative view on value, by representing that it benefits some stakeholder. They do distinguish between value, the events that create value, and the participating objects, although their interrelations are not clearly characterized. A noteworthy caveat to their proposal, however, is the omission of goals to characterize value.

Singh et al. (2014) introduced a method based on *e³value* (Gordijn and Akkermans, 2003) to design a Value Creation view for ArchiMate. Their work differs significantly from what we propose here, as the conceptual foundation of their work, i.e. *e³value*, aims at modeling the exchange of value objects between economic agents. Their work focuses on *what* has value, as evinced by their use of "Warehouse Space" as a value element, whereas we focus on *what*, *why* and *how* things have value.

Lastly, Meertens et al. (2012) mapped the Business Model Ontology (BMO) into ArchiMate. The authors did not aim to model value *per se*, as BMO has a much broader scope. Nonetheless, since one of the core components of a business model is its value proposition, they had to propose a representation for value in ArchiMate. It basically consisted in a high-level goal, which as we discussed in this paper, is necessary but not sufficient to model value.

4.6 Final Remarks

In this paper, we introduced VPL, a pattern language for modeling value in ArchiMate that is based on the Common Ontology of Value and Risk (COVER). We presented the first iteration of the build-and-evaluate loop, which consisted in the development of the language and its demonstration by means of a case describing the value perceived by customers of a low-cost airline.

By deriving the proposed patterns from COVER, we provided clear real-world semantics for its constituting elements, thus reducing the ambiguity and conceptual complexity found in previous value modeling approaches. In particular, we can represent: (i) *what* we can ascribe value to–objects and events; (ii) *why* these have value–because of their impact on goals; (iii) *how* value emerges–by means of value experiences that are composed of value events; and (iv) *who* participates in a value ascription–value subjects and assessors. As future work, we plan to thoroughly evaluate VPL by assessing its applicability in real cases.

Chapter 5

Ontological Analysis and Redesign of Risk Modeling in ArchiMate

Risk analysis is a complex and critical activity in various contexts, ranging from strategic planning to IT systems operation. Given its complexity, several Enterprise Architecture (EA) frameworks and modeling languages have been developed to help analysts in representing and analyzing risks. Yet, the notion of risk remains overloaded and conceptually unclear in most of them. In this paper, we investigate the real-world semantics underlying risk-related constructs in one of such approaches, namely ArchiMate's Risk and Security Overlay (RSO). We perform this investigation by means of ontological analysis to reveal semantic limitations in the overlay, such as ambiguity and missing constructs. Building on the results of this analysis, we propose a well-founded redesign of the risk modeling aspects of the RSO.

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5.1 Introduction

Risk is an inherent aspect of many human endeavors. Since risks often threaten an enterprise's ability to achieve its goals, risks are frequently subject to scrutiny and mitigation in enterprises, under the banner of risk management. Risk management involves a complex number of activities that include identifying, understanding, assessing and addressing potentially unfavorable prospects. It is widely accepted as a business-critical activity in various contexts, ranging from strategic planning to IT systems operation.

Given the importance of risk management to business success, it is no surprise that risk-related concepts have made their way in to Enterprise Architecture (EA) frameworks and modeling languages in an effort to assist architects in representing and analyzing risks in their business contexts. One of such frameworks is ArchiMate, particularly its Risk and Security Overlay (RSO) (Band et al., 2017). The RSO establishes means for representing important aspects of risk-related phenomena in ArchiMate including threats, vulnerabilities, losses, assets at risk, and associated control strategies.

Despite the advances in the representation of risk-related phenomena, we have observed that there are still some limitations in the clarity and expressiveness concerning certain aspects of risk. We trace some of these shortcomings to the difficulty in characterizing the central notion of risk itself, which has been the subject of systematic investigations for over 50 years (Renn, 1998). The notion of risk remains elusive, as evidenced by the plethora of definitions in the literature (Aven et al., 2011), the number of standardization efforts (e.g. ISO 73:2009 (ISO, 2009), IRM (2002), COSO (2004)) and the notable variability among risk modeling languages with respect to the concepts and relations they adopt (e.g. CORAS (Lund et al., 2010), RiskML (Siena et al., 2014), the Goal-Risk Framework (Asnar et al., 2011), and the RSO (Band et al., 2017)).

In this paper, we address some challenges in conceptualizing and modeling risk with a systematic ontology-based approach. We investigate the concept of risk and related notions and propose an ontology of risk as a semantic foundation for the representation of risks in Enterprise Architecture. This ontology is the result of a thorough analysis of the notion of risk in the literature and is aligned with the Unified Foundational Ontology (UFO) (Guizzardi, 2005). We use the proposed risk ontology to perform an ontological analysis of ArchiMate's Risk and Security Overlay (RSO). We have selected ArchiMate and the RSO as they form the most comprehensive Enterprise Architecture approach with support for the representation of risks (other languages and frameworks for risks have not been fully-integrated into EA solutions). We focus on the risk modeling fragment of the

RSO, not addressing here in depth the security elements. Building on the results of the analysis, we propose an ontologically well-founded redesign of the RSO, which clearly distinguishes between different perspectives on risk and is more expressive to represent risk-related phenomena.

The remainder of this paper is structured as follows. In section 5.2, we provide an overview of ArchiMate's Risk and Security Overlay. In section 5.3, we introduce an ontology of risk, which serves as conceptual foundation for the analysis in section 5.4. The results of the analysis are used to redesign the RSO in section 5.5. We conclude with a discussion on related work and final remarks in Sections 5.6 and 5.7.

5.2 ArchiMate's Risk and Security Overlay

The Risk and Security Overlay (RSO) for ArchiMate is the result of a collaboration between The Open Group's ArchiMate and Security Forums, which aimed to support the systematic identification, representation and analysis of risks in organizations. The overlay was developed based on an extensive review of several risk frameworks, including the Open FAIR Risk Taxonomy (The Open Group, 2013), the TOGAF security guide (The Open Group, 2016), and the SABSA framework (Sherwood et al., 2005)), and a consolidation of risk-related concepts, which were then mapped to ArchiMate constructs. The overlay was proposed in compliance with ArchiMate 2.0, but it has been recently revisited to accommodate the improvements of ArchiMate 3.0.1 (Band et al., 2017).

The overlay proposes a representation strategy for risk and security modeling, following the scheme depicted in Figure 5.1, specializing existing ArchiMate constructs. The overlay supports the representation of THREAT AGENTS as those responsible for THREAT EVENTS, which are events that trigger LOSS EVENTS. Both THREAT and LOSS EVENTS are associated with VULNERABILITIES, which in turn are associated with RESOURCES. LOSS EVENTS influence RISK assessments, which can motivate CONTROL OBJECTIVES. These are then realized in SECURITY REQUIREMENTS and CONTROL MEASURES, which are in turn realized in IMPLEMENTED CONTROL MEASURES. Table 5.1 lists the elements that form the RSO risk modeling fragment, including their mapping into basic ArchiMate elements and their respective definitions as proposed by Band et al. (2017).

The RSO defines a THREAT as "a possible danger that might exploit a vulnera-

Table 5.1: Summary of risk modeling elements in ArchiMate's Risk and Security Overlay (RSO)

RSO Element	ArchiMate Element	Definition
Threat Agent	Active Structure Element	Anything that is capable of acting against an asset in a manner that can result in harm.
Threat Event	Business Event	Event with the potential to adversely impact an asset (including attacks).
Loss Event	Business Event	Any circumstance that causes a loss or damage to an asset.
Vulnerability	Assessment	D1: The probability that an asset will be unable to resist the actions of a threat agent. D2: A weakness which allows an attacker to threaten the value of an asset.
Risk	Assessment	D1: The probable frequency and probable magnitude of future loss. D2: The potential of loss resulting from an action, activity or inaction, foreseen or not.
Asset at Risk	Resource, Core Element	D1: Anything tangible or intangible that can be owned or controlled to produce value. D2: Any data, device or environmental component that supports information-related activities.

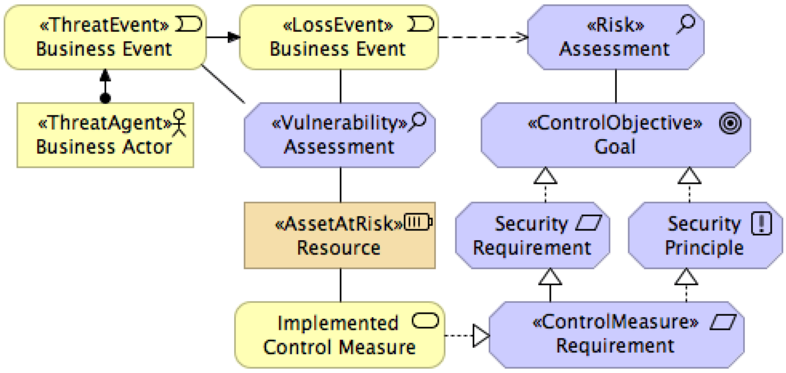

Figure 5.1: ArchiMate's Risk and Security Overlay (Band et al., 2017).

bility to breach security and thus cause possible harm". Recognizing that the term is inherently ambiguous, the authors distinguish between the events that have the potential of harming the organization, which they call Threat Events, from the entities responsible for intentionally or unintentionally causing them, which are labeled Threat Agents. Note that, even though the term "agent" is used, this element is applicable to groups and objects as well. Thus, either a machine or an organization can be classified as a Threat Agent, and thus Threat Agent may be represented by any Active Structure Element. A Threat Event is represented by a specialized Business Event.

A Loss Event is defined as "any circumstance that causes a loss or damage to an asset" and is triggered by a Threat Event. The concept is mapped to a Business Event in ArchiMate.

Vulnerability is given two definitions. In one definition, extracted from (The Open Group, 2013), a Vulnerability is "the probability that an asset will be unable to resist the actions of a threat agent". The second, which seems to be consolidated from the literature, defines a Vulnerability as "a weakness which allows an attacker to threaten the value of an asset". Vulnerabilities are mapped as ArchiMate Assessments, which "represents the result of an analysis of the state of affairs of the enterprise with respect to some driver." (The Open Group, 2017). A Vulnerability can be associated with both Threat Events and Loss Events as well as with resources and other core elements.

Different definitions for risk are provided by Band et al. (2017), which is symptomatic of the difficulty in characterizing its semantics. On the one hand, risk is defined as "the probable frequency and probable magnitude of future loss", following the definition proposed in the Open FAIR Risk Taxonomy (The Open Group, 2013). On the other hand, it is defined as "the potential of loss (an undesirable outcome; however, not necessarily so) resulting from a given action, activity, and/or inaction, foreseen or unforeseen". A third definition, namely that "a risk is a quantification of a threat" is invoked to justify the representation of Risk using a specialization of the Assessment construct in ArchiMate.

In the overlay, risks are usually represented focusing on a particular entity the organization wants to protect. Such an entity is labeled an Asset at Risk. This notion of asset accounts for any kind of object, tangible or intangible, that can be owned or controlled by the organization to create value. Given its general nature, it can be applied to a Resource or any Core Element in ArchiMate (including Business Actors and Business Processes)

The RSO proposes five elements in the Security domain, namely Control Objective, Security Requirement, Security Principle, Control Measure and Implemented Control Measure. Given our scope, we focus here on Control Objective, which is associated with the risk modeling fragment through Risk assessments. These are addressed by Control Objectives, a sort of high level goal that defines what the organization intends to do about an identified risk. For instance, if the Risk of employees getting injured in work-related accidents is considered unacceptable, the organization might decide to reduce it (e.g. by changing safety procedures) or to transfer it (e.g. by purchasing a broader insurance policy). In any case, the result of this decision is captured by a Control Objective, which is mapped as a Goal.

To briefly exemplify how the RSO can be used, we now present three examples introduced by Band et al. (2017), all of which pertain to risks in the Coldhard Steel company. Figure 5.2 depicts an RSO model concerning the risk of losing production due to machine failure. In the example, a *Power supply assembly* is an Asset at Risk that fails when power fluctuates (this failure is represented as a Threat Event). When the power assembly fails, some machines also fail, characterizing a loss for the organization (represented as a Loss Event). In this scenario a risk is identified, namely the Risk of a *Production loss due to machine failure.* Then, the Control Objective *Adequate peak capacity of power supply* implies that the organization seeks to reduce this risk, which is done by *replacing the power supply assembly.*

Although this model provides valuable information for stakeholders of the Cold-

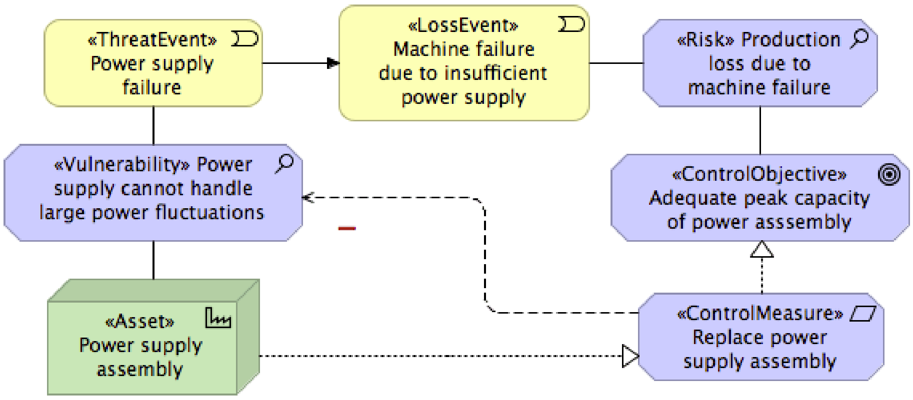

Figure 5.2: Modeling the risk of losing production (Band et al., 2017).

hard Steel company, it leaves some relevant questions unanswered, such as "why is the *Power supply assembly* an ASSET AT RISK if it does not seem to be in any danger?", and "why is a *Machine failure* considered a LOSS EVENT if the loss actually occurs when production is compromised?". Concerning the root cause of the events, one might add "what causes power fluctuations?"

Figure 5.3 depicts another risk scenario present in the RSO paper (Band et al., 2017). In this case, the THREAT EVENT is a *work-related incident*, in which an employee gets injured. Such an incident triggers the *submission of a compensation claim*, an event represented as a loss to the organization. Associated to this LOSS EVENT, there is an assessment (represented as a RISK) that the total cost of such claims is not acceptable to someone in the organization (maybe the business owner?). Thus, a plan to reduce this risk is represented, which will be implemented by extending the currently inadequate safety procedures.

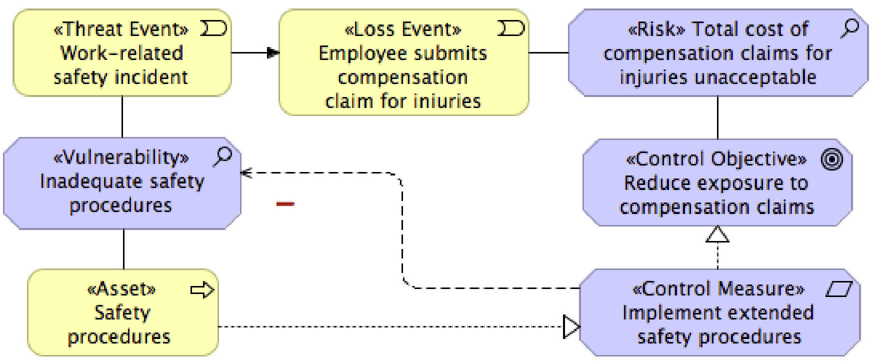

Figure 5.3: Modeling the risk of paying compensation claims (Band et al., 2017).

The classification of the various events in these examples raises some interesting semantic questions. For instance, "Shouldn't an incident where an employee gets hurt be considered a loss?". From the perspective of an employee, it is most likely an unwanted event. This suggests that the classification of events is somewhat contextual in nature, and that stakeholders may classify events differently according to their own goals. A further question is "Why is a submission of a claim already considered a loss?". If the loss regards financial reasons, should not the loss be the compensation claim payment? This suggests that anchoring losses somehow in the motivations of the various stakeholders may be required to clarify the modeler's intent.

Note that the two risk assessments in the examples discussed thus far differ in their nature. In Figure 5.2, the risk assessment concerns consequences of the loss event (*Production loss due to machine failure*), whilst in Figure 5.3, the risk assessment concerns a decision regarding how the organization intends to address the perceived risk (*the risk is unacceptable).* A third example introduced by Band et al. (2017) is depicted in Figure 5.4. It includes an assessment in which no particular statement about the risk is included, and a RISK element is defined with the rather neutral label *Gary Factory reliability risk.* This noteworthy variability in the usage of the RISK element in the proposal indicates that it currently lacks a clear semantics. As a consequence, we argue that the RSO lacks guidance for the modeler concerning the adequate representation of risk-related phenomena.

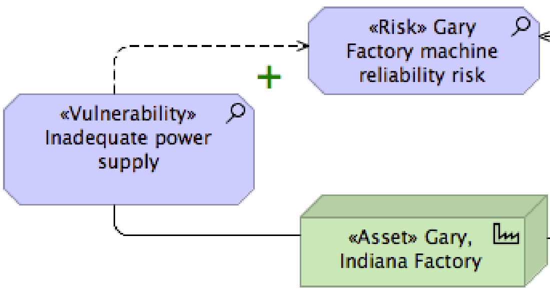

Figure 5.4: Modeling the overall risk that a factory is exposed to (Band et al., 2017).

5.3 Ontological Foundations

In order to systematically address the representation of risks and risk-related phenomena, we propose to first grasp the ontological foundations of risks. This is done here with a fragment of the Common Ontology of Value and Risk (COVER) (Sales, Baião, et al., 2018), which is a reference ontology aiming to unify and clarify conceptualizations about these two phenomena. It was designed as an extension of the Unified Foundational Ontology (UFO) (Guizzardi, 2005) and was built on top of an ontological analysis of value presented by Sales, Guarino, et al. (2017a). In this section, we provide an overview of this reference ontology, focusing exclusively on its risk fragment. We clarify our assumptions on the nature of risk and then introduce its formalization in OntoUML (Guizzardi, 2005), reusing foundational ontological distinctions from UFO (those concerning events, objects, dispositions, situations, etc.)

5.3.1 Assumptions on the Nature of Risk

Our first assumption on risk is that it is **relative**. This means that an event might be simultaneously considered as a risk by one agent and not as a risk by another (it may even be considered as an opportunity by such an agent). To exemplify why this assumption holds, consider a potential terrorist attack. Most people would view such an event as a risk, i.e., as something they do not want to happen and that would "hurt" them in some way. Now, consider a terrorist organization who plans such an attack. For them, the attack itself is not a risk, as it is a way to achieve their goals.

The reason why risk is relative constitutes our second assumption on its nature. A risk is perceived according to its **impact on goals**, i.e. in order to talk about risk, one needs to account for which goals are "at stake". For instance, if one is concerned with the risk of missing a train, this is because missing a train has an impact on one's goals, such as arriving on time at a meeting or saving money.

