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DIORBERT CORRÊA PEREIRA

REPRESENTING ORGANIZATIONAL STRUCTURES IN ENTERPRISE ARCHITECTURE: AN ONTOLOGY-BASED APPROACH

VITÓRIA, BRASIL

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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Informática do Centro Tecnológico da Universidade Federal do Espírito Santo, como requisito parcial para obtenção do Grau de Mestre em Informática.

Orientador: Prof. Dr. João Paulo A. Almeida

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COMISSÃO EXAMINADORA

Prof. Dr. João Paulo Andrade Almeida - Orientador
Universidade Federal do Espírito Santo

Prof. Dr. Ricardo de Almeida Falbo
Universidade Federal do Espírito Santo

Prof. Dr. Marcello Peixoto Bax
Universidade Federal de Minas Gerais

“Knowledge is power only if man knows what facts not to bother with”

- Robert Staughton Lynd

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ABSTRACT

Enterprise Architecture (EA) promotes the establishment of a holistic view of the structure and way of working of an organization. One of the aspects covered in EA is associated with the organization's "active structure", which concerns "who" undertakes organizational activities. Several approaches have been proposed in order to provide a means for representing enterprise architecture, among which ARIS, RM-ODP, UPDM and ArchiMate. Despite the acceptance by the community, existing approaches focus on different purposes, have limitations on their conceptual scopes and some have no real world semantics well-defined.

Besides modeling approaches, many ontology approaches have been proposed in order to describe the active structure domain, including the ontologies in the SUPER Project, TOVE, Enterprise Ontology and W3C Org Ontology. Although specified for semantic grounding and meaning negotiation, some of proposed approaches have specific purposes and limited coverage. In addition, some of them are not defined using formal languages and others are specified using languages without well-defined semantics.

This work presents a well-founded reference ontology for the organizational domain. The organizational reference ontology presented covers the basic aspects discussed in the organizational representation literature, such as division of labor, social relations and classification of structuring units. Further, it also encompasses the organizational aspects defined in existing approaches, both modeling and ontology approaches. The resulting ontology is specified in OntoUML and extends the social concepts of UFO-C.

RESUMO

Arquitetura Corporativa promove o estabelecimento de uma visão holística da estrutura e forma de trabalho de uma organização. Um dos aspectos abordados em Arquitetura Corporativa está associada a "estrutura ativa" da organização, que diz respeito a “quem" realiza as atividades organizacionais. Várias abordagens têm sido propostas a fim de proporcionar um meio para a representação de Arquitetura Corporativa, entre as quais ARIS, RM-ODP, UPDM e ArchiMate. Apesar da aceitação por parte da comunidade, as abordagens existentes se concentram em propósitos diferentes, têm limitações de escopo e algumas não têm semântica de mundo real bem definida.

Além das abordagens de modelagem, muitas abordagens de ontologias têm sido propostas, a fim de descrever o domínio de estrutura ativa, incluindo as ontologias de SUPER Project, TOVE, Enterprise Ontology e W3C Org Ontology. Embora especificadas para fundamentação semântica e negociação de significado, algumas das abordagens propostas têm fins específicos e cobertura limitada. Além disso, algumas das abordagens não são definidas usando linguagens formais e outras são especificadas usando linguagens sem semântica bem definida.

Este trabalho apresenta uma ontologia de referência bem fundamentada para o domínio organizacional. A ontologia organizacional de referência apresentada abrange os aspectos básicos discutidos na literatura organizacional, tais como divisão do trabalho, relações sociais e classificação das unidades estruturais. Além disso, também abrange os aspectos organizacionais definidos em abordagens existentes, levando em consideração tanto abordagens de modelagem quanto abordagens ontológicas. A ontologia resultante é especificada em OntoUML e estende os conceitos sociais de UFO-C.

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OMG – Object Management Group

OntoUML – Ontological Unified Modeling Language

OWL – Ontology Web Language

UFO – Unified Foundational Ontology

UML – Unified Modeling Language

W3C – World Wide Web Consortium

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1 INTRODUCTION

1.1 CONTEXTUALIZATION

With the increased complexity inherent in managing large organizations, the need to have an architecture that encompasses the various business aspects became evident. Enterprise Architecture (EA) promotes the establishment of a holistic view of the organization in order to provide organizations with the ability to understand its structure and way of working. As defined in (JARVIS, 2003), the description of an EA usually "takes the form of a comprehensive set of cohesive models that describe the structure and functions of an enterprise". EA can be viewed as a virtual repository of partial descriptions of subdomains of interest, defining the relationships between the various subdomains and treating them as interchangeable and reusable blocks. Organizations can take advantage of EA "for aligning and integrating strategy, people, business and technology, and enabling an agile enterprise – continually evolving within the ever-changing environment" (NIEMI, 2008).

The alignment and integration of IT with business is indispensable in current business practice (LANKHORST, 2013). "To create an integrated perspective of an enterprise, we need techniques for describing architectures in a coherent way and communicating these with all relevant stakeholders" (LANKHORST, 2013). Guided by this need, many approaches for describing enterprise architectures have been proposed, including frameworks and modeling languages.

The majority of EA frameworks considers an organization as a system whose elements include: (i) organizational activities structured in business processes and services; (ii) information systems supporting organizational activities; (iii) underlying information technology (IT) infrastructures, and (iv) organizational structures (organizational actors, roles and organizational units). This last domain of elements is also called "active structure" (THE OPEN GROUP, 2012) and concerns "who" undertakes organizational activities. Active structure focuses on the business agents that perform tasks and seek to achieve goals, encompassing the definition of business roles, authority relationships, communication lines, work groups, etc. The relevance of

organizational structure is clear from a management perspective in that it defines authority and responsibility relations between the various elements of an enterprise. Further, from the perspective of enterprise information systems, organizational actors can be considered as system owners, system maintainers, system users or simply system stakeholders in general, affecting the usage and evolution of such systems (SANTOS; ALMEIDA; GUIZZARDI, 2013).

1.2 MOTIVATION

Enterprise architects often employ modeling languages in order to create descriptions of an enterprise architecture. These descriptions (or “models”) are used to improve documentation, communication and analysis of the architecture. Many approaches prescribe combining an EA framework with one (LANKHORST; VAN DRUNEN, 2007) or more modeling languages (MINOLI, 2008). For example, one can model business process using BPMN, application components with UML and business goals using i* (DO; FAULKNER; KOLP, 2003). Similarly, we can use ARIS or ArchiMate for describing most of enterprise aspects applying a unique modeling technique (LANKHORST, 2013).

In the task of describing enterprise architectures, the active structure domain has an important role. The social nature of enterprises is inherent to many aspects of the organization. We cannot fully specify a business process without describing its participants’ roles as we cannot define services ignoring the roles of service customers and service providers. Thus, the structure of units and roles that compose the organizations must be described in order to provide a general organizational context.

Many prominent approaches for EA representation include constructs for modeling active structures, including, e.g., ARIS (SANTOS, 2009), RM-ODP (RM-ODP-ISO-ISO/ITU-T, 1995), UPDM (OMG, 2014) and ArchiMate (THE OPEN GROUP, 2012). Despite the acceptance by the community, existing approaches focus on different purposes, have limitations on their conceptual scopes and some have no real world semantics well-defined. The lack of coverage is associated with the limited representation by the approaches. The focus on different purposes and their broader

scope (covering many of the aspects of enterprises) lead to design choices that leave out important concepts for a complete description of the domain. This is an undesirable feature as it affects completeness (GUIZZARDI, 2005). In turn, the absence of a well-defined real-world semantics allows interpretations not originally intended by the approach. This leads to difficulty in communication between users, ambiguous and inaccurate representations, and difficulty in interpreting the created models.

Many problems in EA modeling approaches can be tracked to the lack of semantic grounding. The absence of semantics grounding creates difficulty for users to create and interpret EA modeling artifacts. Thus, the need to build models with well-defined semantics becomes evident.

As defined in (GRUBER, 1993), ontologies are formal and explicit specification of a shared conceptualization. Apart of the purpose of documentation, ontologies has greater concern with a well-defined semantic. Many ontologies have been proposed in order to describe the active structure domain, including the ontologies in the SUPER Project (ABRAMOWICZ et al., 2008), TOVE (FOX, 1992), Enterprise Ontology (USCHOLD et al., 1998) and W3C Org Ontology (W3C, 2014). Although specified for semantic grounding and meaning negotiation, some of the proposed approaches have specific purposes and limited coverage. In addition, some approaches are not defined using formal languages and others are specified using languages without well-defined semantics.

The development of a reference ontology that captures the general aspects of organizational domain can contribute to the semantic integration and evaluation of different approaches and provide a conceptual basis for the creation of languages with greater completeness. Further, an organizational reference ontology might be used for:

- Construction of more specialized ontologies - domain or task ontologies;
- Semantic interoperability between computational artifacts - systems, computational agents;
- Generation of ontology schemas for Semantic Web and semantic applications - publishing of linked open data, semantic annotation;
- Model-driven software development - automated generation of code through the use of models; and,

- Improving the communication between a community - through a shared consensual model.

1.3 RESEARCH GOALS

The main goal of our research is to build an UFO based core ontology for the active structure domain. The proposed ontology has the purpose of serving as a reference ontology for the community. The requirements of the reference ontology combine the concepts found in the organizational representation literature with the coverage provided by the existing approaches (modeling languages and ontologies). As a result, we hope to provide expressivity enough to describe the essential aspects of the organizational domain.

To achieve our research goal, we performed the following tasks:

- Investigate the organizational representation literature to determine expressivity needs;
- Perform an analysis of the existing approaches (EA modeling languages and ontologies) to capture the essential organizational concepts and relationships;
- Settle ontology requirements from the combined expressivity needs (organizational representation literature and existing approaches);
- Develop a reference ontology based on the ontology requirements;
- Evaluate the ontology from the quality perspective;
- Evaluate the ontology from the applicability perspective – Extending the ontology to build a government ontology and evaluating the active structure aspect of ArchiMate.

Our ultimate goal is to support the production of EA models that represent organizational reality faithfully and thus serve for the purposes of EA documentation, analysis and communication.

1.4 THESIS STRUCTURE

This thesis is structured as follows:

Chapter 2 (Theoretical Foundations) presents a discussion about the role of enterprise architecture on organizations. Also in this Chapter, we present a study of the organizational expressivity needs. The expressivity analysis is carried from the study of the organizational representation literature in combination with existing approaches for representation of active structure. In addition, it introduces the ontological theory necessary for the understanding of the remainder of the thesis.

Chapter 3 (OntoUML Organizational Ontology - O3) presents our proposed reference ontology. The ontology is discussed in a modular way to facilitate the understanding of the many views.

Chapter 4 (O3 Evaluation) reports on an evaluation of the reference ontology against quality criteria. Here, an overview about the coverage of existing approaches is also presented in order to contrast them with O3.

Chapter 5 (ArchiMate Analysis) presents a semantic analysis of ArchiMate. The analysis results in the identification of language shortcomings; the shortcomings are addressed in a revised metamodel, which is intended to make the language more expressive and precise for the representation of organizational structures.

Chapter 6 (Proof-of-Concept: Government Ontology) illustrates the applicability of O3 for the development of domain ontologies through the specification of a government ontology.

Chapter 7 (Final Considerations) presents our conclusions, shortcomings and discussion about future works.

2 THEORETICAL FOUNDATIONS

In this chapter we present the theoretical foundations for the rest of this work. First (Section 2.1), we provide an overview about the enterprise architecture theme, discussing its importance and applications. On the sequel (Section 2.2), we present a brief discussion about the organizational representation literature, in the sense of its basic needs for organizational representation; Section 2.3 presents an analysis of a selected set of approaches for organizational description, including modeling languages and ontologies; Section 2.4 initiates a discussion over ontologies foundations, providing definitions and applications; Finally (section 2.5), we discuss in details the Unified Foundational Ontology (UFO) and OntoUML, which are used as a basis for the ontology development later in this work.

2.1 ENTERPRISE ARCHITECTURE

The term “architecture” has been applied to a multitude of domains to specify the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment (LANKHORST, 2013). With the growth of the relevance of information technology on organizational strategy, in addition to its increased administrative complexity, the need to have an architecture that embraces multiple perspectives became evident. In this context, Enterprise Architecture (EA) is defined as a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise’s organizational structure, business processes, information systems, and infrastructure (LANKHORST, 2013). Enterprise architecture captures the essentials of the business, IT and its evolution. The idea is that the essentials are much more stable than the specific solutions that are found for the problems currently at hand (LANKHORST, 2013).

In general, Enterprise Architecture can be viewed as a virtual repository of partial descriptions of subdomains of interest. EA defines the relationships between the various subdomains and treats them as interchangeable and reusable blocks. Among the main benefits of EA development are included (NIEMI, 2008): improved alignment

to business strategy, improved change management, improved communication and improved innovation. The use of Enterprise Architecture contributes to the reduction of organizational costs and increase the chances of business success (ZACHMAN, 1987).