Our third assumption is that risk is **experiential**. This means that we ultimately ascribe risk to events, not objects. This claim may seem counter-intuitive at first, as many conceptualizations assume entities such as "Object at Risk" (Boholm and Corvellec, 2011) and "Asset at Risk" (Band et al., 2017). Our claim is not that such concepts do not exist. Our assumption is that if a risk assessment is made towards an object, the overall identified risk will be derived from the risks ascribed to events that can impact such an object. For instance, consider the risks your phone is exposed to. In order to identify and assess them, you will probably need to consider:

1. which of your goals depend on your phone (e.g. getting in contact with your friends, being responsive to business e-mails);
2. what can happen to your phone such that it would hinder its capability to achieve your goals (e.g. its screen breaking, it being stolen); and
3. which other events could cause these (e.g. you dropping it on the floor or leaving it unattended in a public space)

Then the risk your phone is exposed to is the aggregation of the risk of it falling and breaking, the risk of it being stolen, and so on.

Our next assumption is that risk is **contextual**. Thus, the risk an object is exposed to may vary even if all its intrinsic properties (e.g. its vulnerabilities) are the same. To exemplify this position, consider the risk of a car accident. Naturally, the properties of a car have some influence on this risk, such as having or not an anti-lock braking system (ABS). Still, the properties of the road (e.g. the asphalt's adherence) and the weather (e.g. a snow storm) can significantly increase (or enable) risks.

Lastly, we assume that risk is grounded on **uncertainty** about events and their outcomes. This is very standard position, as proposed by ISO (2009) and extensively discussed by Aven et al. (2011), which implies that likelihood is positively correlated with how risky an event is. For instance, the risk of a smoker having lung cancer is higher than that for a non-smoker simply because it is more probable.

5.3.2 The Ontology of Risk

The risk fragment of the COVER (Sales, Baião, et al., 2018) formally captures our conceptualization of risk following the assumptions discussed in the previous section. Given the polysemic nature of the term "risk" (Fillmore and Atkins, 1992; Kjellmer, 2007), we aim to disentangle three perspectives on risk:

- a perspective of risk centered on (unwanted) events and their causes, which constitute an overall Risk Experience;
- a relational perspective which identifies the subjective nature of risks by establishing a relationship (a Risk Assessment) between those assessing risks and a risk experience; and

- a perspective of RISK as a (quantifiable) quality inherent to a RISK ASSESSMENT.

The core part of the ontology is presented in figures 5.5 and 5.6. They depict diagrams that conform to the following color coding: events are represented in yellow, objects in pink, objectified intrinsic properties (tropes) in blue, objectified relationships (relators) in green, and situations in orange.

Figure 5.5 presents risk centered on the event perspective. A RISK EXPERIENCE is composed by events of two types, namely threat and loss events. A THREAT EVENT is one with the potential of causing a loss. It might be the manifestation of: (i) a VULNERABILITY, such as the flammability of a house which is manifested in a fire; or (ii) a THREAT CAPABILITY, such as the dexterity of a pick-pocketer to grab a wallet without alerting the owner.

A THREAT EVENT might be intentional, such as a hacker attack, or unintentional, such as an accidental liquid spill on a computer. In any case, one can identify a THREAT OBJECT as the entity "responsible" for causing the threat. Note that, in this context, we use the term object in a very general sense, which includes agents, groups and organizations. The second mandatory component of a RISK EXPERIENCE is a LOSS EVENT, which is defined by its impact on GOALS. This can either be:

- a *direct impact*, captured by the HURTS relation that holds between a LOSS EVENT and an INTENTION (e.g. the event of being robbed directly hurts the goal of feeling safe); or
- an *indirect impact*, i.e., a LOSS EVENT bringing about a LOSS SITUATION, which in turn hurts an INTENTION (e.g. having my phone stolen puts me in a phone-less situation, which hurts my goals of calling my family, closing business deals, etc.).

To capture the relative nature of risks, every RISK EXPERIENCE involves at least one RISK SUBJECT, the agent whose INTENTIONS would be affected by a potential loss.

The ontology also introduces an important role in LOSS and THREAT EVENTS, namely that of THREAT ENABLER. This role accounts for objects whose VULNERABILITIES enable threats and losses to happen, but do not cause or are harmed by them. Take for instance a factory accident caused by a worker, who ended up

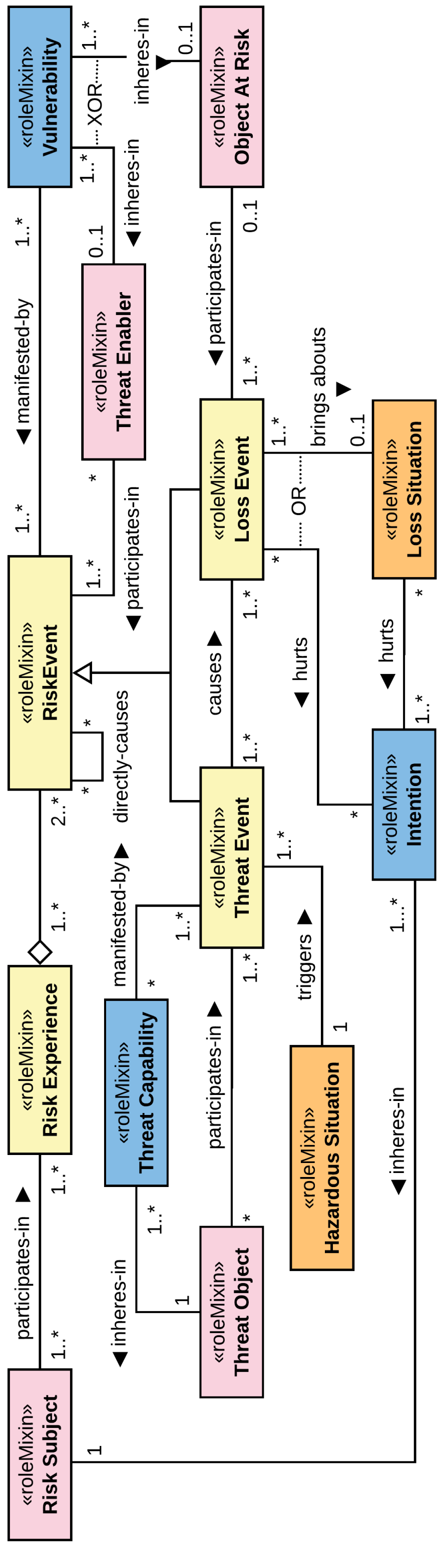

Figure 5.5: Modeling risk as an event composed by threats and losses (aka. Risk Experience).

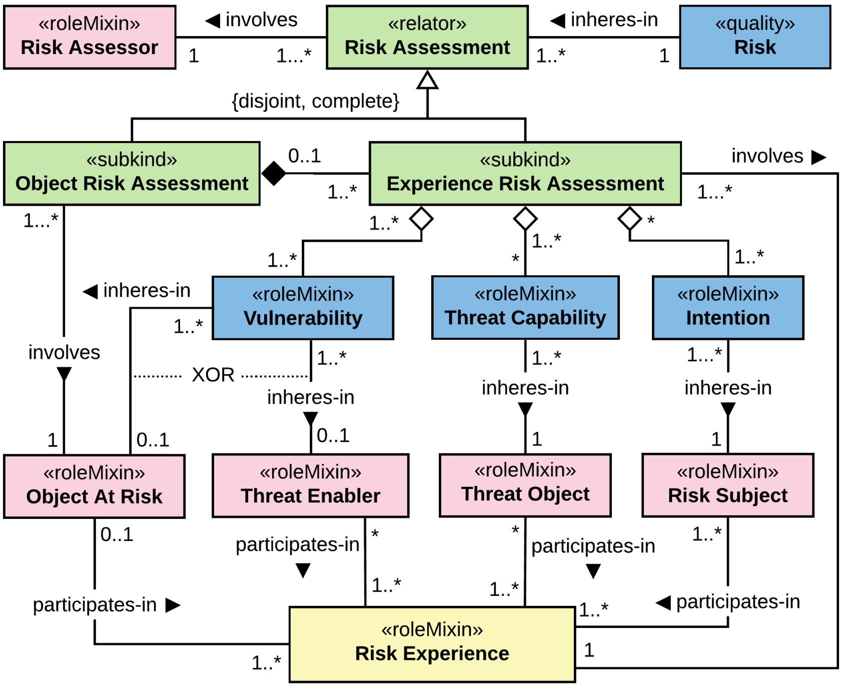

Figure 5.6: Modeling risk as an assessment relationship and as a quality.

injured. In this case, the worker is both the THREAT OBJECT, as he caused the accident, and the OBJECT AT RISK, as he was injured by it. Still, if the reason he actually got hurt was because his safety equipment was not safe enough, the equipment would have played the role of a THREAT ENABLER.

Note that, with the exception of INTENTION, the concepts presented in Figure 5.5 are modeled as roles. This means that the very same event might be a threat to one agent, a loss to another, and neither for a third. The same goes for vulnerabilities and threat capabilities.

The relational perspective of risk is depicted in Figure 5.6. We formalize it as an objectified relationship labeled RISK ASSESSMENT, which involves an agent as the assessor of risk, deemed the RISK ASSESSOR, and the target of the assessment, either an object or an event. Risk assessments on objects are labeled OBJECT RISK ASSESSMENTS and involve exactly one OBJECT AT RISK. Risk assessments on events are deemed EXPERIENCE RISK ASSESSMENTS and involve exactly one RISK EXPERIENCE. Note that, given our assumption that risk is experiential, assessing the risk an object is exposed to means assessing the risk of all the envisioned events (experiences) that may potentially harm the OBJECT AT

Risk. This assumption is formalized by the composition between Object- and Experience Risk Assessments.

The quantitative perspective of risk is also depicted in Figure 5.6. It is captured by the Risk quality inhering in a Risk Assessment. In UFO, a quality is an objectification of a property that can be directly evaluated (projected) into certain value spaces (Guizzardi, 2005). Common examples include the weight of a person, which can be measured in kilograms or pounds, and the color of a flower, which can be specified in RGB or HSV. Representing risk as a quality means that it can also be measured according to some scales, such as an easy discrete scale like $< Low, Medium, High >$ or a more precise continuous scale (e.g. from 0.00 to 100.00).

5.4 Ontological Analysis

Rosemann et al. (2004) define an ontological analysis as *"the evaluation of a modeling grammar, from the viewpoint of a pre-defined and well-established ontology"*. The authors argue that modeling grammars should be isomorphic to their underlying ontology, i.e. there should be an one-to-one mapping between the constructs of a language and the concepts of its ontology. This is a desirable characteristic because it prevents issues such as **construct overload** and **construct deficit**. The former is characterized by the presence of a grammatical construct that represents more than one ontological concept, which would lead to ontological inaccuracy. The latter is characterized by the absence of a grammatical construct for an existing ontological concept, which would result into ontological incompleteness. In the following section we describe the ontological analysis we conducted to assess the risk-related constructs of RSO, in light of the risk ontology we have just discussed.

5.4.1 Analysis of Vulnerabilities

The RSO defines a Vulnerability as:

- "a weakness which allows an attacker to threaten the value of an asset"; and
- "the probability that an asset will be unable to resist the actions of a threat agent" (The Open Group, 2013).

These definitions suggest that a vulnerability may be two very different things. Nonetheless, by analyzing the other constructs that compose the RSO and the uses of the Vulnerability element by Band et al. (2017), it is clear that the first definition prevails. An example is the claim that “a vulnerability of an asset can lead to a loss event” and the representation of “Lack of access control” as a Vulnerability that enables an “Identity theft”. Thus, we shall assume that a vulnerability is understood in the RSO as a weakness that enables threats and losses.

The concept is mapped as an ArchiMate Assessment, as the creators of the RSO argue that it “is the result of analyzing the weaknesses of elements in the architecture”. We observe that this mapping collapses the entity itself (the vulnerability) with the assessment that results in identifying and possibly qualifying the entity. We interpret a vulnerability as a disposition of a special type. A disposition is a property that endows its bearer with the potential of exhibiting some behavior or bringing about certain effects under certain conditions (Guizzardi, Wagner, Falbo, et al., 2013). The difference of a vulnerability from dispositions in general is that the former assumes a negative connotation, i.e., the manifestation of a vulnerability constitutes a loss or can potentially cause a loss from the perspective of a stakeholder. In fact, this is why we represent vulnerabilities as roles played by dispositions in the risk ontology discussed in section 5.3.

An advantage of distinguishing between a vulnerability from an assessment about it made by a stakeholder is the possibility of representing multiple assessments for the same vulnerability. This may capture disagreements between stakeholders on the probability of it being manifested, as well as different assessments concerning how to address it (e.g., that it is too expensive to be removed). We refer to the semantic overload of the Vulnerability construct, which collapses actual vulnerabilities with assessments about them, as *Limitation L1.*

5.4.2 Analysis of Threat Events and Threat Agents

In an effort to consolidate existing risk terminology, the authors of the RSO admit the existence of a general concept of threat, informally defined as “a possible danger that might exploit a vulnerability [...] and thus cause possible harm”. They recognize, however, that the term is inherently ambiguous, as it may refer to:

- *an entity capable of causing harm*, such as a hacker who seeks to steal data from a company or a truck filled with flammable liquids;
- *an actual event that may cause harm*, such as a hacker attack, which can lead

to the leak of sensitive data or a misuse of a machine, which can cause an employee getting hurt; and

- *a threatening circumstance*, such as a blizzard during a snowboarding session that increases the likelihood of an accident, or having untrained workers operating a machine which increases their chance of hurting themselves;

A threat in the first sense, that of a *harm-causing entity*, was introduced in the RSO as a Threat Agent. Given that things of various natures can play this role, it was mapped as an Active Structure Element in ArchiMate, which generalizes elements like Business Actor, Business Role, Facility, Equipment and so on. In the ontology we discussed in section 5.3, this element is interpreted as the Threat Object. Note that this role can be played not just by agents, but also by objects (including those that would be represented as *Passive Structure Elements*). An example is a poisonous gas used in a production process that poses a threat to workers that have manipulated it. Thus, we argue that by ignoring its application to *Passive Structure Elements*, the current mapping is overly restrictive. We label this issue *Limitation L2*.

A threat in the second sense, that of a potentially *harm-causing event*, was introduced in the RSO as a specialization of Business Event labeled Threat Event. In the RSO, a Threat Event:

- is associated to a Vulnerability;
- is assigned from a Threat Agent; and
- triggers a Loss Event

We interpret this element as the homonymous class in our ontology. By only focusing on vulnerabilities, the RSO fails to account for the capabilities of the Threat Agents that enables them to make threats, which we formalized in the ontology as a Threat Capability[1]. As an example, consider a hacker launching a Distributed Denial-of-Service (DDoS) attack against the online platform of an e-commerce company. Such an attack only occurred due to a capability of the attacker to launch such attack. We label this construct deficit as *Limitation L3*.

Lastly, threats in the third sense, that of a *threatening circumstance*, are actually neglected in the RSO. These regard particular configurations of the world that

[1]This particular term is also used with a similar meaning in The Open Group Risk Taxonomy Standard (The Open Group, 2013)

allow or increase the probability of the occurrence of a threat event. We interpret these circumstances as HAZARDOUS SITUATIONS in our ontology and define them as situations which activate vulnerabilities and threat capabilities, which in turn will be manifested as threat events. Explicitly accounting for hazardous situations allow the representation of how several environmental factors increase the likelihood of threat events or empower threat agents, thus providing more information for devising mitigation strategies. We deem this construct deficit as *Limitation L4*.

5.4.3 Analysis of Assets at Risk

An ASSET AT RISK is defined in the RSO both as "anything tangible or intangible that can be owned or controlled to produce value" and as "any data, device or environmental component that supports information-related activities". Still neither definition actually describes what an asset *at risk* is, but what an asset is in general. In fact, the first definition resembles that of a RESOURCE in ArchiMate 3.0.1: "an asset owned or controlled by an individual or organization"(The Open Group, 2017).

In this paper, we assume the ontological interpretation of resources discussed by Azevedo, Iacob, et al. (2015), which explains resources as tangible or intangible things needed to make progress towards a goal. Thus, if something is considered a resource to an organization, it has some value to it. This interpretation of a resource, roughly equivalent to those provided for an asset, shows that introducing an ASSET element in the RSO would be borderline redundant. Still, we argue that the distinction between a RESOURCE (or an ASSET) and an ASSET AT RISK should not be omitted, as it clearly identifies to the organization what assets are considered to be exposed to risks.

In the risk ontology, we distinguished two roles played by objects in a RISK EXPERIENCE, namely the OBJECT AT RISK and the THREAT ENABLER. In both cases, the dispositions of these objects enable the occurrence of threat and loss events. The difference between them is that the former is the thing at stake (i.e., the thing that may be harmed or damaged in a LOSS EVENT), whilst the latter is simply a risk-enabling thing, as it is not exposed to any potential damage. To exemplify this distinction, consider that a machine failed and caused a production loss. It was the machine's vulnerability that caused it to fail. Still, the integrity of the machine might not be affected by the failure at all. In this case, the machine is playing the role of a threat enabler. We label this lack of distinction between an Object at Risk and Threat Enabler as *Limitation L5*.

5.4.4 Analysis of Loss Events

The RSO defines a Loss Event as "any circumstance that causes a loss or damage to an asset" (Band et al., 2017). This highlights that there could be two different emphases in the formulation of a loss event. One of them concerns an event that frustrates one's objectives ("a loss") and the other concerns the negative impact ("damage") to an asset. We consider that the negative impact on an asset should be accounted for by an underlying goal of protecting that asset, as it is considered a resource in a strategy to realize some goal (Azevedo, Almeida, et al., 2015).

By inspecting the RSO metamodel, we find that a Loss Event:

- is triggered by Threat Events;
- is associated to Vulnerabilities; and
- influences a Risk assessment.

None of these relational properties, however, captures a key aspect that constitutes a "loss" – namely that there is a stakeholder whose goal is compromised by such an event. The absence of a relation between loss events and goals prevents a modeler from explaining why there is a risk in the first place. For example, in Figure 5.2, we find a machine failure represented as a Loss Event. Account for the impact on goals would clarify: Is a machine failure a loss because it delays production? Or it is a loss because a machine failure will result in defective products that might end up being shipped to customers? Without precisely representing specifically which events impact particular objectives, such questions cannot be properly addressed in the models. We refer to this construct deficit as *Limitation L6*.

The RSO also lacks a direct relation between Loss Events and Assets at Risk. There is instead an association with a Vulnerability, which in turn is associated with an Asset at Risk. However, some events might be a manifestation of a vulnerability of one object that in turn damages another. In this case, the RSO would be unable to distinguish between objects whose vulnerabilities are manifested in the loss event from those that are compromised by the loss event. Suppose, for instance, that we want to represent that work incidents are caused by a vulnerability in the safety procedures, but that the assets at risk are actually the machines that can be damaged in an accident. We label this deficit as *Limitation L7*.

5.4.5 Analysis of Risks

The risk element is arguably the most complex to analyze, as it embodies a classical scenario of systematic polysemy. Evidences for this claim are the two very different definitions proposed in the RSO. On one hand, risk is defined as "the potential of loss resulting from an action, activity or inaction, foreseen or not", which emphasizes its nature as a causal chain of events that potentially leads to a loss. On the other hand, it is defined as "the probable frequency and probable magnitude of a future loss", which highlights its quantitative nature, mostly popularized by the famous equation, in which $risk = probability \times impact$.