One of the main challenges faced by large enterprises is that understanding and describing them is hard. EA comes in to support the mission of architects to define and communicate a unified and precise business vision. EA encompasses an extensive collection of information about the entire organization, and architects must be able to target the right set of information to address stakeholders concerns.

When analyzing an organizational subdomain, architects specify its vision by modeling the concepts involved and its relationships. This process is guided by the enterprise architecture approach adopted. The architecture modeling process generally covers four aspects: business, data, information systems and technology. Generally, the communication with stakeholders is performed by diagrams, which present the relevant subset of concepts and relationships of the model. The selection of the portion of the model to communicate something must be driven by the stakeholder concerns. In this context, the definition of viewpoints increases the value of the Enterprise Architecture by delivering the right information in the right way. The Figure 1 illustrates the process of EA communication (LANKHORST, 2013).

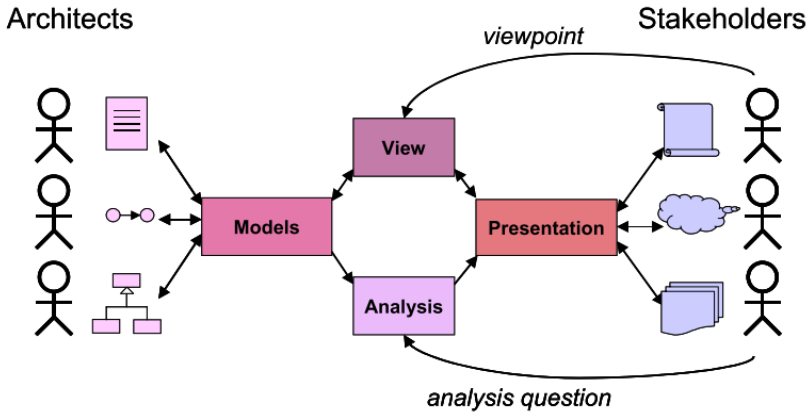

Figure 1. Communicating about architecture (LANKHORST, 2013)**.**

In order to develop Enterprise Architecture in a coordinated way, architects can make use of various available approaches for EA development. A complete Enterprise Architecture approach should define method, taxonomy and techniques. The method

describes how to build an Enterprise Architecture according to industry best practices. The taxonomy classify the elements involved with the process of building an EA, like terms, artifacts (income and outcome) and aspects covered. Finally, techniques are provided to support the production of the expected outcomes. The result of the application of an EA approach commonly is an Enterprise Architecture repository.

Several frameworks to specification of Enterprise Architecture have been proposed, such as Zachman Framework (ZACHMAN, 1987), TOGAF (HAREN, 2011), DoDAF (US DEPARTMENT OF DEFENSE, 2010), FEAF (Federal Enterprise Architecture Framework) [54]. In parallel, modeling languages have been proposed to support the representation of aspects of EA, which includes, RM-ODP (RM-ODP-ISO-ISO/ITU-T, 1995), ARIS, ArchiMate, among others. The frameworks differs in degree of support to specifying EA. Some of these approaches focus only on the definition of taxonomy and do not indicate any process (method) for its use, in addition, a subset also provides guidelines or indicates visual languages for Enterprise Architecture modeling.

The next sections provide an overview of the most prominent Enterprise Architecture approaches.

2.1.1 The Zachman Framework

Originally conceived by John Zachman at IBM in the 1980s, the Zachman framework (ZACHMAN, 1987) defines the organizational context from the aspects: data, functions, geographic distribution, people, time and motivation, compared to levels of abstraction, starting with a description of the scope to a specific and detailed description. Abstraction levels are also associated with certain profiles of interest (perspectives) in the organization, such as the views of the owner, the designer and builder. Although defining subdomains, Zachman Framework does not present a method for guiding use of the approach and does not provide a visual modeling language. Figure 2 presents the architecture specified on the Zachman Framework (version 2 of 2008).

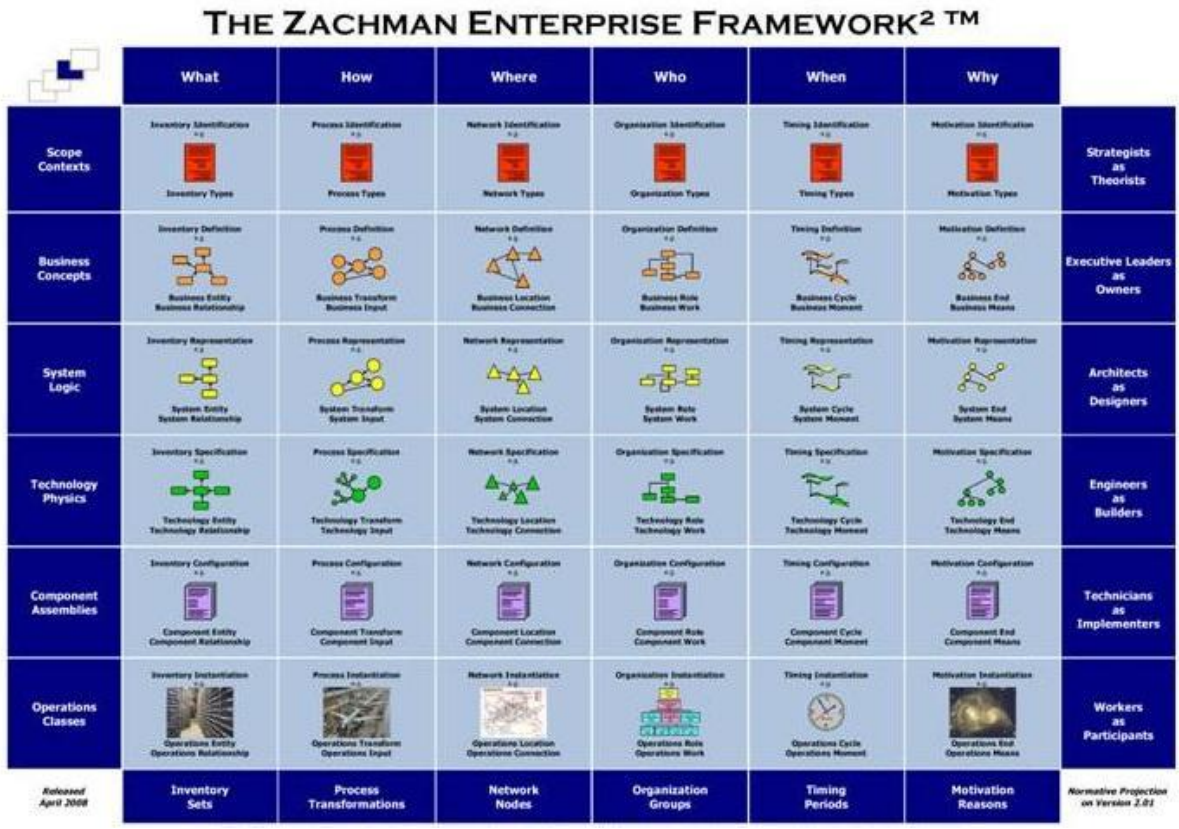

Figure 2. The Zachman Enterprise Framework 2, version of 2008.

Despite the lack of a method and a language for representation, the Zachman Framework remains as a reference for Enterprise Architecture. Many approaches was released based on Zachman Framework and many others still can be complemented by its application. Intuitively, we can observe the Zachman Framework as a box containing several compartments, each reserved for a category of entities. Detailed partial descriptions of these entities (as UML diagrams and BPMN, for example) are classified and placed in their respective compartments.

From the various enterprise aspects covered, the Zachman Framework demonstrates concern about the physical and social agents that contextualize the other aspects (some elements of the "who" column). It includes the description of how the enterprise is organized in term of organizational units and organizational roles. Among the benefits of the Zachman Framework are included the provision of a holistic and integrated view of enterprise architecture and its enterprise driven characteristic.

2.1.2 The Open Group Architecture Framework (TOGAF)

As defined in (HAREN, 2011), TOGAF is a process-oriented definition for Enterprise Architecture, defined in 1995, as result of good organizational practices employed by organizations. TOGAF is a well-known and much applied approach. There are four architectural domains that are commonly accepted as subsets of an overview of Enterprise Architecture, for which TOGAF provides support: business architecture, data architecture, application architecture and infrastructure architecture. TOGAF defines a process for developing Enterprise Architecture (ADM - Architecture Development Method), where all activities are performed following an iterative and continuous cycle consisting of stages (Figure 3). In order to support its architectural modeling process, TOGAF recommends the use of the ArchiMate modeling language.

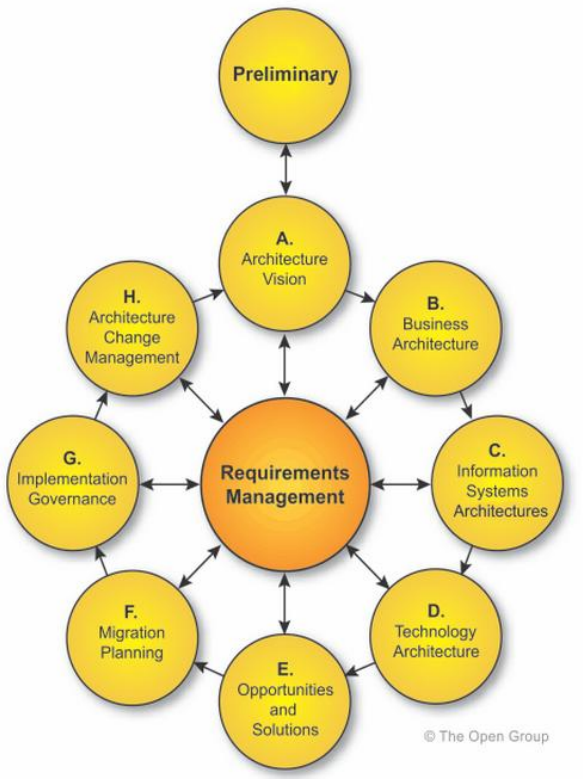

Figure 3. TOGAF's Architecture Development Method in detail (HAREN, 2011)**.**

Besides ADM, TOGAF defines other elements that permeate the proposed method (Figure 4).

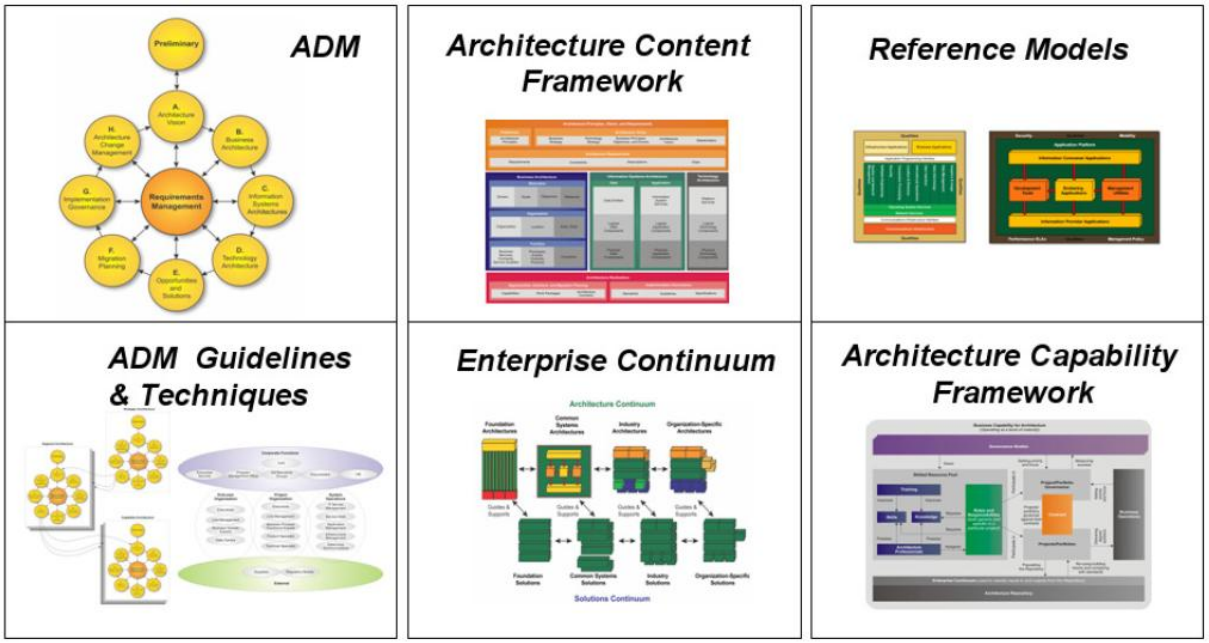

Figure 4. The elements (parts) of TOGAF (HAREN, 2011)**.**

The Architecture Content Framework specifies what need to be built, i.e., what is the result of the Enterprise Architecture effort (Figure 5). Here, similarly to The Zachman Framework, are presented the many aspects relevant to the specification of EA in the form of compartments that promote reuse and provide a holistic view of the organization. Among the aspects covered, TOGAF demonstrates concern about who (organization units, actors and roles) are participants in the process, consumers and responsible for services (business and applications services), etc. These elements composes the active structure aspect (part of the Business Architecture) which have special relevance for this work.