Another evidence of the polysemous nature of risk is found in the examples presented in section 5.2. In these examples, risk is used to represent the following elements:

R1: "*Production loss due to machine failure*";

R2: "*Total costs of compensation claims for injuries unacceptable*"; and

R3: "*Gary Factory machine reliability risk*"

In the examples, R1 and R2 are directly connected to their respective loss events, while R3 is connected only to vulnerabilities – in the sense that the vulnerabilities increase the risk. Note that, by analyzing the description of these risks, one can clearly see that they refer to entities of different ontological natures. R1 refers to a complex event composed by a particular loss (the production loss) that was caused by particular threat (the machine failure). R2 refers to a risk assessment, which captures:

- a perception that compensation claims are a risk, and
- a judgment that this risk is unacceptable to the organization (or at least to some hidden stakeholder).

Lastly, R3 refers to the aggregated risk a particular asset (the machines in the Gary Factory) is exposed to, which does not directly refer to any particular threat or event.

The nature of these different concepts represented by the same construct can be unveiled by means of the risk ontology discussed in section 5.3. We interpret that cases like R1 refer to RISK EXPERIENCES, thus capturing the perspective of risk as an unwanted event. Cases like R2 refer to relationships of RISK ASSESSMENT. Such relationships represent that a stakeholder, the RISK ASSESSOR, interprets an event as a RISK EXPERIENCE according to someone's perspective, the RISK SUBJECT[2]. Lastly, R3 refers to the RISK quality, which inheres in a RISK ASSESSMENT. In sum, by offering modelers a single construct to represent three different concepts, the RSO suffers from another problem of construct overload. We label this *Limitation L8*.

5.5 Redesigning the Risk and Security Overlay

In order to address the identified shortcomings, summarized in Table 5.2, we now propose a redesign of the risk-related portion of the RSO, which also follows its original strategy of only using existing ArchiMate constructs.

Addressing *Limitations L1, L2 and L3* is fairly straightforward. Concerning *L1*, we propose to map the VULNERABILITY concept as a CAPABILITY in ArchiMate instead of an ASSESSMENT. Then, as many assessments as necessary can be represented about a vulnerability, such as the beliefs of individual stakeholders about its relevance. This mapping is consistent with the interpretation of the ArchiMate CAPABILITY construct as a disposition by Azevedo, Iacob, et al. (2015), albeit a disposition with negative connotation in the case of a vulnerability. Concerning *L2*, we propose it be addressed by also allowing RESOURCES to be qualified as THREAT AGENTS. This opens up the possibility for passive structure elements to play the role of THREAT OBJECTS in threat events. *Limitation L3* can be addressed simply by representing CAPABILITIES of THREAT AGENTS explicitly.

To address *Limitation L4*, we would need to add a HAZARDOUS SITUATION element to the RSO. However, since ArchiMate does not provide a native construct for modeling situations in general, we propose to model assessments of hazardous situations associated to threat events. This way, one can represent, for instance, that employees working overtime increase the probability of safety incidents.

To address *Limitation L5*, we propose to distinguish the two roles played by

[2]Note that in context of a RISK ASSESSMENT, the roles of RISK ASSESSOR and RISK SUBJECT might be played by the same agent or by different ones.

Table 5.2: Summary of ontological limitations.

Ontological limitation
L1. A *construct overload* on the VULNERABILITY construct, which collapses actual vulnerabilities with assessments about them.
L2. A *construct deficit* to capture THREAT OBJECTS that are not active structure elements.
L3. A *construct deficit* to represent THREAT CAPABILITIES.
L4. A *construct deficit* to model a HAZARDOUS SITUATION, that activates vulnerabilities or increases the likelihood of threat events.
L5. A *construct overload* on the ASSET AT RISK construct, which collapses assets that are exposed to potential damages and those whose vulnerabilities enable threats and losses.
L6. A *construct deficit* to model a core property of a LOSS EVENT: its negative impact on goals of an affected stakeholder (the RISK SUBJECT).
L7. A *construct deficit* to model a LOSS EVENT's damage to an asset.
L8. A *construct overload* on the RISK construct, which collapses: (i) a complex event, (ii) the overall risk an asset is exposed to, and (iii) an assessment regarding what to do about an identified risk.

bearers of vulnerabilities, namely ASSET AT RISK and THREAT ENABLER. Both of these elements are associated to vulnerabilities, as their bearers, and to threat and loss events, as their participants. We propose to explicitly stereotype ASSETS AT RISK. Any other ArchiMate STRUCTURE ELEMENTS involved in threat and loss events and not considered ASSET AT RISK nor THREAT AGENTS represents THREAT ENABLERS. These changes are illustrated in Figure 5.7. A "Power supply failure" is a THREAT EVENT that is the manifestation of a vulnerability from a "Power supply assembly", which plays the role of a THREAT ENABLER. Additionally, this threat leads to a "Machine failure", a LOSS EVENT that damages a "Machine", which is then playing the role of an ASSET AT RISK. To illustrate all the roles played by assets (or other objects) in the risk experiences, we represented a root cause event that caused the power supply failure, namely the power fluctuation. In this event, the power grid is causing the threat, and thus, playing the role of a THREAT AGENT.

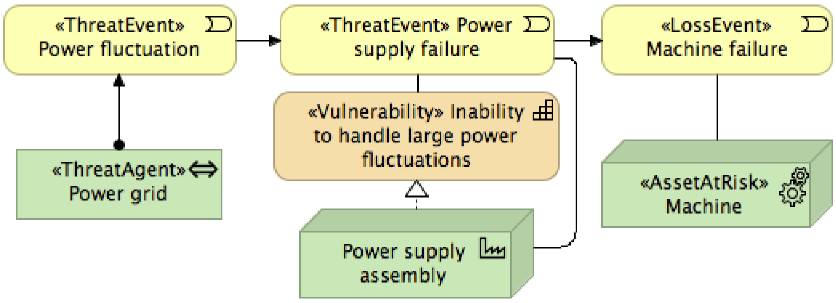

Figure 5.7: Modeling the different roles played by assets and other objects.

In order to address *Limitation L6*, we propose the representation of a negative INFLUENCES association between a LOSS EVENT and a GOAL, which captures why an event is considered a loss. To address *L7*, we propose the representation of an association between a LOSS EVENT and an ASSET AT RISK, in order to represent that some events are considered losses because they harm or damage an asset. We illustrate the impact of these changes in Figure 5.8, which redesigns part of the examples discussed in section 5.2.

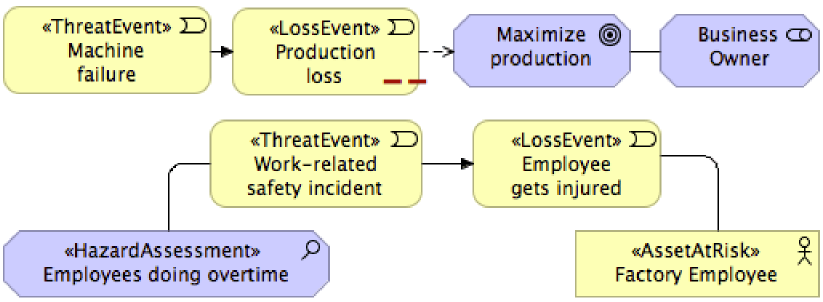

Figure 5.8: Modeling LOSS EVENTS with their core properties.

On the top part of the figure, we separated the event of a “Machine failure” from the actual event of “Production loss”. Note, however, that the loss event is properly characterized by its negative impact on the goal of “Maximizing production”. Additionally, note that we also represented the stakeholder who wants to maximize production: the Business Owner. In the context of this example, he is playing the role of the RISK SUBJECT, i.e., that to whom the event constitutes a loss. On the bottom part of the example, we represent a loss named "Employee gets injured”, which is characterized by a damage to an asset, the “Factory employee”. For the sake of conciseness of the figure, we omitted the goal compromised by an employee

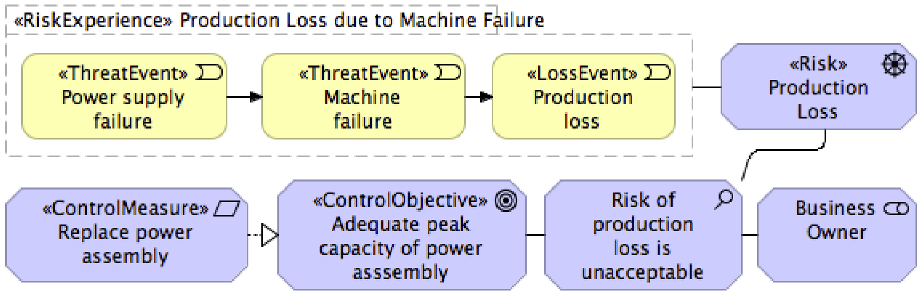

Figure 5.9: Modeling the three perspectives of risk.

getting injured, which could belong to the employee himself, a business owner or a worker's union.

Finally, we address *Limitation L8* by splitting the original Risk element into three. The first captures the risk experience. We map this concept as a type of Grouping, stereotyped as a Risk Experience, which aggregates the elements and the relations in the experience. The second represents risk from a quantitative perspective, commonly described as *probability* × *impact*. We map this concept as a Driver stereotyped as Risk, as drivers represent "conditions that motivate an organization to define its goals and implement the changes necessary to achieve them" (The Open Group, 2017). Since a risk quantification is about some event, we propose to represent Risk in association with a Risk Experience. The third element is a Risk Assessment, which naturally maps as an Assessment in ArchiMate, as this concept represents "the result of an analysis of the state of affairs of the enterprise with respect to some driver" (The Open Group, 2017). In this case, the drivers are risk drivers. Additionally, we propose to represent the associated Risk Assessors, to capture which stakeholders analyzed an identified risk. The application of this last proposal is depicted in Figure 5.9. In the example, we represent a Risk Experience named "Production loss due to machine failure", defined by its threat and loss events. Associated to this experience, there is Risk simply labeled "Production loss", which reflects the likelihood that all the parts of the experience occur and cause each other, as well as on the quantitative impact of the potential losses. Lastly, the Risk Assessment "Risk of production loss is unacceptable" concerns the production loss Risk.

The resulting representation scheme which aggregates all of the discussed modifications is shown in Figure 5.10. The elements we added or modified are represented with bold labels and thicker lines. Note that the resulting scheme clearly

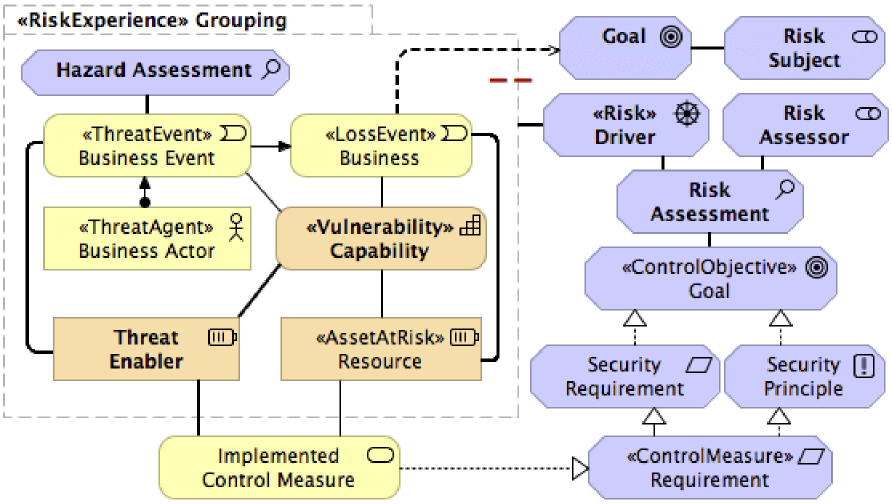

Figure 5.10: Proposal for evolving the Risk and Security Overlay.

separates (but links) the motivation elements employed (to the right-hand side), and the risk experience elements (to the left-hand side). In case the risk experience grouping is omitted (due to abstraction), a derived negative influence relation between the risk driver and the affected goal enables the motivation elements to be used on their own. We consider this a benefit of this scheme, as it enables risk to be integrated into an overall motivational analysis, even if specific details of events are omitted. The mapping between the ontological risk-related concepts and their representation in ArchiMate are listed in Table 5.3.

5.6 Related Work

Recently, Mayer and colleagues proposed two applications of the Information System Security Risk Management (ISSRM) domain model: (i) integrated with plain ArchiMate to model and analyze risks related to information systems security (Mayer, Aubert, et al., 2018), and (ii) to evaluate the expressiveness of the RSO w.r.t to the risk domaby Mayer and Feltus (2017). The ISSRM domain model, however, suffers from some similar deficiencies as the RSO, as it does not untangle the various dimensions of risk, focusing on the risk experience perspective.

Besides the efforts to model risk in an Enterprise Architecture context, a number of risk modeling frameworks have been proposed in other domains. One of them is CORAS (Lund et al., 2010), a visual modeling language designed to be

Table 5.3: Representation of risk concepts in ArchiMate.

Ont. Concept	Representation in ArchiMate
Vulnerability	Capability stereotyped with «Vulnerability»
Threat Object	Structure Element stereotyped with «ThreatAgent»
Threat Event	Event stereotyped with «ThreatEvent»
Hazard Assmt.	Assessment stereotyped with «HazardAssessment»
Loss Event	Event stereotyped with «LossEvent»
Intention	Goal
Risk Subject	Stakeholder associated with a Goal that is negatively impacted by a «LossEvent»
Object at Risk	Structure Element stereotyped with «AssetAtRisk»
Threat Enabler	Structure Element associated with a «ThreatEvent» or a «LossEvent»
Risk Exp.	Grouping stereotyped with «RiskExperience»
Risk	Driver stereotyped with «Risk»
Risk Assmt.	Assessment associated with a «Risk»
Risk Assessor	Stakeholder associated with a Risk Assessment

a "common tongue" among those involved in risk management activities, from risk analysts to stakeholders. Its distinguishing feature is a comprehensive series of methodological guidelines on how to systematically identify, analyze and treat risks. Still, it suffers from ontological deficiencies similar to those we discussed in section 5.4, such as an ambiguity regarding the risk construct. Moreover, it has not been properly integrated with Enterprise Architecture approaches, so to leverage existing architectural model of organizations.

Another modeling framework is RiskML (Siena et al., 2014), an i*-based approach designed specifically for assessing risks related to the adoption of open source components in software projects. In comparison with the other approaches we discussed so far, RiskML is extremely concise. It does not distinguish, for instance, threat events from loss events, relying mostly on relations to represent these concepts. It is, however, the only one that explicitly represents the negative impact on a stakeholder's objectives.

5.7 Final Remarks

In this paper, we presented an ontological analysis of the risk modeling fragment of ArchiMate's Risk and Security Overlay. This analysis, which was grounded on the well-founded Common Ontology of Value and Risk (Sales, Baião, et al., 2018), allowed us to clarify the real-world semantics underlying the risk-related constructs of the overlay, as well as to unveil several ontological deficiencies in it. We then addressed these deficiencies by redesigning the risk modeling fragment of the RSO, making it more precise and expressive.

The redesigned risk modeling fragment proposes a number of solutions for the representation of notions that were not present in the original RSO. These include threat capabilities, vulnerabilities of threat enablers and assets at risk (as opposed to assessments about vulnerabilities), threat objects beyond active structure elements and hazardous situations. Risk experiences (and more specifically) losses are explicitly characterized as such by their relations to the goals of an affected risk subject. Finally, the redesigned fragment distinguishes between the three perspectives on risk:

- the risk experience grouping captures threat and loss events along with their causality relations as well as the capabilities and vulnerabilities that are manifested in the risk experience;
- the risk driver captures the qualitative aspect of risks, opening up the possibility for quantification, and introducing risk as a concern that motivates mitigation efforts; and
- the risk assessment is separated from risk driver, enabling different evaluations of risk to emerge and coexist. The latter can be attributed to different stakeholders which perceive risk differently, emphasizing risk's subjective nature.

Since our analysis focused on the risk elements of the RSO, a natural direction of future work is conducting a similar analysis of the security elements (e.g. control measure, security principle). Moreover, since the reference ontology we used in this paper unifies the phenomena of risk and value, it could also be used to revisit *value modeling* in ArchiMate, a domain that is significantly less developed in the current version of the language. Lastly, we would like to further develop the risk ontology, especially regarding the representation of types of expected events and how these can impact the conceptualization of risk.

Chapter 6

Ontological Foundations of Competition

It is widely recognized that accurately identifying and classifying competitors is a challenge for many companies and entrepreneurs. Nonetheless, it is a paramount activity which provide valuable insights that affect a wide range of strategic decisions. One of the main challenges in competitor identification lies in the complex nature of the competitive relationships that arise in business environments. These have been extensively investigate over the years, which lead to a plethora of competition theories and frameworks. Still, the concept of competition remains conceptually complex, as none of these approaches properly formalized their assumptions. In this paper, we address this issue by means of an ontological analysis on the notion of competition in general, and of business competition, in particular, leveraging theories from various fields, including Marketing, Strategic Management, Ecology, Psychology and Cognitive Sciences. Our analysis, the first of its kind in the literature, is grounded on the Unified Foundational Ontology (UFO) and allows us to formally characterize why competition arises, as well as to distinguish between three types of business competitive relationships, namely market-level, firm-level and potential competition.

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6.1 Introduction

Dealing with competition is an important aspect of companies' management and strategy (Gur and Greckhamer, 2018), as it impacts a wide range of important decisions, from where to expand to how to protect a company's position within a market. Still, it has been long recognized that companies recurrently fail to accurately identify and classify their competitors (Levitt, 1960), an issue that affects both established organizations and startups (Krzyżanowska and Tkaczyk, 2013). This is such a well-known problem that it has even received its own name, *competitive blindspot* (Ng et al., 2009).

Identifying and understanding business competition is a challenging task for many reasons. Market boundaries keep changing, there is no default "place" to look for competitors and it is not up to a company to choose their competitors. Still, the issue is that, ultimately, competition is a complex socially-constructed concept that one needs to properly grasp to accurately identify competitors.

Given the importance and complexity of dealing with competition, a significant amount of effort has been employed in understanding the nature and types of competitive relationships (DeSarbo et al., 2006; Henderson, 1983; Peteraf and Bergen, 2003; Porter, 2008a), as well as in the development of automated tools to identify competitors (Ma et al., 2011). Despite these efforts, competition theories have not been properly investigated from an ontological perspective, which hinders their expressiveness and clarity, and in turn, impairs their application and integration with one another (Gur and Greckhamer, 2018). In this paper, we extend our previous work (Sales, Guarino, et al., 2018) to address this issue by using the Unified Foundational Ontology (UFO), via the modeling language OntoUML (Guizzardi, 2005; Guizzardi, Fonseca, et al., 2018), to conduct an ontological analysis of competition, a domain that, so far, received little attention from business ontologies and enterprise modeling approaches. Our main goal is to unveil and formally characterize the ontological nature of *competitive relationships*, including when and why they occur and who is involved in them.

We stress that it is not the aim of this paper to model the dynamics of competition. We do not want to explain how the actions of a competitor affect those of their opponents or what is the best strategy to win a competition. These questions are far better answered by models based on, for example, Game Theory (Myerson, 1997). Instead, we focus on creating a model that can answer questions such as whether or not Google competes with Amazon and why.

The remainder of this paper is organized as follows. In section 6.2, we briefly introduce the reader to UFO and OntoUML. We continue, in section 6.3, with a discussion on the general principles of competition and formalize them in a concise OntoUML model. Next, in section 6.4, we exploit this analysis to conceptualize business competition, while distinguishing between three types of business competitive relationships, namely market-level, firm-level and potential competition. We then finalize this paper with a discussion of related work in section 6.5 and some final remarks in section 6.6.

6.2 The Unified Foundational Ontology (UFO)

The aim of this paper is to provide ontological foundations for the domain of competition. Since we build these foundations on top of the Unified Foundational Ontology (UFO), we provide below a brief description of the approach[1]. UFO is an axiomatic domain independent formal theory based on theories from Analytic Metaphysics, Philosophical Logics, Cognitive Psychology and Linguistics, which is a result of an integration and re-visitation of previous foundational approaches such as OntoClean (Guarino and Welty, 2009), DOLCE (Borgo and Masolo, 2009) and GFO (Herre, 2010). UFO is the theoretical basis of OntoUML, a language for Ontology-driven Conceptual Modeling that has been successfully employed in a number of academic and industrial projects in several domains, such as services, value, petroleum and gas, media asset management, and telecommunications (Guizzardi, Wagner, Almeida, et al., 2015).

In our analysis of competition, we shall rely on a recent re-visitation of the notion of *relationship* made by Guarino and Guizzardi (2016). In UFO, most relationships (the so-called *descriptive* ones) are *reified*, that is, they are considered as elements of the domain of discourse. These relationships (termed *relators* in UFO) are conceived as clusters of relational qualities. Moreover, they are considered as truth-makers of the corresponding relations, i.e., a relation holds because a relationship exists. Take for instance the relation between a student and a university. Why is it true that a particular students studies at a particular university? Because there is an enrollment relationship (a relator) that sustains this relation. An important consequence of relationship reification in an ontology is the possibility

[1]For a complete description of UFO and OntoUML, see (Guizzardi, 2005).

to describe how they can change through time. Reified relationships have been shown to be fundamental for modeling social and enterprise phenomena such as services and contracts (Guizzardi, Wagner, Almeida, et al., 2015).

6.3 The General Ontology of Competition

In this paper, we take the widespread position on the nature of competition defended by Henderson (1983), which assumes that the principles of competition are universal. This means that a general account of competition should be able to explain competitive relationships that arise in any scenario, whether involving animals cohabiting in an ecosystem or companies operating in the same market. Thus, before elaborating on the ontological nature of *business* competition, let us first analyze it on a more general level.

6.3.1 Conflicts and Competition

Our primary assumption on competition is that it emerges from *conflicts*, a position in line with Deutsch's pioneering Theory of Cooperation and Competition (Deutsch, 2015). A conflict is a situation characterized by a set of goals whose satisfaction are negatively interdependent, i.e., the more one such goal is satisfied, the less its interdependent goals are. A simple example of a conflict is a situation in which two applicants, John and Mary, apply for the same position in a company. If they did so, it is safe to assume that each of them has the goal of getting the position. However, since there is only one, John's and Mary's goals cannot be satisfied at the same time, for if Mary gets hired, John does not, and if John gets hired, Mary does not. Thus, John is in conflict with Mary. In an alternative scenario, if the company was to be hiring two new employees and John and Mary were the only two applicants, there would be no conflict, as it would have been possible for both their goals to be simultaneously realized.

Note that the very definition of negative interdependence between goals implies symmetry. Meaning that g_1 and g_2 are interdependent if and only if g_1 negatively depends on g_2 and g_2 negatively depends on g_1. Still, the degree of such an interdependency does not need to be either maximal nor symmetrical. By degree of dependency, we mean how much the satisfaction of one goal hinders the satisfaction of another. In the maximal case, two goals are negatively interdependent to such an extent that the satisfaction of one implies the negation of the other (e.g. the

John and Mary example we have previously discussed). Still, note that the degree of dependency between two goals, g_1 and g_2, can be asymmetric, being so when the satisfaction of g_1 negatively impacts the satisfaction of g_2 more than the other way around. For instance, consider two ice cream shops operating side by side. One has the goal of selling a hundred ice creams per day, whilst the other has the goal of selling a thousand. If the maximum number of customers they can reach is a thousand, both goals cannot be simultaneously satisfied. Nonetheless, if the *hundred-ice-creams* goal is satisfied, the *thousand-ice-creams* can still be partially satisfied. Conversely, if the *thousand-ice-creams* goal is satisfied, the *hundred-ice-creams* will not be satisfied in any extent.

As discussed by Castelfranchi (2015), the nature of conflicts might be *logical* or *practical*. Two goals are said to be *logically* conflicting when the satisfaction of one logically entails the negation of the other. An example would be wanting to win the lottery and not wanting to play it. Alternatively, two goals are said to be *practically* conflicting when the satisfaction of one entails the negation of (or has a negative impact on) the other only because of the current state of the world. For instance, in our John and Mary example, a conflict will exist only as long as there is a single position available. This distinction between logical and practical conflicts evinces that the conflict relation *necessarily* holds between goals if it is logical, and *contingently* holds if it is practical. In other words, if a logical conflict exists, it does so regardless of how the world is or how it changes, whilst if a practical conflict exists, it is exactly because of how the world currently is and it may cease to exist depending on how the world unfolds. As it shall become clear later on this paper, practical conflicts are what grounds competition.

By using conflicts to ground competition, it follows that those involved, i.e. the competitors, must necessarily be agents. This conclusion holds if we assume that intentionality can only be ascribed to agents and not objects (Guizzardi and Guizzardi, 2010). Note, however, that the interpretation of agents we adopt here is not limited to physical agents, such as a person, a robot, or a dog, but also includes collective (e.g. a group of people) and social or group agents (e.g. a company) (Guizzardi and Guizzardi, 2010; Porello, Bottazzi, et al., 2014). Therefore, if competitors are always agents, statements such as “the iPhone competes with Google Pixel” or “the Fiat 500 is facing tough competition” cannot be interpreted at face value. In the latter case, it is Fiat, the company who produces the Fiat 500, who is facing tough competition. An alternative interpretation for such statements is that they actually refer to functional equivalence. Whenever we say that two products are competitors, what we intuitively mean is that the they can be used to achieve the same goals. In fact, functional equivalence is what underlies the definition of substitutes in Porter's five-forces framework (Porter, 2008a).

The number of agents involved in a conflict allows us to further distinguish them in two groups, namely *internal* and *external* conflicts (Castelfranchi, 2015). *Internal conflicts* occur in situations in which a single agent has two negatively interdependent goals (e.g. one wanting to have a baby and also wanting to sleep eight hours a day). Conversely, *external conflicts* are characterized by situations in which the conflicting goals belong to different agents (e.g. our John and Mary example). Our claim is that competition only emerges from external conflicts, and thus, we explicitly rule out the possibility of one competing with one-self. Thus, expressions such as "my biggest competition is myself" should be simply interpreted as metaphors.

It is important to stress that even though competition is grounded on conflicts, and these involve agents, awareness is not a requirement for conflicts. For instance, in our previous John and Mary example, the conflict exists regardless of whether one knows about the application of the other. Thus, if competition emerges from conflicts, competition is also a matter of *objective reality*[2]. Naturally, it is possible that a conflict occurs and those involved are unaware of it, but it is just as possible that no conflict exists and one believes it does. By not requiring awareness for the characterization of conflicts (and thus, competition), we are not denying the cognitive process associated to perceiving competitive situations and the impact it has on one's actions. This phenomenon, however, is more closely associated to rivalry than competition, as explained by Mead (2002): *"competition is behavior oriented towards a goal, in which the other competitors for the goal are secondary; rivalry is behavior oriented towards another human being, whose worsting is the primary goal"*. Thus, within this paper, whenever we refer to competition, we mean objective competition, not perceived competition.

[2]Given that intentional states of agents are necessarily involved in our definition of competition, we could say that it is a matter of *inter-subjective reality*, which may be ontologically relative but epistemically absolute.

6.3.2 Resources, Scarcity and Competition

External conflicts are necessary, but not sufficient to characterize competitive situations. To illustrate why, consider the following example. Dylan wants to date Hailey, but Hailey's mother, Claire, is against it. There is a clear conflict between them, but still, we would not say that Claire and Dylan are competing. Alternatively, if both Dylan and Andy wanted to date Hailey, we would not only say that they are in a conflict, but also that they are competing against each other. The reason why it feels natural to say that there is a competition in the latter case, but not in the former, is the presence of a *scarce resource* that both agents desire, namely the position of being Hayley's boyfriend.

Grounding competition on the presence of mutually desired scarce resources is our second core assumption on the nature of this relationship. This assumption, which is in line with competition theories in Ecology (Alley, 1982), helps us filter out which kinds of external conflicts lead to competition, namely those that arise from the collective pursue of scarce resources. To explain scarce resources and how they are related to competition, we first need to elaborate on what we mean by resource. Note that it is not our goal here to provide a complete ontological analysis of resources, as such an endeavor is still an open research problem in itself. Thus, we shall rely on a working definition of resources, as it suffices for our goal of explaining the nature of competition.

The term resource spans throughout various fields with varying definitions. In Ecology, resources are intuitively understood as "things" animals need to survive, such as food, water or territory (Alley, 1982). From a manufacturing point of view, resources are objects that play a role in manufacturing processes (Fadel et al., 1994), including raw materials that will be processed, machines required to do so, but also human skills and information necessary to execute these processes. In Strategic Management, the resources of a firm include "*all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc, controlled by a firm that enable the firm to conceive and implement strategies that improve its efficiency and effectiveness*" (Barney, 1991). What emerges from these different views, implicitly or explicitly, is that being a resource is:

- a *contingent property*, as it is not essential for any individual to be a resource;
- a *relational property*, as an individual x is a resource for agent y if y needs to control x to achieve her goals; and

- an *all-embracing* property, as it is ascribed a wide range of things, including objects (either physical and immaterial), agents, qualities and relationships.

The specification of which resources an agent desires may be more or less precise. In the simplest case, an agent wants a determinate resource, such as a company who wants to acquire a particular customer. Alternatively, an agent might have a generic desire for resources of a given group or type. This second case describes, for instance, the desire of smartphone vendors like Apple and Samsung. It is not the case that either company wants to sell to a particular customer, such as you and I; instead, they want to acquire customers in the smartphone market. Note that generic desires might include a restriction w.r.t. to how many resources are demanded, as in a company who wants to hire five developers.

Note, however, that resources must be both mutually desired and scarce to give rise to competition. By being *mutually desired*, we mean that multiple agents must simultaneously seek to control the same resources. By being *scarce*, we mean that the number of available resources should be inferior to the collective demand for them. We emphasize that one should not confuse scarcity with rareness. A resource is rare if it is not found in abundance in comparison with other resources (e.g. diamonds are rarer than coal), regardless of how many people want them. A resource is scarce if there is less of it than people need, regardless of how many exist. Thus, it is possible that an abundant resource is scarce, while a rare resource is not.

6.3.3 Representing the Ontology of Competition in OntoUML

Given the characterization of competition we have given so far, we define it as *a practical external conflict that arises from the collective pursue of scarce resources*. We represent this definition with its embedded concepts and relations in the OntoUML model depicted in Figure 6.1. This model leverages two concepts from UFO-C (an ontology of social entities (Guizzardi and Guizzardi, 2010)), namely Agent and Intention. An Agent is an individual who bears intentional moments, such as beliefs, desires and intentions and is able to perform actions. An Intention is an internal commitment of an Agent to bring about a desired state of affairs. Two Intentions are conflicting if they cannot be satisfied simultaneously.

In the domain of competition, we are concerned with a particular type of in-

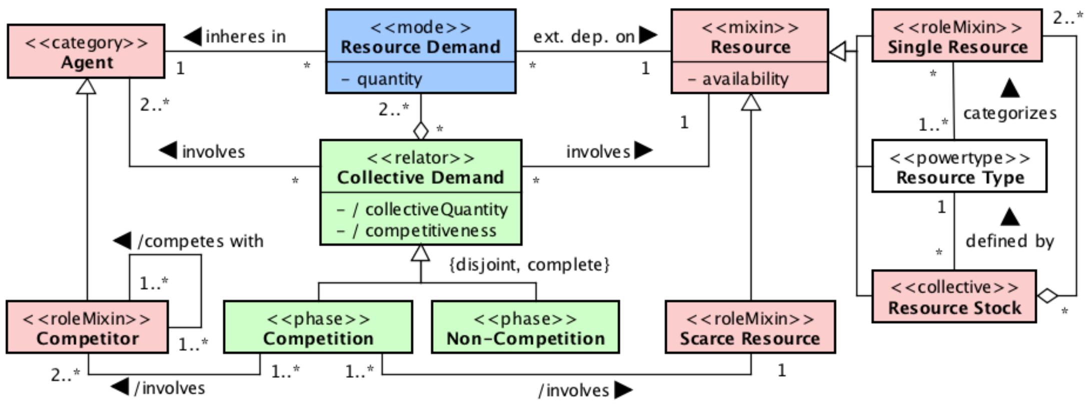

Figure 6.1: A fragment of the general ontology of competition in OntoUML.[3]

tention, namely those that are about acquiring or keeping control (or ownership, possession..) of resources. We label these as Resource Demand and represent them as being externally dependent on (symbolized in Figure 6.1 as ext.dep.on) a Resource. Demands for resources have a particular quality inhering in them[4], labeled as quantity and that accounts for how many resources an agent is seeking (e.g. a company who wants to hire *two* developers). Resources, instead are characterized by another quality, availability, which refers to how many of it are available (e.g. *five* positions available in a company). Notice that we use the term resource in a very broad sense, being the generalization of Single Resource, Resource Type, and Resource Stock. The first refers to particulars, the second to types (e.g. fast food customers), and the third to a collection of particulars (e.g. the collection of fast food customers in Italy). The relation categorizes, holding between Single Resource and Resource Type, represents that instances of the latter are instantiated by those of the former[5]. Lastly, note that the availability of a Single Resource is naturally always one. Mutatis mutandis, the same for the quantity of Resource Demands that refer to them.

The sum of demands for a common resource gives rise to an external and descriptive (Guarino and Guizzardi, 2016) relationship we name Collective Demand, which involves at least two Agents and exactly one Resource. It is a descriptive relation because it holds in virtue of some individual aspects (modes)

[4]For the sake of conciseness, we represent qualities as attributes in this diagram.
[5]As proposed by Carvalho et al. (2017)

of its relata, namely the agents' resource demands. Moreover, since these demands are externally dependent on resources, the relationship is external. A Collective Demand relationship is characterized by two derived qualities, collectiveQuantity and competitiveness. The former equals to the sum of the individual demands for resources that form the relationship, whilst the latter equals to the ratio between the former and the availability of the commonly desired Resource.

A Collective Demand relationship becomes a Competition whenever its composing Resource Demands cannot be simultaneously satisfied. Practically, this occurs whenever the availability of a Resource is lower than the demanded collectiveQuantity, which makes the resource scarce and the Agents who seek it Competitors. From the Competition relationship, we derive the competes-with relation that holds between Competitors. This relation is irreflexive, symmetric and non-transitive. It is irreflexive because competition emerges from external conflicts. It is symmetric because competition arises from mutually desired resources, thus, if John demands the same resource as Mary, the opposite claim is also true. Lastly, it is non-transitive because agents might be engaged in multiple Competition relationships for different Resources at the same time. For instance, Facebook competes with Google for online advertising customers and Google competes with Spotify for music streaming customers, still Facebook does not compete with Spotify (so far!).

6.4 The Case of Business Competition

Companies need a wide range of limitedly available resources to survive. These include capital, customers, employees, infrastructure, information, technology, partners, and many others. It is often the case that various companies seek the same resources, thus, they end up competing in many dimensions, often against a significant number of opponents. In this paper, however, we limit our analysis of business competition to those arising for arguably the most valuable resource for a company – customers[6].

[5] We adopt the following color coding in this paper: substantials are represented in pink, relators in green, intrinsic aspects in blue, and powertypes in white.

[6] We are aware that labeling customers as resources is a simplification of the phenomena. What companies want, in fact, are the resources controlled by these customers, such as their money, time and attention.

Given the inherently competitive nature of business, identifying and coping with competition is a fundamental aspect of firms' management and strategy (Gur and Greckhamer, 2018). Competitor identification, in particular, may seem to be a straightforward task at a first glance – a firm competes with every other firm that wants the same scarce resources as it does – however, it is in fact a much harder task than it seems. The big challenge comes from a simple, yet powerful barrier, namely the lack of access to what other firms really want. This barrier led academics to investigate a range of proxies that would indicate such intentions, which given the complex ontological nature of competition, gave rise to various frameworks and classification schemas for competition (Chen, 1996; Czepiel and Kerin, 2012; Ferrell and Hartline, 2012; Peteraf and Bergen, 2003; Porter, 2008a).

From the analysis of this plethora of competition theories, we extracted three recurring types of relationships that they directly or indirectly discuss. We refer to them as *market-level* competition, *firm-level* competition, and *potential* competition. In the following sections, we shall discuss each of them in detail.

6.4.1 Market-level Competition

Whenever we say that two companies compete, the intuition we most likely have in mind is that they offer similar products and services. This intuition makes it natural to claim that McDonald's competes with Burger King, as both companies are specialized in selling fast food hamburgers. It also makes it reasonable to claim that McDonald's competes with Subway and Pizza Hut, as they all offer low-priced quick meals, even if of different types. But what about companies that sell frozen meals? Could we still claim that they compete with McDonald's? To answer such a question, we need to elaborate on what we call *market-level competition*, the most basic competitive relationship in business. This type of relationship is characterized by conflicts between companies arising from the collective pursue of a common group of customers, a limited pool of resources commonly referred to as a *market segment*. Using product/service similarity works well as a proxy for identifying such relationships because functionally equivalent products and services help customers to fulfill equivalent needs. If you are hungry and on a budget, either a hamburger, a pizza or a frozen lasagna will suffice to fulfill that need.

A natural way to identify market-level competition, thus, is to look at the value propositions companies make, as argued in the theory of *Jobs to be Done* (Christensen et al., 2016). As we discussed in a previous work (Sales, Guarino, et al., 2017a), value propositions are “promises” companies make towards a group of customers to fulfill a set of customer goals by means of an offering they make. When a company makes a value proposition to a group, it is straightforward to assume it wants to acquire customers from that group. Thus, any other company making a value proposition build upon the same goals of these customers would also want to acquire them, leading to a conflict over a scarce resource, and thus, competition.

Note, however, that customer goals can be defined in various levels of abstraction (or levels of saturation), which means that, depending how they are defined, the question of who competes with whom may have different answers. If we define, for instance, a customer need as “eating a hamburger”, we would identify McDonald’s and Burger King as competitors. Instead, if we define it as “eating a fast and cheap meal” we would identify all fast-food companies as competitors, but also all of those who sell frozen meals, bakeries and deli shops. If we were to define the need simply as “having a meal”, virtually all companies in the food industry would be identified, from those selling frozen pizzas to high-scale sushi restaurants.