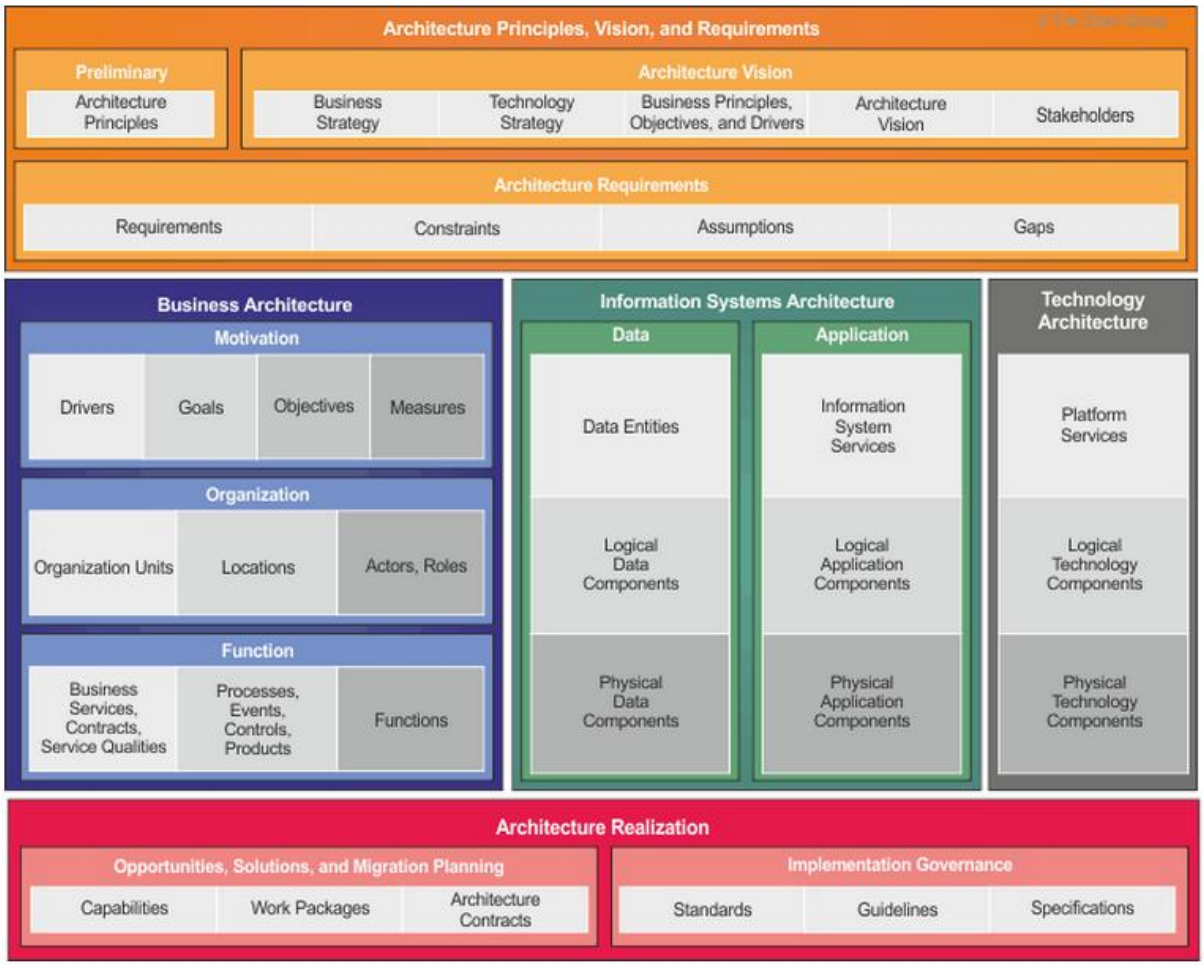

Figure 5. Content Metamodel Overview (HAREN, 2011).

2.1.3 Department of Defense Architecture Framework (DoDAF)

The Department of Defense Architecture Framework (DoDAF) (US DEPARTMENT OF DEFENSE, 2010) is an approach for development of Enterprise Architecture created and maintained by the US Department of Defense. DoDAF (current version, 2.02) is a specific purpose and data-focused framework. It does not follow the traditional architecture arrangement (business, data, application and infrastructure), but specifies seven viewpoints: capability, data and information, operational, project, service, standards and systems. Each viewpoint is associated with many models which describes the specific content that permeates it. Despite the fact DoDAF does not adopt the traditional architectural stratification, the various visions of DoDAF permeate aspects of business, application and infrastructure. From this vision, the Operational

View has great relevance to us, once describes business aspects, including common elements of active structure (OV-4 model – Organizational Relationships). Figure 6 presents how these viewpoints correlate. On DoDAF's architectural modeling process, it is recommended the use of the UPDM modeling language (US DEPARTMENT OF DEFENSE, 2010)(OMG, 2014).