This variation w.r.t the level of abstraction in which we define goals is not arbitrary. We can find an explanation for them in the goal modeling literature (e.g. (Horkoff, Aydemir, et al., 2017)), in which goals are usually organized by means of OR- and AND-refinements. If a goal is decomposed by an OR-refinement, the satisfaction of any of the subgoals entails the satisfaction of the original goal, whilst in AND-refinements, only with the satisfaction of all subgoals the original goal is satisfied. In our previous example, "eating a hamburger" is a *mean to achieve* (therein called an OR-refinement) "eating a fast and cheap meal", which in turn is a means of "having a meal". These goal hierarchies help us to distinguish between two types of market-level competition:

- *direct market-level competition*, which arises when companies create value for customers by fulfilling a common low-level goal. Examples include the competition between McDonald’s and Burger King, who satisfy the goal of “eating a fast and cheap hamburger”, and that between Netflix and Amazon, who satisfy the goal of “watching movies on-demand”
- *indirect market-level competition*, which arises when companies create value for customers by fulfilling common higher-level goals by means of different lower-level goals. Examples include McDonald’s and local bakeries, and Net-

flix and broadcasting companies like BBC and RAI.

This characterization of direct and indirect competition integrates various distinctions made in competition theories. For instance, in Porter's five forces models (Porter, 2008a), they would be equivalent to rivals and substitutors, whilst in Peteraf and Berger's framework (Peteraf and Bergen, 2003), they would capture the distinction between direct rivals and vertical differentiators.

Notice that leveraging on goals to define market segments is not sufficient to fully characterize market-level competition. We also need to account for a market's geographical boundaries, as they define exactly which group of customers a company is pursuing. For instance, let us consider the need of "watching movies online on-demand". If we look into the European market, we identify Amazon and Netflix as direct competitors. Instead, if we consider the Japanese market, we would additionally identify Hulu as competitor. In the Chinese market, however, we would not identify any of the former three, but iQiyi and Youku instead.

Note that just as goals, geographical regions may be defined in multiple levels of granularity. The Japanese market of on-demand video is part of the Asian market, which in turn is part of the Global market. Differently from goals, however, companies competing in submarkets of a common broader market are not necessarily indirect competitors. For instance, both the Japanese and Chinese markets are part of the Asian market. Still, companies operating in these submarkets are not currently competing.

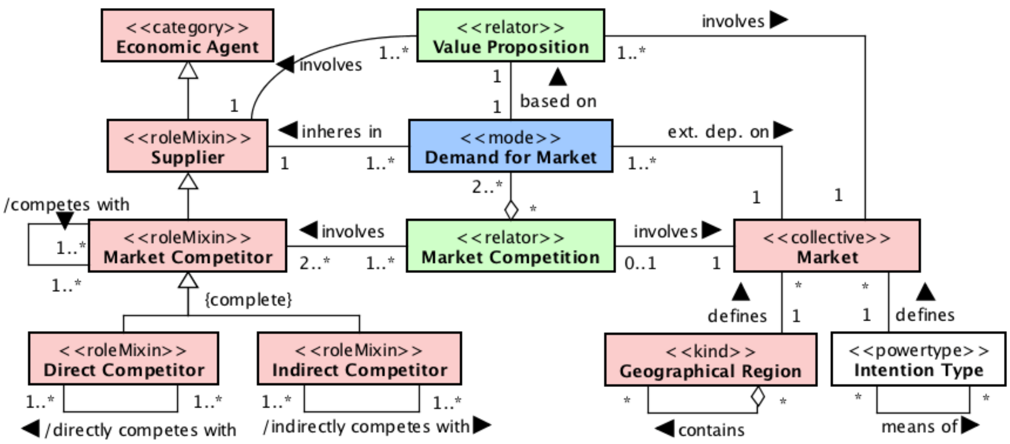

Figure 6.2: A model fragment on market-level competition.

We represent market-level competition, in its direct and indirect form, in the model of Figure 6.2. Following the general case, MARKET COMPETITION is a descriptive extrinsic relationship (Guarino and Guizzardi, 2016). It is composed by the intention of competitors to acquire customers of the same market segment. Such intentions can be identified by the VALUE PROPOSITIONS made by COMPETITORS towards a MARKET SEGMENT. These, in turn, are individuated by specific descriptions of customer needs (represented in the ontology as INTENTION TYPE) and GEOGRAPHICAL REGIONS. The part-whole relation between MARKETS captures the varying level of abstraction in which these can be defined. More precisely, a market A is direct part of a market B (a sort of *unity criterion* for B) if:

- A is defined by a customer need that is a means for that which defines B; and A and B are defined by the same geographical region; or
- A and B are defined by the same customer need; and the geographical region that defines A is contained by that of B.

6.4.2 Firm-level Competition

Competitive relationships at the market level are crucial to identify interdependence between companies w.r.t. specific customer segments. However, it is often the case that companies compete against each other in multiple markets, a phenomenon which has a direct impact in strategic decision making. To explain this competitive tension between a given pair of companies that spans throughout various markets, Chen (1996) distinguished two "levels" of competition: market-level competition, which we have just discussed, and firm-level competition.

The difference between market-level and firm-level competition regards the chosen unit of analysis. In the former, we fix a set of customer needs and identify, as competitors, all firms aiming to fulfill them. In firm-level competition, however, we fix the actual firms as the unit of analysis, and search for all market-level competitive relationships involving them. This characterization implies that, while market-level competition is a relationship involving at least two, but potentially multiple parties, firm-level competition is a relationship involving exactly two parties. It also follows that competitors in the firm-level are necessarily competitors in the market-level. In sum, firm-level competition can be understood as a complex conflict between two companies that emerges from multiple pursues of different types of scarce resources.

We also borrow from Chen (1996) two properties to characterize firm-level competition, namely market commonality and capability similarity[7]. *Market commonality* is a derived property calculated from the number of markets the two companies compete in divided by the number of markets each individual company competes in. These markets can be defined by different customer needs in the same geographical region (e.g. Unilever and P&G selling personal care and food products in Italy), by the same needs in different regions (e.g. Spotify and Deezer who offer the music streaming services in various countries), or by a mix of the two.

Capability similarity, on the other hand, refers to how similar companies are in terms of what they can achieve, what kind of strategy they can adopt and what kind of offerings they can make. To clarify on what we mean by capability similarity, we make use of follow definition of capability (Azevedo, Iacob, et al., 2015): "*capabilities are intrinsic dispositional properties of agents that endow them with the power of exhibiting some behavior or bringing about certain effects in the world*". Examples include the Netflix's capability of streaming videos to a large number of users worldwide, as well as Amazon's logistics capability of quickly delivering orders. Capability similarity, then, refers to a relation between capabilities of different agents that enable them to achieve similar enough outcomes.

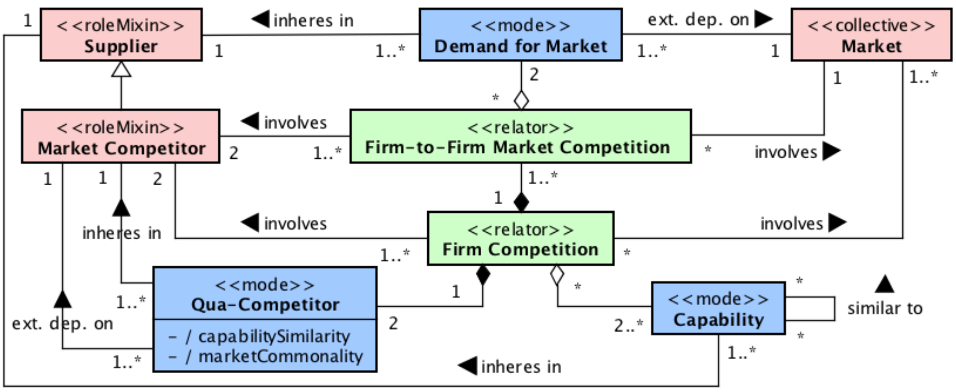

Figure 6.3: A model fragment on firm-level competition.

We formalize firm-level competition in the OntoUML model in Figure 6.3. Starting from top to bottom, we represent again the basic "building blocks" of market competition: SUPPLIERS' demands to acquire customers in MARKETS.

[7] Originally dubbed *resource similarity* by Chen (1996)

We use these demands to represent FIRM-TO-FIRM MARKET COMPETITION, a binary relationship that arises between every pair of competitors in a given MARKET. The sum of the firm-to-firm relationships is then used to compose the more complex relationship called FIRM COMPETITION, which always involves two competitors and all the markets they compete in. A FIRM COMPETITION is also formed by the COMPETITORS' CAPABILITIES. Note that we explicitly introduce *relational qua-individuals* (please refer to (Guizzardi, 2005)) for the FIRM COMPETITION relationship, labeled as QUA-COMPETITORS. This allows us to account for the qualities that characterize this relation, namely CAPABILITYSIMILARITY and MARKETCOMMONALITY (represented as attributes for conciseness). At the instance level, in a FIRM COMPETITION between Amazon and Google, the QUA-COMPETITOR class would be instantiated by *Amazon-qua-competitor-of-Google* and *Google-qua-competitor-of-Amazon.*

6.4.3 Potential Competition

The third recurrent type of competitive relationship found in the literature is the *potential competition* (Peteraf and Bergen, 2003; Porter, 2008a). In general, the potential competitors of a given agent are those who are prone to be interested in the resources this agent currently desires. This suggests that potential competition is grounded on external conflicts over resources that are *expected* to happen, but that have not happened yet. Since many factors influence which resources an agent might desire in the future, a proxy suggested by Peteraf and Bergen (Peteraf and Bergen, 2003) for identifying potential competitors is *capability similarity.* The assumption underlying this idea is that the potential competitors of an agent are those who have the proper *means* to compete for the resources the agent desires.

To exemplify this intuition, consider the following illustrative example. Jamie and Gordon are two chefs with an expertise on Italian cuisine, i.e. they are able to create and cook Italian dishes. Only Gordon, however, is an expert on French cuisine. Jamie owns an Italian restaurant and Gordon owns a French one, thus, they are not in a direct competition, for they serve two different market segments. Still Gordon poses a threat to Jamie, as he has the *means* to open his own Italian restaurant – Gordon's expertise on Italian cuisine. Jamie, however, does not pose an equivalent threat to Gordon, as he does not have the expertise in French cuisine. In this case Gordon is said to be a potential competitor of Jamie for the Italian restaurant market.

In this paper, we limit our analysis to potential competition between companies for market segments. Thus, we model it (see Figure 6.4) as a relationship involving:

- a (reference) Supplier, defined as a company that already makes a value proposition towards a Market;
- a Potential Competitor, defined as a company who does not make a value proposition towards the same Market, but has Capabilities that are equivalent to those that the reference Supplier needs in order to deliver its value proposition; and
- a Market, the reason for the potential conflict.

Note that potential competition involves exactly two companies and is always defined from the perspective of one of them. As an external descriptive relationship (Guarino and Guizzardi, 2016), potential competition "deserves" reification. We represent it as the sum of the reference Supplier's Capabilities required to deliver value for a particular market segment and the Potential Competitor's Capabilities that would allow them to make an equivalent value proposition to the same segment.

Regarding its formal properties, potential competition is an *irreflexive*, *non-symmetric* and *non-transitive* relationship. It is irreflexive and non-transitive by the same reasons that standard competition is so. It is non-symmetric, however, because it emerges from capability similarity between agents, a non-symmetric relation, as we have demonstrated above in the Jamie and Gordon example.

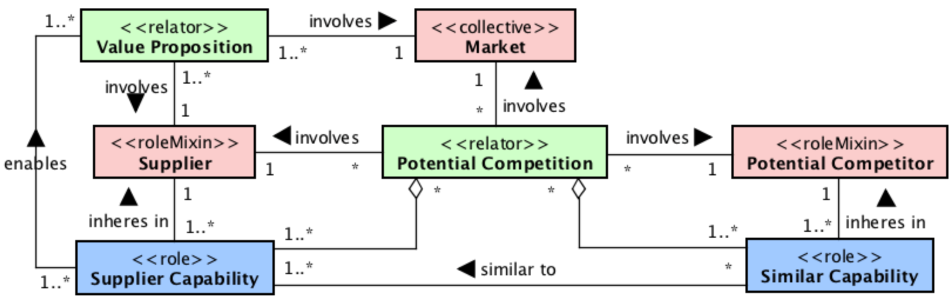

Figure 6.4: A model fragment on potential competition.

6.5 Related Work

To the best of our knowledge, no in depth ontological account of competition has been proposed in the literature, despite its clear relevance in strategic analysis. Thus, in this section, we compare the ontological analysis we propose with enterprise and business modeling contributions that use the concept of competition or a closely related notion.

One of such contributions is *c³value* (Weigand et al., 2007), an extension of *e³value* designed to support competition, customer and capability analysis. Although the authors do not explicitly define competition, the underlying intuition is that the competitors of a company are those who offer the same primary value object to customers. Competitors can also be classified according to the secondary values they offer (e.g. convenience, reliability). This allows companies to identify their competitors and represent how they distinguish themselves from the competition. In *c³value's* account of competition, one can represent direct and indirect competition between multiple companies.

Another extension of *e³value* that is related to this research is the *e³forces* model (Pijpers and Gordijn, 2007). In this extension, the authors leverage on Porter's five-forces framework (Porter, 2008a), a well-known strategic tool to analyze the competitiveness of industries, to describe how environmental factors impact a business value model. Three of such forces regard competitive relationships in the sense we have used in this paper, namely the rivalry between competitors, the threat of substitution, and the threat of new entrants. The first two refer to direct and indirect competition, respectively, whilst the third refers to potential competition. Although *e³forces* accounts for the same three relationships we discuss in this paper, it does not provide a precise characterization of why they hold and how to systematically identify them, relying solely on the intuitions put forth by Porter. Still in the domain of Enterprise Modeling, Pant and Yu (Pant and Yu, 2018) propose to model competition and cooperation using the i* goal modeling language. In their approach, competition is represented by means of resource dependencies: two actors compete if they depended on an external common actor for a particular resource. By doing so, however, their approach does not distinguish between the three types of competition we discussed in this paper, and neither on the different types of resource demand companies may have (single resources, resource types and resource stocks).

A last related work is the Enterprise Ontology (EO) (Uschold et al., 1998), a broad ontology about enterprises that marginally touches the notion of competition. EO defines a competitor as *"a role of a vendor in a relationship with another vendor whereby one offers one or more products for sale that could limit the sales of one or more products of the other vendor"*. With this definition, however, EO only describes binary direct competition, which, as we discussed, is just a particular case of one type of business competitive relationships.

6.6 Final Remarks

In this paper, we presented an ontological analysis of competition in general, and of business competition in particular. We first defined the general concept of competition as a *practical external conflict that arises from the collective demand for a common scarce resource* and formalized it in a concise OntoUML model. Then, we applied this conceptualization to investigate the ontological nature of business competition, which lead to the formal characterization of three types of business competitive relationships, namely market-level, firm-level, and potential competition.

The ontology presented in this paper can serve as a basis for future business ontologies and as a conceptual foundation for the development of several types of competitor analysis tools. These include modeling languages to support competitor identification and classification, machine learning algorithms that autonomously search for competitors, and linked open data repositories of competition information that could be fruitfully explored by entrepreneurs and researchers.

Chapter 7

Conclusions

In this final chapter, we summarize the main contributions made in this thesis, discuss how they achieve the general and specific research objectives defined in chapter 1, and argue why and to whom they are relevant. We also explain the main limitations involving our work and elaborate on future research directions on both the short- and long-term.

7.1 Research Contributions

In the introduction of this thesis, we defined our main objective as *"to define conceptual foundations for the modeling of strategic business information, particularly that which is related to value, risk and competition, in order to support organizations in formally representing and reasoning with it"*. We refined it into more specific objectives, which guided the development of this thesis. Now, we discuss how the ontologies and applications reported in this thesis achieve them.

Specific Objective 1: *Define sound conceptual foundations for value modeling that can explain what, how, and why things have value, such that it can be used to characterize the notion of value propositions.*

To achieve this objective, we conducted an in-depth ontological analysis of the notion of value based on theories from marketing, strategic management, business modeling and service science. In our analysis, reported in chapters 2 and 3, we argue that value emerges from changes in the degree of satisfaction of an agent's goals. This position clarifies a number of important aspects of the nature of value, namely that it is neutral, relative, experiential, and contextual. By neutral, we mean that value emerges from either positive or negative impacts on goals. By *relative*, we mean that the very same object may have a high value to a person and low value to another. By *experiential*, we mean that even when we ascribe value to objects, we always need to refer to experiences afforded by them. By *contextual*, we mean that the value of an object for a given agent may vary due to environmental conditions, even if it remains exactly the same. We also discuss the role of *uncertainty* in the value ascription process, an insight achieved by realizing that value and risk are two ends of the same spectrum. Lastly, we identified two roles played by agents in the value ascription process, namely the value beholder and the value subject. The former refers to the agent that "judges" the value of something, whilst the latter refers to the agent from whose perspective the valuation is being made.

This general analysis on the nature of value allowed us to characterize a value proposition as a particular type of value ascription, in which the proposing party acts as the value beholder, and the target party acts as the value subject. In a value proposition, the object being valuated is an offering made by the proposing party, or to be more precise, the experiences the target party may enjoy if the offer of the proposing party is accepted.

Specific Objective 2: *Define sound conceptual foundations for risk modeling that can disentangle and harmonize different perspectives on risk found in the literature.*

To accomplish this objective, we conducted an in-depth ontological analysis of the notion of risk, in which we explored the theoretical literature on risk management, but also relevant enterprise modeling approaches such as CORAS and RiskML. By studying the domain and better grasping the ontological commitments made by different authors, we developed a hypothesis that assessing risk was a particular case of ascribing value. We further developed this hypothesis by comparing the properties ascribed to both phenomena. We were able to show that, just as value, risk also emerges from changes in the degree of satisfaction of an agent's goals– although the changes considered are usually negative. From this, it followed that risk was also relative, experiential, and contextual. This joint characterization of value and risk resulted in the Common Ontology of Value and Risk (COVER), reported in chapter 3.

Moreover, our analysis showed that the term risk is recurrently used to refer to three distinct, yet closely related notions: (i) a complex (usually unwanted) chain of events that is expected to impact an agent's goals, which we label risk experience in our ontology; (ii) a quality that represents the expected disutility of a risk experience, i.e., risk as used in the sense of likelihood times impact; and (iii) an assessment made by an agent that classifies an event as a risk experience and that ascribes a particular expected disutility for it.

Lastly, our analysis identified a number of important roles played by objects when considering risk experiences. We defined a threat object as that which is the source of risk, the object at risk as that which is exposed to potential damage, and the risk enabler as that whose vulnerabilities allow risk experiences to occur, but that are not the source of risk.

Specific Objective 3: *Define sound conceptual foundations for modeling business competition, such that it supports competitor identification and classification.*

We address this objective by means of a multidisciplinary ontological analysis of the notion of competition, which was based on theories from marketing, strategic management, ecology, psychology and cognitive sciences. First, we build a general ontology that describes competitive relationships arising in any scenario, in which we define competition as a *practical external conflict that arises from the collective pursue of scarce resources*. Then, we applied this general ontology to describe three types of competitive relationships that arise in business environments, namely market-level, firm-level and potential competition. We defined market-level competition as one that arises between all firms that seek to acquire customers from a common market segment. We defined firm-level competition as a complex relationship between exactly two firms that emerges from the aggregation of all market-level competition involving them. Lastly, we realized that potential competition could not be explained in terms of current conflicts over customers, but instead by comparing capabilities of firms that do not yet compete.

Specific Objective 4: *Apply the reference ontologies to an existing modeling framework in order to (i) reveal potential semantic limitations, and (ii) improve its modeling power regarding the representation of strategically relevant information.*

We achieve our last objective by means of two applications of COVER in ArchiMate, a standardized enterprise architecture modeling language that is adopted by many organizations worldwide. One of these applications, reported in chapter 4, is a pattern language for value modeling, which we developed by: (i) mapping the categories and relations defined in COVER as ArchiMate constructs, (ii) identifying patterns of strongly connected value-related elements, and (iii) defining a process to support users in combining these patterns. We demonstrate the applicability of the pattern language by means of a case study about how customers of a low-cost airline perceive value.

The second application, reported in chapter 5, consists in using COVER to analyze the real-world semantics of the risk modeling fragment of ArchiMate's Risk and Security Overlay (RSO). In this analysis, we identified a number of limitations, particularly regarding ambiguous and missing constructs, that hinder the adequacy of the overlay to model the risk domain. For instance, we identified that the overlay did not account for threat capabilities, threat enablers, and threat objects that go beyond active structure elements. It also did not properly define what makes an event a loss event–the negative impact on a stakeholder's goal. More significantly, it overloaded the risk construct, using it to model risk as a complex event, risk as an assessment about an unwanted event, and risk as an aggregated quantitative analysis regarding an asset. With these limitations in hand, we redesigned the overlay in order to improve its expressivity and clarity.

7.2 Relevance for Researchers and Practitioners

For *enterprise modeling researchers*, the ontologies put forth in this thesis (see chapters 2, 7 and 6) lay a well-founded conceptual foundation that can be leveraged in the (re)engineering of tools and modeling languages to assist organizations in representing and reasoning with value, risk and competition. As demonstrated in the ArchiMate applications in chapters 4 and 5, the ontologies can be directly reused to identify semantic limitations in existing approaches and to more quickly develop new ones. Additionally, this thesis further evinces that enterprise modeling approaches significantly benefit from being grounded on well-founded ontologies, as argued by Guizzardi (2013) and Rosemann et al. (2004). The semantic deficiencies we found in ArchiMate's Risk and Security Overlay serve as further evidence that the conceptual complexities inherent to the domains covered by enterprise modeling should not be underestimated.

For *requirements engineering researchers*, our ontological investigation on value suggests that tackling requirements from a use-value perspective, as argued by Boehm (2006), is a worthwhile research direction to pursue. Given the grounding of value on goal satisfaction and frustration, value-orientation seems as a natural evolution from the main stream goal-orientation in requirements engineering. To understand how a software system would create value for a user, one would have to account for the envisioned experiences that user would go through, how this would satisfy and frustrate her (e.g. the effort to use a functionality), what external factors might affect this experience. Altogether, this could result in more successful software projects.

For *social science academics*, this thesis demonstrates that ontologies are efficient means for describing and communicating their theories and conceptual frameworks about the various aspects of social reality. With proper ontological representation in addition to the natural language description currently provided, the assumptions made and concepts proposed in a theory can be more easily understood and reused by others. In addition, it would facilitate the comparison between alternative theories on the same topic and the assessment of the extent to which a given theory can explain its domain of interest. Moreover, the ontologies can serve as a schema to characterize data about a given domain according to a chosen theory.

For *enterprise architects*, particularly those working with ArchiMate, this thesis is relevant in two ways. First, because the redesign of ArchiMate's Risk and Security Overlay proposed in chapter 5 provides a more complete and precise set of modeling constructs to represent and assess risks pertaining an enterprise. With the redesigned overlay, architects can model the chains of events an enterprise wants to protect itself against, their expected impact on goals of multiple stakeholders, the things and situations that cause them (or allow them to happen), and much more. Second, because the Value Pattern Language proposed in chapter 4 solves the long standing deficiency of ArchiMate to model value in a meaningful manner. Using the pattern language, architects can now model how any given stakeholder, such as a customer or a partner, experience value by engaging with the enterprise. This is a particularly important aspect to cover, as value creation can motivate a number of improvements to the architecture of an enterprise.

For *entrepreneurs* (or virtually any person designing a business model), the relevance of this thesis lies mostly in the ontological analysis reported in chapter 2. By investigating the ontological nature of value propositions, we were able reduce the conceptual confusion surrounding them and properly distinguish them from offerings and a collection of benefits–two notions that are often confused with value propositions. Moreover, the general account on the nature of value we discussed in chapters 2 and 3 suggests that when (re)designing a product or service, companies can benefit from carefully considering: the motivation that drives customers (not just the main goal a product or service is meant to satisfy), the whole experience customers will go through, and which external factors may influence such experiences.

7.3 Limitations

In each research paper that composes this thesis (chapters 2-6), we have discussed the limitations regarding its respective contributions. Now, we revisit the more general and relevant limitations of this thesis as a whole.

The ontologies reported in this thesis are all represented using OntoUML (Guizzardi, 2005) and thus, their instances represent ontologically consistent state of affairs. We have not, however, properly specified all instance-level domain constraints that guarantee that all their valid instances correspond to intended states of affairs according to the their underlying conceptualization. An example of such a constraint for COVER would be to force that all intentions that compose an experience value ascription inhere in the value subject that participates in the value experience that is involved in the ascription. This could be done, for instance, using OCL, as proposed by Guerson and Almeida (2016) and Guerson, Almeida, and Guizzardi (2014). After being further restricted with domain constraints, the ontologies would still need to be assessed using proper validation tools, such as visual simulation (Benevides et al., 2010) and ontological anti-patterns (Sales and Guizzardi, 2015; 2016; 2017), to further guarantee that all intended instances are admissible by the ontologies, but only those.

Another limitation we recognize is that the ontology of value propositions, reported in chapter 2, and COVER, reported in chapter 3, commit to the existence of future events. For readers not particularly acquainted with the philosophical literature on events, this may seem completely natural. In our daily lives, we often refer to events that we expect to happen, such as the next Olympic games, the trip we will take next month, or the presentation we are preparing ourselves to give. By inspecting the main stream literature on the topic, such as (Casati and Varzi, 2015), however, one can easily see that this is a very unorthodox commitment, as most assume that events are “frozen in time” and thus, can only exist in the past

(Guarino, 2017). The commitment to existence of only past events is also made in the most popular foundational ontologies–including UFO, the basic pillar from which we build the ontologies reported in this thesis. Nonetheless, it seems like an oxymoron for us to talk about value proposition and risk without referring to the future. One can only propose value or assess a risk by conceiving potential events and evaluating their expected impact on one's goals. In this work, we relied on the intuitions discussed by Guarino (2017), but to provide an even more stable conceptual grounding to our work, we should develop a proper event ontology that can cope with past, on-going and future events.

Another limitation pertaining to COVER is that we did not fully explore the nature of priority relations that hold between goals of an agent. When developing VPL, we assumed that they could simply be derived from the level of "importance" an agent ascribes to her goals. We recognize, however, that we have not properly clarified important questions such as "What affects this importance?" and "Can the importance of a goal change with time"?

A third limitation can be found in the ontology of competition, in which we commit to the interpretation of resource as a relational contingent property that potentially applies to any type of endurant. This is captured in the ontology by the representing the class RESOURCE as an OntoUML «roleMixin». We have not, however, actually formalized the relational dependency that characterizes this role. We have only informally described it by claiming that something becomes a resource for an agent, if by employing its capacities, this agent can achieve one of her objectives. Although this informal definition conveys our intuition and suffices to the account of competition we wanted to formalize, we believe that it does not fully cover the notion of resource as used across several disciplines. Such a complete ontological account of resource is a complex research question in itself that, which was out of the scope of this thesis.

7.4 Future Perspectives

Building upon the work reported in this thesis, our long-term research objective is to develop a network of well-founded ontologies for management and strategy. From this broad domain, we have only ontologically investigated three important concepts–value, risk and competition–and thus, plenty more are still left to be addressed. The need for such an ambitious endeavour is clearly justified by the sheer number of publications discussing conceptual and definitional issues with many notions in this domain (e.g. strategy (Mintzberg et al., 2005), business model (Timmers, 1998), competitive advantage (Powell, 2001), risk (Aven et al., 2011; Kjellmer, 2007), value and value co-creation (Bowman and Ambrosini, 2000; Boztepe, 2007; Sánchez-Fernández and Iniesta-Bonillo, 2006), competition (Gur and Greckhamer, 2018), brand (Grassi, 1998), personas (Junior and Almeida, 2018), customer loyalty (Dick and Basu, 1994), market and industry (Nightingale, 1978), service (Nardi et al., 2015)). This type of issue has several negative consequences for researchers, students and practitioners, as it hinders: (i) the application of these theories in practice, (ii) the classification and sharing of data about these phenomena, (iii) the integration of this ever-growing body of knowledge, and (iv) the development of tools to support those who work in the respective field.

We envision the development of a network instead of a monolithic ontology because of the nature of the domain at hand. First, it contains a significantly large number of conceptually complex notions. Thus, properly investigating and formalizing their ontological nature should be done incrementally. Second, and most importantly, these notions are mostly socially created and somehow intangible. They are different from simpler concepts, such as that of a chair or a car. One cannot "see" or "touch" a risk, a brand, or a market. Therefore, creating ontologies for these concepts means unveiling the underlying ontological commitments made by those who create the theories that define them. Naturally, for most concepts, there are several such theories, which often make conflicting commitments. Thus, a network of ontologies would allow for competing theories to be accounted for and their differences made clear.

In order to realize this long-term plan, an important direction to pursue is the integration of the existing core ontologies on this domain. Besides the natural step of integrating COVER with our ontology of competition, we also plan to integrate it with reference ontologies on the domain of service (Nardi et al., 2015), preference (Porello and Guizzardi, 2018), contracts (Griffo et al., 2018), and decision making (Guizzardi, Perini, et al., 2018).

Another important line of research in this direction is to proper characterize concepts that we have only marginally addressed in our ontological analyses, but that we keep running into. One is that of *resource* (as discussed in the limitations of this thesis). We grounded competition on conflicts arising over scarce resources and we discussed how some risks involve potential damage to resources that have value to organizations. Resources are also recurrently mentioned in strategic management to explain competitive advantage (Barney, 1991) and in service science to characterize value co-creation (Vargo et al., 2008) (as in resource integration). Still a proper characterization and formalization is missing in the literature. A second recurrently used and "problematic" concept is that of *capability*. Again, it appeared in the ontology of value and risk, and in our characterization of competition (in the definition of potential competition, to be more precise). Capabalities were the several subject of ontological analysis, such as those proposed by Azevedo, Iacob, et al. (2013) and Thongtra and Aagesen (2010), but we still believe they have not been fully explored.

In addition to broadening the scope of analysis, we also envision to further investigate those we already addressed. In particular, we plan to leverage COVER to disentangle and properly characterize the notion of value co-creation. Moreover, we plan to apply COVER in more specific domains in which value and risk are used, particularly in the financial and software domain. This will serve a two-fold purpose. First, it will demonstrate how the ontology can be reused and extended in practice, which is particularly relevant in the design of domain specific languages and tools. Second, it will further validate the ontology's expressivity, while identifying limitations that can be leveraged in its evolution.

7.4.1 Additional Research Opportunities

In addition to the broad direction of future research we have just discussed, we also envision a number of more focused and shorter-term research opportunities. One of them is to develop a stand-alone modeling approach for value propositions based on the ontologies we presented in this thesis. Such a language would resemble the Value Pattern Language for ArchiMate we introduced in chapter 4, but it would be more focused on representing value propositions and how customers experience them. In addition to providing a modeling language, we plan to design a number of analysis mechanisms to support value analysis at design-time and run-time.

By value analysis at design-time, we mean analyzing the possible ways in which a company may design a customer experience to help it optimize value creation for its customers and itself. This type of optimization analysis is directly inspired by works in requirements engineering, such as that presented by Nguyen et al. (2018). Design-time analysis can also include a sort of competitive analysis, in which a tool may compare value propositions to identify weak and strong points made by that of the focal company. By value analysis at run-time, we mean identifying and measuring the appropriate indicators to measure value delivery in actual customer experiences, so that companies can identify opportunities to improve their offerings.

Another opportunity is to leverage COVER to perform ontological analysis and redesign of risk management frameworks and modeling methods, just as we have done with ArchiMate's Risk and Security Overlay (reported in chapter 5). These may include CORAS (Lund et al., 2010), RiskML (Siena et al., 2014), the Bowtie methodology (American Institute of Chemical Engineers and Energy Institute, 2018), and the Systems-Theoretic Accident Model and Processes (STAMP) (Leveson, 2011).

Regarding the competition ontology, we believe it can serve as a conceptual foundation for the development of an enterprise modeling approach (or an extension of an existing one) to support competitor analysis. Surprisingly, this domain has been mostly ignored by current approaches, despite it being a fundamental aspect in strategy. Such a framework should allow one to represent and reason with competitive information, thus supporting strategists in dealing with the complexities inherent to competitive analysis.

Another potential application of the competition ontology is to develop a linked open data repository about business competition. Such a repository could provide data about markets, competitors and value propositions, thus supporting entrepreneurs in better grasping who their competitors are and how important they are, as well as exploring the state of markets they are interested in entering.

Bibliography

Aldea, A., Iacob, M. E., Hillegersberg, J. van, Quartel, D., and Franken, H. (2015). "Modelling value with ArchiMate". In: *27th International Conference on Advanced Information Systems Engineering (CAiSE) Workshops*. Vol. 215. Springer, pp. 375–388. DOI: https://doi.org/10.1007/978-3-319-19243-7_35.

Alexander, C., Silverstein, M., and Ishikawa, S. (1977). *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press.

Alley, T. R. (1982). "Competition theory, evolution, and the concept of an ecological niche". In: *Acta Biotheoretica* 31.3, pp. 165–179.

Almeida, J. P. A. and Guizzardi, G. (2013). "An ontological analysis of the notion of community in the RM-ODP enterprise language". In: *Computer Standards & Interfaces* 35.3, pp. 257–268.

American Institute of Chemical Engineers and Energy Institute (2018). *Bow Ties in Risk Management: A Concept Book for Process Safety*. John Wiley & Sons.

Anderson, J. C. and Narus, J. A. (2006). "Customer Value Propositions in Business Markets". In: *Harvard Business Review* 84.3, pp. 90–99. DOI: https://doi.org/10.4135/9781452229669.n945.

Andersson, B., Guarino, N., Johannesson, P., and Livieri, B. (2016). "Towards an Ontology of Value Ascription". In: *9th International Conference on Formal Ontology in Information Systems (FOIS)*. Vol. 283. IOS Press, pp. 331–344. DOI: https://doi.org/10.3233/978-1-61499-660-6-331.

Andersson, B., Johannesson, P., and Zdravkovic, J. (2009). "Aligning goals and services through goal and business modelling". In: *Information Systems and e-Business Management* 7.2, pp. 143–169. DOI: https://doi.org/10.1007/s10257-008-0084-2.

Annosi, M. C., De Pascale, A., Gross, D., and Eric, S. (2008). "Analyzing Software Process Alignment with Organizational Business Strategies using an Agent-and Goal-oriented Analysis Technique-an Experience Report." In: *3rd International i* Workshop (iStar)*. Vol. 322. CEUR-WS.org, pp. 9–12.

Arp, R., Smith, B., and Spear, A. D. (2015). *Building ontologies with Basic Formal Ontology*. MIT Press.

Asnar, Y., Giorgini, P., and Mylopoulos, J. (2011). "Goal-driven risk assessment in requirements engineering". In: *Requirements Engineering* 16.2, pp. 101–116.

Aven, T. (2010). "On how to define, understand and describe risk". In: *Reliability Engineering & System Safety* 95.6, pp. 623–631. DOI: `https://doi.org/10.1016/j.ress.2010.01.011`.

— (2011). *Misconceptions of risk*. John Wiley & Sons.

Aven, T., Renn, O., and Rosa, E. A. (2011). "On the ontological status of the concept of risk". In: *Safety Science* 49.8, pp. 1074–1079. DOI: `https://doi.org/10.1016/j.ssci.2011.04.015`.

Azevedo, C. L., Iacob, M.-E., Almeida, J. P. A., van Sinderen, M., Pires, L. F., and Guizzardi, G. (2013). "An ontology-based well-founded proposal for modeling resources and capabilities in ArchiMate". In: *17th International Enterprise Distributed Object Computing Conference (EDOC)*. IEEE, pp. 39–48. DOI: `https://doi.org/10.1109/EDOC.2013.14`.

Azevedo, C. L. B., Almeida, J. P. A., van Sinderen, M., and Pires, L. F. (2015). "Towards Capturing Strategic Planning in EA". In: *19th International Enterprise Distributed Object Computing Conference*, pp. 159–168. DOI: `https://doi.org/10.1109/EDOC.2015.31`.

Azevedo, C. L. B., Iacob, M. E., Almeida, J. P. A., van Sinderen, M., Pires, L. F., and Guizzardi, G. (2015). "Modeling resources and capabilities in enterprise architecture: A well-founded ontology-based proposal for ArchiMate". In: *Information systems* 54, pp. 235–262. DOI: `https://doi.org/10.1016/j.is.2015.04.008`.

Bagchi, S. and Tulskie, B. (2000). "E-business models: integrating learning from strategy development experiences and empirical research". In: *20th Annual International Conference of the Strategic Management Society*, pp. 15–18.

Ballantyne, D., Frow, P., Varey, R. J., and Payne, A. (2011). "Value propositions as communication practice: Taking a wider view". In: *Industrial Marketing Management* 40.2, pp. 202–210. DOI: `https://doi.org/10.1016/j.indmarman.2010.06.032`.

Ballantyne, D. and Varey, R. J. (2006). "Creating value-in-use through marketing interaction: the exchange logic of relating, communicating and knowing". In: *Marketing Theory* 6.3, pp. 335–348. DOI: `https://doi.org/10.1177/1470593106066795`.

Band, I., Engelsman, W., Feltus, C., Paredes, S. G., Hietala, J., Jonkers, H., Koning, P. d., and Massart, S. (2017). *Modeling Enterprise Risk Management and Security with the ArchiMate Language – W172*. The Open Group.

Barcelos, P. P. F., Santos, V. A. dos, Silva, F. B., Monteiro, M. E., and Garcia, A. S. (2013). "An Automated Transformation from OntoUML to OWL and SWRL." In: *6th Seminar on Ontology Research in Brazil (ONTOBRAS)*. Vol. 1041, pp. 130–141.

Barnes, C., Blake, H., and Pinder, D. (2009). "What is a Value Proposition?" In: *Creating and Delivering Your Value Proposition Managing Customer Experience for Profit*. Kogan Page. Chap. 2, pp. 21–38.

Barney, J. (1991). "Firm resources and sustained competitive advantage". In: *Journal of Management* 17.1, pp. 99–120. DOI: `https://doi.org/10.1177/014920639101700108`.

Barone, D., Topaloglou, T., and Mylopoulos, J. (2012). "Business Intelligence Modeling in Action: A Hospital Case Study". In: *24th International Conference on Advanced Information Systems Engineering (CAiSE)*. Ed. by J. Ralyté, X. Franch, S. Brinkkemper, and S. Wrycza. Springer, pp. 502–517. URL: `https://doi.org/10.1007/978-3-642-31095-9_33`.