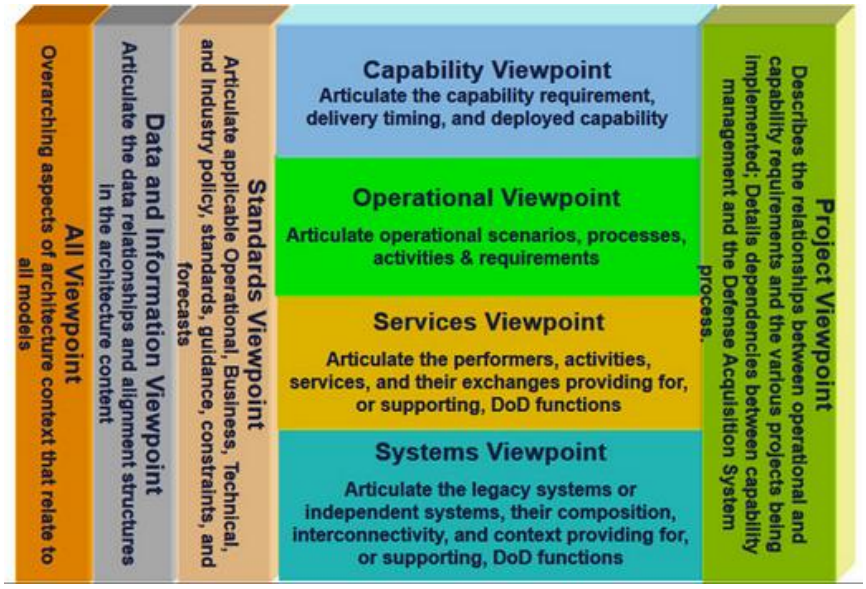

Figure 6. Overview of DoDAF viewpoints (US DEPARTMENT OF DEFENSE, 2010)**.**

2.1.4 Federal Enterprise Architecture Framework (FEAF)

The FEAF, acronym to Federal Enterprise Architecture Framework, is the Enterprise Architecture approach developed and maintained by the US Federal Government. Motivated by the need of the congress and citizens for greater cost-efficiency and transparency (OFFICE OF MANAGEMENT AND BUDGET, 2012), the FEAF covers the main EA aspects through the many levels of scope (international, national, federal, agency, sector, segment and others). The FEAF has the purpose of serving as a common and repeatable approach for the many government bodies, providing a common vocabulary and increasing the reuse of solutions and knowledge (OFFICE OF MANAGEMENT AND BUDGET, 2012). The approach goes further the four basic aspects of EA (business, data, application and infrastructure) and gives support for six sub-domains: strategy, business, data, applications, infrastructure, and security. An overview of the Federal Enterprise Architecture Framework is shown in the Figure 7.

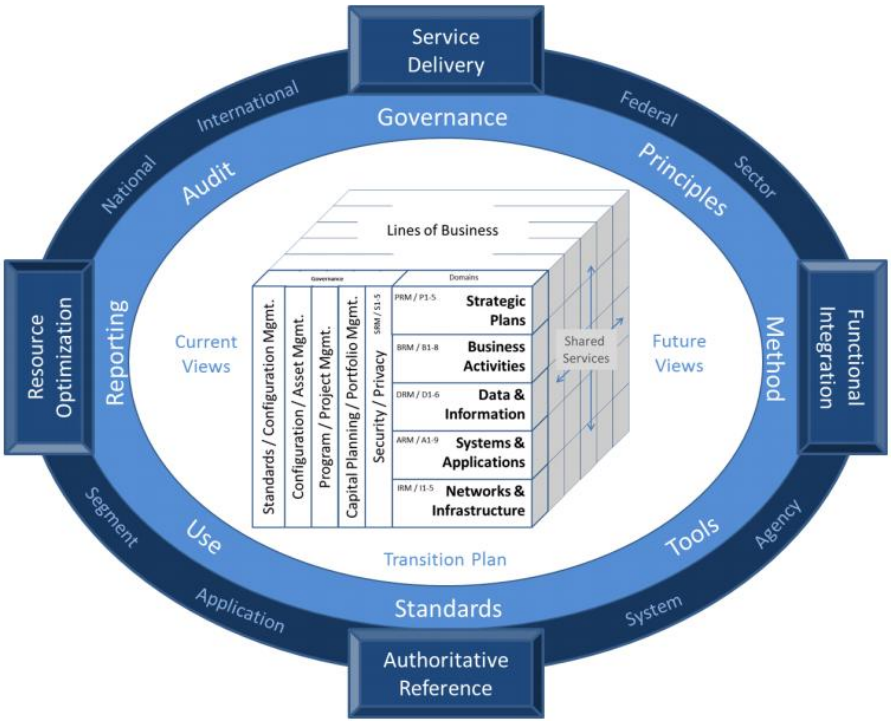

Figure 7. Overview of the Federal Enterprise Architecture Framework (OFFICE OF MANAGEMENT AND BUDGET, 2013)**.**

The basic elements of FEAF comprises principles, method (CPM), tools, standards, use, reporting, audit and governance. All these elements support the EA development to provide FEAF's main outcomes: Service Delivery, Functional Integration, Resource Optimization and Authoritative Reference. Here, the goal is to deliver services to citizens and partners, optimizing the resources and providing internal and external functional integration. Another outcome related with the development of EA is an authoritative reference. The authoritative reference aggregates all the artifacts, models and capabilities generated and updated during the process of Enterprise Architecture development. It provides an integrated, consistent view of strategic goals, mission and support services, data, and enabling technologies across the entire organization, including programs, services, and systems (OFFICE OF MANAGEMENT AND BUDGET, 2012). The authoritative reference maintenance is a continuum process and can serve as an input for future architectures.

In order to increase the effectiveness of the framework application, FEAF defines six reference models: Perform, Business, Data, Application, Infrastructure and Security Reference Models. The reference models provide standardized categorization for strategic, business, and technology models and information. Each of them presents its

own taxonomy, methods, touch points, and use cases (OFFICE OF MANAGEMENT AND BUDGET, 2012). “Collectively, the reference models comprise a framework for describing important elements of federal agency operations in a common and consistent way” (OFFICE OF MANAGEMENT AND BUDGET, 2013). Figure 8 presents in detail the consolidated reference model (CRM).

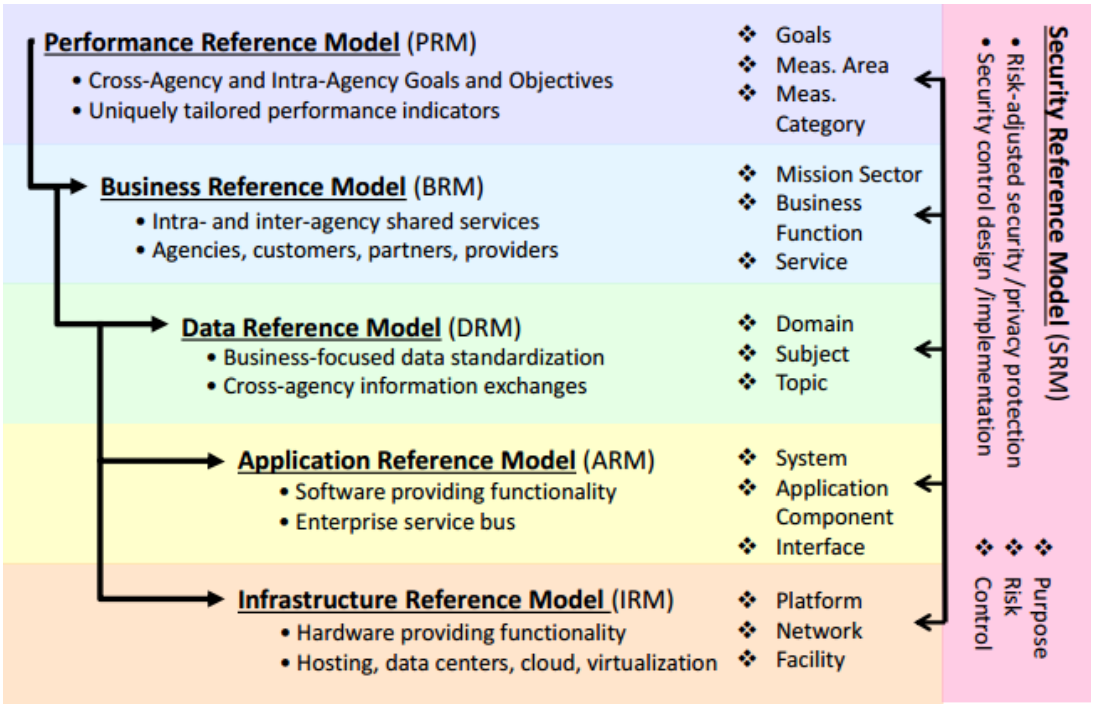

Figure 8. Consolidated reference models (OFFICE OF MANAGEMENT AND BUDGET, 2013)**.**

Among the many reference models provided, BRM has great relevance for this work. The Business Reference Model treats of business layer, including the description of the many agents that can be involved in a service (as providers or customers), business function (as partners) and mission sector (as responsible agencies).

2.1.5 Conclusion

No matter the selected approach, the effort of defining enterprise architecture need to be supported by modeling languages for their formalization and communication. The major EA frameworks include the description of the organizational active structure explicitly as an aspect of interest. On the Zachman Framework this aspect is described on column “who” (people). TOGAF and FEAF describe this aspect on their business

layer. In the case of TOGAF, the recommended modeling language ArchiMate provides support for the modeling of the active structure natively. Finally, DoDAF does not describe a business layer, but gives support for the description of the organizational structure by means of its view descriptions (OV-4). Its recommended modeling language (UPDM) provides natively support for this aspect.

The precise definition of the active structure plays an eminent role on EA by its organizational contextualization. Here, the business agents (physical and social) and their roles are specified, providing inputs for the traceability of responsibilities and consumers.

2.2 AN ANALYSIS OF ORGANIZATIONAL REPRESENTATION LITERATURE

In the organizational representation literature, some basic organizational notions are frequently referred to in order to characterize organizations. In this chapter, we discuss these notions, as they form basic requirements of expressiveness of organizational structure. We do not aim at exhausting all relevant aspects concerning organizational structure. We focus on three dominant themes in the management literature: (i) division of labor, (ii) social relations and (iii) nature of structuring units.

2.2.1 Division of Labor

We, as human beings, have limitations on processing information and on accomplishing tasks (SIMON, 1981). Division of labor manages our human limitations and coordinates us to achieve organizational goals. Apart of the formal organizational view, we can also observe the division of labor in the nature, such as in ants and bees communities. Communitary bees are organized in queen and workers, respectively the mother and her daughters. The kind of bee and age define the responsibilities of each bee with relation to the whole beehive. The duties of the workers change as they get older and ranges from cleaning out cells, removing bodies of dead bees, attending to the queen bee, collecting nectar for the hive and guarding the hive. The queen, in turn,

is a solitary adult bee, female and sexually mature. The responsibility of the queen is associated with reproduction.

Similarly to the bee community, humans apply the division of labor formally and informally to address complex work. The formal analysis of the division of labor surfaced around 1900 with Taylor's principles of scientific management (TAYLOR, 1911). In his study, Taylor performed a scientific analysis about the work itself (time and motion), rewards and distribution of responsibilities. In the past, the work was distributed to few different trades. The workmen in each of these trades have had their knowledge handed down to them by word of mouth (TAYLOR, 1911). This method evolved to the state of great and growing subdivision of labor, in which each man specializes upon some comparatively small class of work (TAYLOR, 1911). Contemporary to Taylor, Fayol focused on the application of division of labor as a way to increase productivity. Fayol defined in (FAYOL, 1949) that the division of labor aims to produce more and better, with the same effort, in addition to reducing the number of objectives upon which the attention and effort should be applied. Figure 9 illustrates (on the left) the informal division of labor versus the formal division of labor (on the right) present in modern organizations.

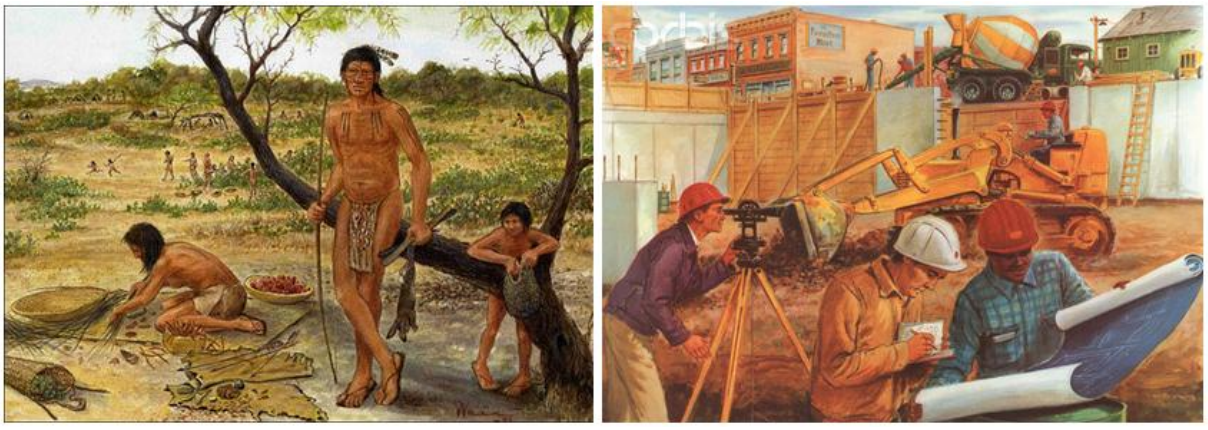

Figure 9. Division of labor. (left) Informal division of labor. (right) Formal division of labor.

In a top-down view, organizations can be considered as systems composed of subsystems, each of which can be nested into subsystems recursively (DAFT, 2010). Division of labor consists in the top-down view of dividing an overarching organizational mission into specialized goals or tasks allocated to distinct well-defined units of work in order to increase efficiency. The creation of working groups aggregating individuals

with heterogeneous skills that pursue a common purpose represents the definition of these subsystems (which we will call here Organizational Units). In a bottom-up view, “we are confronted by the task of analyzing everything that has to be done and determining in what grouping it can be placed […] Workers may be easily combined in a single aggregate and supervised together” (GULICK; URWICK, 1954).