Benevides, A. B., Guizzardi, G., Braga, B. F. B., and Almeida, J. P. A. (2010). "Validating Modal Aspects of OntoUML Conceptual Models Using Automatically Generated Visual World Structures." In: *Journal of Universal Computer Science* 16.20, pp. 2904–2933.

Boehm, B. W. (2006). "Value-based software engineering: Overview and agenda". In: *Value-based software engineering*. Ed. by S. Biffl, A. Aurum, B. Boehm, H. Erdogmus, and P. Grünbacher. Springer, pp. 3–14. DOI: `https://doi.org/10.1007/3-540-29263-2_1`.

Boholm, Å. and Corvellec, H. (2011). "A relational theory of risk". In: *Journal of Risk Research* 14.2, pp. 175–190. DOI: `https://doi.org/10.1080/13669877.2010.515313`.

Borgo, S. and Masolo, C. (2009). "Foundational choices in DOLCE". In: *Handbook on Ontologies*. Ed. by S. Staab, S. Staab, and R. Studer. Berlin, Germany: Springer Verlag, pp. 361–381. DOI: `https://doi.org/10.1007/978-3-540-92673-3_16`.

Bowman, C. and Ambrosini, V. (2000). "Value creation versus value capture: towards a coherent definition of value in strategy". In: *British journal of management* 11.1, pp. 1–15.

Boztepe, S. (2007). "User value: Competing theories and models". In: *International Journal of Design* 1.2, pp. 55–63.

Buschmann, F., Henney, K., and Schimdt, D. (2007). *Pattern-oriented Software Architecture: on patterns and pattern language*. Vol. 5. John Wiley & Sons.

Carvalho, V. A., Almeida, J. P. A., Fonseca, C. M., and Guizzardi, G. (2017). "Multi-level ontology-based conceptual modeling". In: *Data & Knowledge Engineering* 109, pp. 3–24.

Casati, R. and Varzi, A. (2015). "Events". In: *The Stanford Encyclopedia of Philosophy*. Ed. by E. N. Zalta. Winter 2015. Metaphysics Research Lab, Stanford University.

Castelfranchi, C. (2015). "The cognition of conflict: ontology, dynamics, and ideology". In: *Conflict and Multimodal Communication*. Ed. by F. D'Errico, I. Poggi, A. Vinciarelli, and L. Vincze. Springer, pp. 3–32. DOI: `https://doi.org/10.1007/978-3-319-14081-0_1`.

Cavalcante, S. A. (2013). "Understanding the impact of technology on firms' business models". In: *European Journal of Innovation Management* 16.3, pp. 285–300. URL: `https://doi.org/10.1108/ejim-10-2011-0085`.

Chen, M.-J. (1996). "Competitor analysis and interfirm rivalry: Toward a theoretical integration". In: *Academy of management review* 21.1, pp. 100–134.

Christensen, C. M., Hall, T., Dillon, K., and Duncan, D. S. (2016). "Know your customers' "jobs to be done"". In: *Harvard Business Review* 94.9, pp. 54–62.

Clark, M. and Bryan, A. (2013). "Customer Effort: Help or hype?" In: *Henley Business school*.

Committee of Sponsoring Organizations of the Treadway Commission (2004). *Enterprise Risk Management - Integrated Framework*.

Corcho, O., Fernández-López, M., and Gómez-Pérez, A. (2003). "Methodologies, tools and languages for building ontologies. Where is their meeting point?" In: *Data & Knowledge Engineering* 46.1, pp. 41–64. URL: `https://doi.org/10.1016/S0169-023X(02)00195-7`.

Czepiel, J. A. and Kerin, R. A. (2012). "Competitor analysis". In: *Handbook of marketing strategy*. Ed. by V. Shankar and G. S. Carpenter. Northampton, MA: Edward Elgar Publishing, pp. 41–57.

Derks, J., Gordijn, J., and Siegmann, A. (2018). "From chaining blocks to breaking even: A study on the profitability of bitcoin mining from 2012 to 2016". In: *Electronic Markets* 28.3, pp. 321–338.

DeSarbo, W. S., Grewal, R., and Wind, J. (2006). "Who competes with whom? A demand-based perspective for identifying and representing asymmetric competition". In: *Strategic Management Journal* 27.2, pp. 101–129.

Deutsch, M. (2015). "Cooperation, Competition, and Conflict". In: *Morton Deutsch: A Pioneer in Developing Peace Psychology*. Springer, pp. 47–70.

Dick, A. S. and Basu, K. (1994). "Customer loyalty: toward an integrated conceptual framework". In: *Journal of the academy of marketing science* 22.2, pp. 99–113.

Diekemper, J. (2014). "The Existence of the Past". In: *Synthese* 191.6, pp. 1085–1104.

Dölling, J. (2018). "Systematic polysemy". In: *The Blackwell Companion to Semantics*. Ed. by D. Gutzmann, L. Matthewson, C. Meier, H. Rullmann, and T. E. Zimmermann. Forthcoming.

Fadel, F. G., Fox, M. S., and Gruninger, M. (1994). "A generic enterprise resource ontology". In: *3rd Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*. IEEE, pp. 117–128.

Falbo, R. A. (2014). "SABiO: Systematic Approach for Building Ontologies." In: *1st Joint Workshop Onto.com/ODISE on Ontologies in Conceptual Modeling and Information Systems Engineering*. Vol. 1301. CEUR-WS.org. URL: `http://ceur-ws.org/Vol-1301/ontocomodise2014_2.pdf`.

Falbo, R. A., Guizzardi, G., Guizzardi, R. S. S., Barcellos, M., and Ruy, F. (2016). "Ontology Pattern Languages". In: *Ontology Engineering with Ontology Design Patterns: Foundations and Applications*. Ed. by P. Hitzler, A. Gangemi, and K. Janowicz. Vol. 25. IOS Press.

Feltus, C., Proper, E. H., and Haki, K. (2018). "Towards a Language to Support Value Cocreation: An Extension to the ArchiMate Modeling Framework". In: *Federated Conference on Computer Science and Information Systems (ACSIS)*. Ed. by M. Ganzha, L. Maciaszek, and M. Paprzycki. Vol. 15. IEEE, pp. 751–760. DOI: `https://doi.org/10.15439/2018F27`.

Ferrell, O. C. and Hartline, M. (2012). *Marketing strategy, text and cases*. Nelson Education.

Fillmore, C. J. and Atkins, B. T. (1992). "Toward a frame-based lexicon: The semantics of RISK and its neighbors". In: *Frames, fields, and contrasts: New essays in semantic and lexical organization* 103, pp. 75–102.

Frost, F. A. (2003). "The use of strategic tools by small and medium-sized enterprises: an Australasian study". In: *Strategic change* 12.1, pp. 49–62.

Frow, P. and Payne, A. (2008). "A stakeholder perspective of value: Extending the value proposition concept in the context of stakeholders and service-dominant logic". In: *Forum on markets and marketing: Extending service-dominant logic*. Vol. 4.

Gailly, F., Roelens, B., and Guizzardi, G. (2016). "The Design of a Core Value Ontology Using Ontology Patterns". In: *35th International Conference on Conceptual Modeling (ER)*. Ed. by S. Link and J. Trujillo. Vol. 9975. Springer, pp. 183–193. DOI: `https://doi.org/10.1007/978-3-319-47717-6_16`.

Gordijn, J. and Akkermans, H. (2001). “Designing and evaluating e-business models”. In: *IEEE Intelligent Systems* 16.4, pp. 11–17. DOI: https://doi.org/10.1109/5254.941353.

Gordijn, J. and Akkermans, J. M. (2003). “Value-based requirements engineering: exploring innovative e-commerce ideas”. In: *Requirements Engineering* 8.2, pp. 114–134. DOI: https://doi.org/10.1007/s00766-003-0169-x.

Gordijn, J., De Leenheer, P., and Razo-Zapata, I. (2011). “Generating service value webs by hierarchical configuration: A case in intellectual property rights clearing”. In: *44th Hawaii International Conference on System Sciences (HICSS)*. IEEE, pp. 1–10.

Grassi, W. (1998). “The Reality of Brands: Towards an Ontology of Marketting”. In: *American Journal of Economics and Sociology* 58.2, pp. 313–359.

Griffo, C., Almeida, J. P. A., and Guizzardi, G. (2016). “A Pattern for the Representation of Legal Relations in a Legal Core Ontology”. In: *29th Annual Conference on Legal Knowledge and Information Systems (JURIX)*. Vol. 294. IOS Press, pp. 191–194. DOI: https://doi.org/10.3233/978-1-61499-726-9-191.

— (2018). “Conceptual Modeling of Legal Relations”. In: *37th International Conference on Conceptual Modeling (ER)*. Ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 169–183. DOI: https://doi.org/10.1007/978-3-030-00847-5_14.

Grüninger, M. and Fox, M. S. (1995). “Methodology for the design and evaluation of ontologies”. In: *Workshop on Basic Ontological Issues in Knowledge Sharing*.

Guarino, N. (2017). “On the Semantics of Ongoing and Future Occurrence Identifiers”. In: *36th International Conference on Conceptual Modeling (ER)*. Ed. by H. C. Mayr, G. Guizzardi, H. Ma, and O. Pastor. Springer, pp. 477–490. DOI: https://doi.org/10.1007/978-3-319-69904-2_36.

Guarino, N. and Guizzardi, G. (2016). “Relationships and events: towards a general theory of reification and truthmaking”. In: *15th Conference of the Italian Association for Artificial Intelligence (AI*IA)*. Springer, pp. 237–249. DOI: https://doi.org/10.1007/978-3-319-49130-1_18.

Guarino, N., Guizzardi, G., and Sales, T. P. (2018). “On the Ontological Nature of REA Core Relations”. In: *12th International Workshop on Value Modeling and Business Ontologies (VMBO)*. Ed. by J. Gordijn and E. Proper. CEUR-WS.org, pp. 89–98.

Guarino, N., Sales, T. P., and Guizzardi, G. (2018). “Reification and Truthmaking Patterns”. In: *37th International Conference on Conceptual Modeling (ER)*. Ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 151–165. DOI: https://doi.org/10.1007/978-3-030-00847-5_13.

Guarino, N. and Welty, C. (2009). “An Overview of OntoClean”. In: *Handbook on Ontologies*. Ed. by S. Staab and R. Studer. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 201–220. DOI: https://doi.org/10.1007/978-3-540-92673-3_9.

Guerson, J. and Almeida, J. P. (2016). “Representing Dynamic Invariants in Ontologically Well-Founded Conceptual Models”. In: *Enterprise, Business-Process and Information Systems Modeling*. Ed. by R. Schmidt, W. Guédria, I. Bider, and S. Guerreiro. Cham: Springer International Publishing, pp. 303–317. DOI: https://doi.org/10.1007/978-3-319-39429-9_19.

Guerson, J., Almeida, J. P. A., and Guizzardi, G. (2014). "Support for Domain Constraints in the Validation of Ontologically Well-Founded Conceptual Models". In: *Enterprise, Business-Process and Information Systems Modeling*. Ed. by Bider et al. Springer, pp. 302–316. URL: https://doi.org/10.1007/978-3-662-43745-2_21.

Guizzardi, G. (2005). *Ontological foundations for structural conceptual models*. University of Twente.

— (2006). "The role of foundational ontologies for conceptual modeling and domain ontology representation". In: *7th International Baltic Conference on Databases and Information Systems (Baltic DB&IS)*. Ed. by O. Vasilecas, J. Eder, and A. Caplinskas, pp. 17–25. DOI: https://doi.org/10.1109/dbis.2006.1678468.

— (2007). "On ontology, ontologies, conceptualizations, modeling languages, and (meta) models". In: *Frontiers in Artificial Intelligence and Applications* 155, p. 18.

— (2013). "Ontology-based evaluation and design of visual conceptual modeling languages". In: *Domain Engineering*. Springer, pp. 317–347.

Guizzardi, G., Almeida, J. P. A., Guarino, N., and Carvalho, V. A. de (2015). "Towards an Ontological Analysis of Powertypes". In: *1st Joint Ontology Workshops (JOWO)*. Ed. by Papini et al. Vol. 1517. CEUR-WS.org.

Guizzardi, G., Baião, F., Lopes, M., and Falbo, R. (2010). "The role of foundational ontologies for domain ontology engineering: An industrial case study in the domain of oil and gas exploration and production". In: *International Journal of Information System Modeling and Design* 1.2, pp. 1–22.

Guizzardi, G., Falbo, R. A., and Guizzardi, R. S. S. (2008). "Grounding software domain ontologies in the Unified Foundational Ontology (UFO)". In: *11th Ibero-American Conference on Software Engineering (CIbSE)*, pp. 127–140.

Guizzardi, G., Fonseca, C. M., Benevides, A. B., Almeida, J. P. A., Porello, D., and Sales, T. P. (2018). "Endurant Types in Ontology-Driven Conceptual Modeling: Towards OntoUML 2.0". In: *37th International Conference on Conceptual Modeling (ER)*. Ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 136–150. DOI: https://doi.org/10.1007/978-3-030-00847-5_12.

Guizzardi, G., Graças, A. P. das, and Guizzardi, R. S. S. (2011). "Design patterns and inductive modeling rules to support the construction of ontologically well-founded conceptual models in OntoUML". In: *23rd International Conference on Advanced Information Systems Engineering (CAiSE)*. Ed. by C. Salinesi and O. Pastor. Springer, pp. 402–413. DOI: https://doi.org/10.1007/978-3-642-22056-2_44.

Guizzardi, G., Guarino, N., and Almeida, J. P. A. (2016). "Ontological Considerations About the Representation of Events and Endurants in Business Models". In: *International Conference on Business Process Management (BPM)*. Springer, pp. 20–36.

Guizzardi, G. and Sales, T. P. (2017). "“As Simple as Possible but not Simpler”: Towards an Ontology Model Canvas". In: *3rd Joint Ontology Workshops (JOWO)*. Ed. by S. Borgo, O. Kutz, F. Loebe, and F. Neuhaus. Vol. 2050. CEUR-WS.org.

Guizzardi, G., Wagner, G., Almeida, J. P. A., and Guizzardi, R. S. S. (2015). "Towards ontological foundations for conceptual modeling: the Unified Foundational Ontology (UFO) story". In: *Applied ontology* 10.3-4, pp. 259–271. DOI: https://doi.org/10.3233/AO-150157.

Guizzardi, G., Wagner, G., Falbo, R. A., Guizzardi, R. S. S., and Almeida, J. P. A. (2013). "Towards ontological foundations for the conceptual modeling of events". In: *32nd International Conference on Conceptual Modeling (ER)*. Ed. by W. Ng, V. C. Storey, and J. Trujillo. Springer, pp. 327–341. DOI: https://doi.org/10.1007/978-3-642-41924-9_27.

Guizzardi, R. S. S. and Guizzardi, G. (2010). "Ontology-Based Transformation Framework from Tropos to AORML". In: *Social Modeling for Requirements Engineering*. Ed. by E. Yu, P. Giorgini, N. Maiden, and J. Mylopoulos. MIT Press. Chap. 16, pp. 547–570.

Guizzardi, R. S. S., Li, F.-L., Borgida, A., Guizzardi, G., Horkoff, J., and Mylopoulos, J. (2014). "An Ontological Interpretation of Non-Functional Requirements". In: *8th International Conference on Formal Ontology in Information Systems (FOIS)*. Vol. 267, pp. 344–357. DOI: https://doi.org/10.3233/978-1-61499-438-1-344.

Guizzardi, R. S. S., Perini, A., and Susi, A. (2018). "Aligning Goal and Decision Modeling". In: *30th International Conference on Advanced Information Systems Engineering (CAiSE)*. Springer, pp. 124–132.

Gur, F. A. and Greckhamer, T. (2018). "Know Thy Enemy: A Review and Agenda for Research on Competitor Identification". In: *Journal of Management*. DOI: https://doi.org/10.1177/0149206317744250.

Henderson, B. D. (1983). "The anatomy of competition". In: *The Journal of Marketing*, pp. 7–11. DOI: https://doi.org/10.2307/1251489.

Herre, H. (2010). "General Formal Ontology (GFO): A foundational ontology for conceptual modelling". In: *Theory and Applications of Ontology: Computer Applications*. Ed. by R. Poli, M. Healy, and A. Kameas. Springer, pp. 297–345. DOI: https://doi.org/10.1007/978-90-481-8847-5_14.

Hevner, A. R., March, S. T., Park, J., and Ram, S. (2008). "Design science in information systems research". In: *Management Information Systems Quarterly* 28.1, p. 6. DOI: https://doi.org/10.2307/25148625.

Horkoff, J., Aydemir, F. B., Cardoso, E., Li, T., Maté, A., Paja, E., Salnitri, M., Piras, L., Mylopoulos, J., and Giorgini, P. (2017). "Goal-oriented requirements engineering: an extended systematic mapping study". In: *Requirements Engineering*, pp. 1–28. DOI: https://doi.org/10.1007/s00766-017-0280-z.

Horkoff, J., Barone, D., Jiang, L., Yu, E., Amyot, D., Borgida, A., and Mylopoulos, J. (2014). "Strategic business modeling: representation and reasoning". In: *Software & System Modeling* 13.3, pp. 1015–1041. DOI: https://doi.org/10.1007/s10270-012-0290-8.

Iacob, M.-E., Quartel, D., and Jonkers, H. (2012). "Capturing business strategy and value in enterprise architecture to support portfolio valuation". In: *16th IEEE International Enter-*

prise Distributed Object Computing Conference (EDOC). Ed. by C.-H. Chi, D. Gasevic, and W.-J. van den Heuvel. IEEE, pp. 11–20. DOI: `https://doi.org/10.1109/EDOC.2012.12`.

Institute of Risk Management (2002). *A Risk Management Standard*.

International Organization for Standardization (2009). *Risk Management - Vocabulary, ISO Guide 73:2009*.

— (2018). *Risk Management - Guidelines, ISO 31000:2018*.

ISO/ITU-T (1995). *Open Distributed Processing – Reference Model, International Standard ISO/IEC 10746-2, ITU-T Recommendation X.902*. Standard.

Jarzabkowski, P. and Paul Spee, A. (2009). "Strategy-as-practice: A review and future directions for the field". In: *International Journal of Management Reviews* 11.1, pp. 69–95.

Jarzabkowski, P. and Wilson, D. C. (2006). "Actionable Strategy Knowledge:: A Practice Perspective". In: *European Management Journal* 24.5, pp. 348–367. URL: `https://doi.org/10.1016/j.emj.2006.05.009`.

Junior, M. C. and Almeida, J. P. A. (2018). "Toward an Ontological Analysis of Archetypal Entities in the Marketing Domain: Personas and Related Concepts". In: *11th Seminar on Ontology Research in Brazil (ONTOBRAS)*. Ed. by J. L. Carbonera, G. Guizzardi, S. R. Fiorini, and M. Abel. CEUR-WS.org, pp. 173–184.

Kalbach, J. (2016). *Mapping experiences: A complete guide to creating value through journeys, blueprints, and diagrams*. O'Reilly Media, Inc.

Kambil, A., Ginsberg, A., and Bloch, M. (1996). "Re-inventing value propositions". In: *Information Systems Working Papers Series*.

Keet, C. M. (2011). "The use of foundational ontologies in ontology development: an empirical assessment". In: *8th Extended Semantic Web Conference*. Ed. by Antoniou, G. et al. Vol. 6643. Springer, pp. 321–335. DOI: `https://doi.org/10.1007/978-3-642-21034-1_22`.

Kjellmer, G. (2007). "On the Awkward Polysemy of the Verb 'risk'". In: *Nordic Journal of English Studies* 6.1.

Krzyżanowska, M. and Tkaczyk, J. (2013). "Identifying competitors: challenges for start-up firms". In: *International Journal of Management Cases* 15.4, pp. 234–247.

Lankhorst, M. et al. (2013). *Enterprise Architecture at Work: Modelling, Communication and Analysis*. The Enterprise Engineering Series. Springer.

Lanning, M. J. and Michaels, E. G. (1988). "A business is a value delivery system". In: *McKinsey staff paper* 41.

Leveson, N. (2011). *Engineering a safer world: Systems thinking applied to safety*. MIT Press.

Levitt, T. (1960). "Marketing myopia". In: *Harvard business review* 38.4, pp. 24–47.

Lund, M. S., Solhaug, B., and Stølen, K. (2010). *Model-driven risk analysis: the CORAS approach*. Springer Science & Business Media. DOI: `https://doi.org/10.1007/978-3-642-12323-8`.

Ma, Z., Pant, G., and Sheng, O. R. (2011). "Mining competitor relationships from online news: A network-based approach". In: *Electronic Commerce Research and Applications* 10.4, pp. 418–427. DOI: `https://doi.org/10.1016/j.elerap.2010.11.006`.

Massin, O. and Tieffenbach, E. (2016). "The Metaphysics of Economic Exchanges". In: *Journal of Social Ontology*, pp. 1–39. DOI: `https://doi.org/10.1515/jso-2015-0057`.

Mayer, N., Aubert, J., Grandry, E., Feltus, C., Goettelmann, E., and Wieringa, R. (2018). "An integrated conceptual model for information system security risk management supported by enterprise architecture management". In: *Software & Systems Modeling*, pp. 1–28. DOI: https://doi.org/10.1007/s10270-018-0661-x.

Mayer, N. and Feltus, C. (2017). "Evaluation of the risk and security overlay of ArchiMate to model information system security risks". In: *9th International Workshop on Vocabularies, Ontologies and Rules for the Enterprise (VORTE)*. IEEE, pp. 106–116. DOI: https://doi.org/10.1109/EDOCW.2017.30.

Mead, M. (2002). *Cooperation and competition among primitive peoples*. Transaction Publishers.

Meertens, L., Iacob, M.-E., Nieuwenhuis, L., van Sinderen, M., Jonkers, H., and Quartel, D. (2012). "Mapping the business model canvas to ArchiMate". In: *27th Annual ACM Symposium on Applied Computing (SAC)*. ACM, pp. 1694–1701. DOI: https://doi.org/10.1145/2245276.2232049.

Mintzberg, H., Ahlstrand, B., and Lampel, J. (2005). *Strategy Safari: a guided tour through the wilds of strategic mangament*. Simon and Schuster.

Moreira, J. L. R., Sales, T. P., Guerson, J., Braga, B. F. B., Brasileiro, F., and Sobral, V. (2016). "Menthor Editor: An Ontology-Driven Conceptual Modeling Platform". In: *2nd Joint Ontology Workshops (JOWO)*. Ed. by O. Kutz and S. de Cesare. Vol. 1660. CEUR-WS.org.

Myerson, R. B. (1997). *Game Theory*. Harvard University Press.

Nardi, J. C., Falbo, R. A., Almeida, J. P. A., Guizzardi, G., Pires, L. F., van Sinderen, M. J., Guarino, N., and Fonseca, C. M. (2015). "A commitment-based reference ontology for services". In: *Information systems* 54, pp. 263–288. DOI: https://doi.org/10.1016/j.is.2015.01.012.

Ng, D., Westgren, R., and Sonka, S. (2009). "Competitive blind spots in an institutional field". In: *Strategic Management Journal* 30.4, pp. 349–369. DOI: https://doi.org/10.1002/smj.741.

Nguyen, C. M., Sebastiani, R., Giorgini, P., and Mylopoulos, J. (2018). "Multi-objective reasoning with constrained goal models". In: *Requirements Engineering* 23.2. DOI: https://doi.org/10.1007/s00766-016-0263-5.

Nightingale, J. (1978). "On the Definition of 'Industry' and 'Market'". In: *The Journal of Industrial Economics*, pp. 31–40. DOI: https://doi.org/10.2307/2098116.

Noy, N. F. and McGuinness, D. L. (2001). *Ontology development 101: A guide to creating your first ontology*. Technical Report.

Object Management Group (2011). *Business Process Model and Notation (BPMN). Version 2.0*. Standard.

— (2018). *Value Delivery Modeling Language (VDML) 1.1*. Version 1.1. URL: https://www.omg.org/spec/VDML/1.1/Beta1/PDF.

Osterwalder, A. and Pigneur, Y. (2004). "An ontology for e-business models". In: *Value Creation from e-Business Models*. Ed. by W. Currie. 1st. Elsevier. Chap. 4, pp. 65–97.

— (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*. John Wiley & Sons.

Osterwalder, A., Pigneur, Y., Bernarda, G., and Smith, A. (2014). *Value proposition design: How to create products and services customers want*. John Wiley & Sons.

Pant, V. and Yu, E. (2018). “Modeling Simultaneous Cooperation and Competition Among Enterprises”. In: *Business & Information Systems Engineering*, pp. 1–16. DOI: https://doi.org/10.1007/s12599-017-0514-0.

Pereira, D. C. and Almeida, J. P. A. (2014). “Representing Organizational Structures in an Enterprise Architecture Language.” In: *6th Workshop on Formal Ontology Meets Industry (FOMI)*. Vol. 1333. URL: http://ceur-ws.org/Vol-1333/fomi2014_2.pdf.

Peteraf, M. A. and Bergen, M. E. (2003). “Scanning dynamic competitive landscapes: a market-based and resource-based framework”. In: *Strategic Management Journal* 24.10, pp. 1027–1041.

Pickton, D. and Wright, S. (1998). “What’s swot in strategic analysis?” In: *Strategic change* 7.2, pp. 101–109.

Pijpers, V. and Gordijn, J. (2007). “*e3forces*: understanding strategies of networked *e3value* constellations by analyzing environmental forces”. In: *19th International Conference on Advanced Information Systems Engineering (CAiSE)*. Springer, pp. 188–202. DOI: https://doi.org/10.1007/978-3-540-72988-4_14.

Porello, D. and Guizzardi, G. (2018). “Towards an ontological modelling of preference relations”. In: *17th International Conference of the Italian Association for Artificial Intelligence (IA*AI)*. Vol. 11298. Springer, pp. 152–165. DOI: https://doi.org/10.1007/978-3-030-03840-3_12.

Porello, D., Bottazzi, E., and Ferrario, R. (2014). “The Ontology of Group Agency”. In: *8th International Conference on Formal Ontology in Information Systems (FOIS)*. Vol. 267, pp. 183–196. DOI: https://doi.org/10.3233/978-1-61499-438-1-183.

Porter, M. (2001). “The value chain and competitive advantage”. In: *Understanding Business Processes*. Routledge London, pp. 50–66.

— (2008a). *Competitive strategy: Techniques for analyzing industries and competitors*. Simon and Schuster.

— (2008b). “The five competitive forces that shape strategy”. In: *Harvard Business Review* 86.1, pp. 78–93.

Powell, T. C. (2001). “Competitive advantage: logical and philosophical considerations”. In: *Strategic management journal* 22.9, pp. 875–888.

Renn, O. (1998). “Three decades of risk research: accomplishments and new challenges”. In: *Journal of Risk Research* 1.1, pp. 49–71. DOI: https://doi.org/10.1080/136698798377321.

Rintamäki, T., Kuusela, H., and Mitronen, L. (2007). “Identifying competitive customer value propositions in retailing”. In: *Managing Service Quality* 17.6, pp. 621–634. DOI: https://doi.org/10.1108/09604520710834975.

Roelens, B., Steenacker, W., and Poels, G. (2017). “Realizing strategic fit within the business architecture: the design of a Process-Goal Alignment modeling and analysis technique”. In: *Software & Systems Modeling*, pp. 1–32. DOI: https://doi.org/10.1007/s10270-016-0574-5.

Rokeach, M. (1973). *The nature of human values*. Free press.

Rosa, E. A. (1998). “Metatheoretical foundations for post-normal risk”. In: *Journal of Risk Research*. DOI: https://doi.org/10.1080/136698798377303.

Rosemann, M., Green, P., and Indulska, M. (2004). “A reference methodology for conducting ontological analyses”. In: *23rd International Conference on Conceptual Modeling (ER)*. Ed. by Atzeni, P. et al. Springer, pp. 110–121. DOI: https://doi.org/10.1007/978-3-540-30464-7_10.

Rybola, Z. and Pergl, R. (2016). “Towards OntoUML for Software Engineering: Transformation of Anti-rigid Sortal Types into Relational Databases”. In: *6th International Conference on Model and Data Engineering (MEDI)*. Ed. by L. Bellatreche, Ó. Pastor, J. M. Almendros Jiménez, and Y. Aït-Ameur. Springer, pp. 1–15.

Sadgrove, K. (2016). *The complete guide to business risk management*. Routledge.

Sales, T. P., Almeida, J. P. A., Santini, S., Baião, F., and Guizzardi, G. (2018). “Ontological Analysis and Redesign of Risk Modeling in ArchiMate”. In: *22nd IEEE International Enterprise Distributed Object Computing Conference (EDOC)*. IEEE, pp. 154–163. URL: http://doi.org/10.1109/EDOC.2018.00028.

Sales, T. P., Baião, F., Guizzardi, G., Guarino, N., and Mylopoulos, J. (2018). “The Common Ontology of Value and Risk”. In: *37th International Conference on Conceptual Modeling (ER)*. Ed. by Trujillo, J. et al. Vol. 11157. Springer, pp. 121–135. DOI: https://doi.org/10.1007/978-3-030-00847-5_11.

Sales, T. P., Guarino, N., Guizzardi, G., and Mylopoulos, J. (2017a). “An Ontological Analysis of Value Propositions”. In: *21st IEEE International Enterprise Distributed Object Computing Conference (EDOC)*. Ed. by S. Hallé, R. Villemaire, and R. Lagerström. IEEE, pp. 184–193. DOI: https://doi.org/10.1109/EDOC.2017.32.

— (2017b). “Towards an Ontological Analysis of Value Propositions”. In: *11th International Workshop on Value Modeling and Business Ontologies (VMBO)*. CEUR-WS.org.

— (2018). “Towards an Ontology of Competition”. In: *12th International Workshop on Value Modeling and Business Ontologies (VMBO)*. Ed. by J. Gordijn and E. Proper. CEUR-WS.org, pp. 64–73.

Sales, T. P. and Guizzardi, G. (2015). “Ontological anti-patterns: Empirically uncovered error-prone structures in ontology-driven conceptual models”. In: *Data & Knowledge Engineering* 99, pp. 72–104. DOI: https://doi.org/10.1016/j.datak.2015.06.004.

— (2016). “Anti-patterns in Ontology-driven Conceptual Modeling: The Case of Role Modeling in OntoUML”. In: *Ontology Engineering with Ontology Design Patterns: Foundations and Applications*. Ed. by A. Gangemi, P. Hizler, K. Janowicz, A. Krisnadhi, and V. Presutti. Studies on the Semantic Web. IOS Press. Chap. 8, pp. 161–187. DOI: https://doi.org/10.3233/978-1-61499-676-7-161.

— (2017). ““Is It a Fleet or a Collection of Ships?”: Ontological Anti-patterns in the Modeling of Part-Whole Relations”. In: *21st European Conference on Advances in Databases and Information Systems (ADBIS)*. Ed. by M. Kirikova, K. Nørvåg, and G. A. Papadopoulos. Springer, pp. 28–41. DOI: https://doi.org/10.1007/978-3-319-66917-5_3.

Sales, T. P., Porello, D., Guarino, N., Guizzardi, G., and Mylopoulos, J. (2018). "Ontological foundations of competition". In: *10th International Conference on Formal Ontology in Information Systems (FOIS)*. Vol. 306. IOS Press, pp. 96–109. DOI: `http://doi.org/10.3233/978-1-61499-910-2-96`.

Sales, T. P., Roelens, B., Poels, G., Guizzardi, G., Guarino, N., and Mylopoulos, J. (2019). "A Pattern Language for Value Modeling in ArchiMate". In: *31st International Conference on Advanced Information Systems Engineering (CAiSE)*. Springer.

Sánchez-Fernández, R. and Iniesta-Bonillo, M. Á. (2006). "Consumer perception of value: literature review and a new conceptual framework". In: *Journal of Consumer Satisfaction, Dissatisfaction and Complaining Behavior* 19, p. 40.

Scheer, A. W. (2000). *Aris – Business Process Modeling*. 3rd. USA: Springer-Verlag New York, Inc.

Schmidt, D. C., Stal, M., Rohnert, H., and Buschmann, F. (2000). *Pattern-Oriented Software Architecture: Patterns for Concurrent and Networked Objects*. Wiley.

Schulz, S. (2018). "The Role of Foundational Ontologies for Preventing Bad Ontology Design". In: *1st International Workshop on BadOntoloGy (BOG)*. Vol. 2205. CEUR-WS.org. URL: `http://ceur-ws.org/vol-2205/paper22_bog1.pdf`.

Sherwood, N. A., Clark, A., and Lynas, D. (2005). *Enterprise security architecture: a business-driven approach*. CRC Press.

Siena, A., Morandini, M., and Susi, A. (2014). "Modelling risks in open source software component selection". In: *33rd International Conference on Conceptual Modeling (ER)*. Ed. by E. Yu, G. Dobbie, M. Jarke, and S. Purao. Vol. 8824, pp. 335–348. DOI: `https://doi.org/10.1007/978-3-319-12206-9_28`.

Singh, P. M., Jonkers, H., Iacob, M. E., and van Sinderen, M. (2014). "Modeling value creation with enterprise architecture". In: *16th International Conference on Enterprise Information Systems (ICEIS)*. Vol. 3, pp. 343–351. DOI: `https://doi.org/10.5220/0004883903430351`.

Suárez-Figueroa, M. C., Gómez-Pérez, A., and Fernández-López, M. (2012). "The NeOn methodology for ontology engineering". In: *Ontology engineering in a networked world*. Ed. by M. C. Suárez-Figueroa, A. Gómez-Pérez, E. Motta, and A. Gangemi. Springer, pp. 9–34. DOI: `https://doi.org/10.1007/978-3-642-24794-1_2`.

Sure, Y., Tempich, C., and Vrandecic, D. (2006). "Ontology engineering methodologies". In: *Semantic Web Technologies: Trends and Research in Ontology-based Systems*. Wiley Online Library. Chap. 9, pp. 171–190.

Svee, E.-O. and Zdravkovic, J. (2015). "Extending enterprise architectures to capture consumer values: the case of TOGAF". In: *27th International Conference on Advanced Information Systems Engineering (CAiSE) Workshops*. Ed. by A. Persson and J. Stirna. Vol. 215. Springer, pp. 221–232. URL: `http://doi.org/10.1007/978-3-319-19243-7_22`.

Sweeney, J. C. and Soutar, G. N. (2001). "Consumer perceived value: The development of a multiple item scale". In: *Journal of retailing* 77.2, pp. 203–220.

The Open Group (2013). *Risk Taxonomy (O-RT). Standard C13K*. Version 2.0.

— (2016). *Integrating Risk and Security within a TOGAF Enterprise Architecture - G152*.

The Open Group (2017). *ArchiMate 3.0.1 Specification. Standard C179.* Version 3.0.1. URL: http://pubs.opengroup.org/architecture/archimate3-doc/.

— (2018). *TOGAF v9.2.*

Thongtra, P. and Aagesen, F. A. (2010). "Capability ontology in adaptable service system framework". In: *5th International Multi-conference on Computing in the Global Information Technology.* IEEE, pp. 279–286. DOI: https://doi.org/10.1109/ICCGI.2010.14.

Timmers, P. (1998). "Business models for electronic markets". In: *Electronic markets* 8.2, pp. 3–8.

Treacy, M. and Wiersema, F. (1993). "Customer Intimacy and Other Value Disciplines". In: *Harvard Business Review* 71.9301, pp. 84–93. DOI: https://doi.org/10.1225/93107.

Uschold, M., King, M., Moralee, S., and Zorgios, Y. (1998). "The Enterprise Ontology". In: *The Knowledge Engineering Review* 13.1.

Vargo, S. L., Maglio, P. P., and Akaka, M. A. (2008). "On value and value co-creation: A service systems and service logic perspective". In: *European Management Journal* 26.3, pp. 145–152. DOI: https://doi.org/10.1016/j.emj.2008.04.003.

Verdonck, M. and Gailly, F. (2016). "Insights on the Use and Application of Ontology and Conceptual Modeling Languages in Ontology-Driven Conceptual Modeling". In: *35th International Conference on Conceptual Modeling (ER).* Ed. by I. Comyn-Wattiau, K. Tanaka, I. Y. Song, S. Yamamoto, and M. Saeki. Springer, pp. 83–97. DOI: https://doi.org/10.1007/978-3-319-46397-1_7.

Verdonck, M., Sales, T. P., and Gailly, F. (2018). "A Comparative Illustration of Foundational Ontologies: BORO and UFO". In: *6th International Workshop on Ontologies and Conceptual Modeling (Onto.Com).* Ed. by Gailly, F. et al. Vol. 2205. CEUR-WS.org.

Vrandečić, D. (2009). "Ontology evaluation". In: *Handbook on ontologies.* Ed. by S. Staab, S. Staab, and R. Studer. Berlin, Germany: Springer, pp. 293–313. DOI: https://doi.org/10.1007/978-3-540-92673-3_13.

Weigand, H., Johannesson, P., Andersson, B., Bergholtz, M., Edirisuriya, A., and Ilayperuma, T. (2007). "Strategic Analysis Using Value Modeling – The c^3*value* Approach". In: *40th Annual Hawaii International Conference on System Sciences (HICSS).* DOI: https://doi.org/10.1109/HICSS.2007.501.

Williams, C. A. (1966). "Attitudes toward speculative risks as an indicator of attitudes toward pure risks". In: *The Journal of Risk and Insurance* 33.4, pp. 577–586. URL: http://doi.org/10.2307/251231.

Woodruff, R. B. (1997). "Customer value: The next source for competitive advantage". In: *Journal of the Academy of Marketing Science* 25.2, pp. 139–153. DOI: https://doi.org/10.1007/BF02894350.

World Wide Web Consortium (2012). *OWL 2 Web Ontology Language – Structural Specification and Functional-Style Syntax (2nd Edition).* Standard. URL: https://www.w3.org/TR/owl2-syntax/.

Wright, R., Paroutis, S., and Blettner, D. (2013). "How useful are the strategic tools we teach in business schools?" In: *Journal of Management Studies* 50.1, pp. 92–125.

Yu, E., Giorgini, P., Maiden, N., and Mylopoulos, J. (2011). *Social modeling for requirements engineering*. MIT Press.