The division of labor in its highest degree of specialization is represented by defining “positions”. At this level of granularity, the tasks are distributed among the various positions as official duties. This infers a clear division of labor between positions, as defined in (GUETZKOW, 1962). Positions also allow the formalization of the organization based on descriptions of duties, rights, requirements and social relations assigned to reusable organizational roles and not directly on the specific actors who play them. Once positions are defined independently of its player, a mechanism is necessary to select the suitable player in order to guarantee the efficient accomplishment of goals. Usually, the requirements of a position comprise a set of capabilities (skills) necessary to performing the expected behavior.

2.2.2 Social Relations

We are part of an organizational society, have employment or otherwise establish social relationships with organizations, whether as consumers or producers. As stated in (ETZIONI, 1964), organizations are the most rational and efficient way of social grouping and creates a powerful social instrument through the coordination of large numbers of human actions. Within the universe of a formal organization, we have the definition of roles that specialize organizational work. In addition, to establish a coordinated social environment, we also have the definition of social relations maintained between these roles, such as power relations and communication. The validity of social actions that involves social relations is based on the belief in the existence of a legitimate order (WEBER; ROTH; WITTICH, 1968).

Concerning power relations, Fayol (FAYOL, 1949) defines that the authority is the right to command and the power to be obeyed. Without authority, i.e., without explicit formal organization in upper and lower positions, where the superiors have more power than

the lower, the organization ceases to be a coordinated entity (ETZIONI, 1964). As described in (WEBER; ROTH; WITTICH, 1968), in social relations, the actions performed by certain members (representatives) impact the others (represented). The participants in this case are called “mutually responsible members” and share the resulting advantages as well as the disadvantages. The establishment of power “may be (a) completely appropriated in all its forms - the case of self-appointed authority; (b) conferred in accordance with particular characteristics, permanently or for limited term; (c) conferred by specific acts of the members or of outside persons, again permanently or for a limited term - the cases of ‘derived’ or ‘delegated’ power” (WEBER; ROTH; WITTICH, 1968).

Apart from power relations, communication relations are also very important since they allow the definition of interactions between business actors without requiring the establishment of relations of authority. The existence of a relationship of authority between two organizational actors implies the existence of a relationship of communication between them, but in some cases, it is necessary to explain the existence of communication without establishing authority. A communication relationship can be vertical or horizontal. The vertical communication relationship is that which is associated with the control of the organization and occur between the top and bottom of the organization, while the horizontal communication relationship is related to coordination occurring between departments (DAFT, 2010). Without the establishment of communication relationships the exchange of information between departments is less efficient and follow the command chain, as presented in Figure 10. In the first case (a), the information flows vertically until reach the destination. In the second case (b) there is a direct relationship between “X” and “Y” and the information flows without intermediation of superiors.

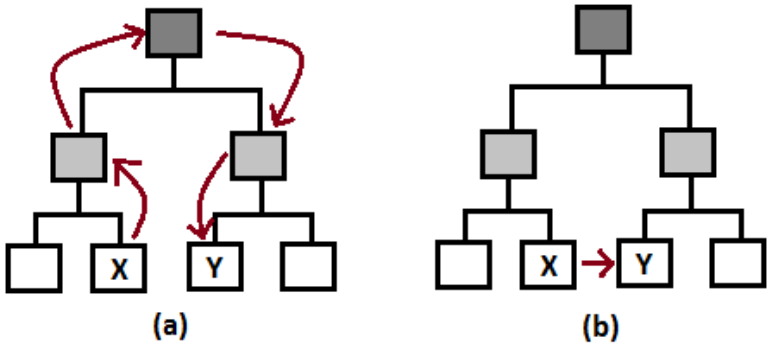

Figure 10. Communication issue. (a) Information flows vertically unit reach the destination. (b) Exists a direct relationship between the participants of a communication.

2.2.3 Nature of Structuring Units

The working groups that compose organizations have different natures. Different structuring principles lead to different types of structuring units like departments, divisions, line units, staff units, teams and task forces. The management experience has noticed that different organizational structures provide different results. There are many structuring principles being applied in present organizations, including functional, line-staff, divisional, matrix and flat structures. Each approach has benefits and disadvantages, being appropriate to a set of environments and desired effects. Despite the individual characteristics of each structural principle, such approaches can be used together to create hybrid organizations.

The functional structure is one of the most common organizational structures and is decomposed in departments, each one gathering specialists to perform a specific function. In contrast, the divisional structure segregates the organization in small semi-autonomous groups (called divisions). Divisions consists in several parallel groups, each of which is self-contained (all necessary functions are present in the division) and has with few or no intercommunication between the groups. Each group focuses on a specific aspect of the organization, such as a product, a service or a customer. With an atypical approach, organizations that adopt the flat structure have a short chain of command in combination with a large span of control. In other words, the flat approach employs the elimination of layers of management and the increasing of the number of

subordinates by manager. It improves the level of communication and creates a more democratic environment, where the employee actively participates in decisions.

In organizations structured following the line-staff model, one of the main distinctions is between line and staff units. The line units comprise the functional organization and represent the specialization of division of labor in functional/production units following different criteria of aggregation of individuals. It encompasses the line managers who possess the administrative authority and are responsible to perform the end activities of the organization. The line units can relate through relationships of authority and are composed of other line units (RADNER, 1990). In contrast, staff units are units without administrative authority, who have the responsibility of advising the production units to perform actions and do not have full responsibility for the execution of tasks (ETZIONI, 1959). The “staff authority is subordinate to line authority, and they tend to identify line with managers or administrators and staff with experts and specialists” (ETZIONI, 1959).

Finally, the matrix structure provides the intersection between departments and teams bringing together employees and managers from different departments to work toward accomplishing a goal. It is a combination of the functional and divisional structures. Other types of working groups present in organizations that adopt the matrix model are the teams and task forces (GALBRAITH, 1971), which are units with dual authority relationship, where the relationship of power is balanced between formal authority and technical authority (GALBRAITH, 1971). Teams and task forces aggregate employees belonging to different departments/divisions/line units and can have limited lifetime. In addition, these types of structuring units put together in a single unit the authority and information necessary for performing tasks (GALBRAITH, 1971). The main difference between teams and task forces lies in the fact that task forces are used to solve temporary problems, while teams are used to solve recurring problems (GALBRAITH, 1971).

2.3 ACTIVE STRUCTURE REPRESENTATION

The theme of our research has been explored by many approaches. Some of those are similar to our approach in that they propose ontologies to serve as a reference conceptual model for the organizational domain. They differ in scope, purpose and rigor in formalization (e.g., some are described solely in natural language some include some formal description, such as a lightweight ontology in OWL). In contrast, a group of approaches focuses on language representation (instead of capturing the underlying conceptualization), providing a "tool" for organizational domain definition. These approaches differ in coverage, application and concrete syntax.

2.3.1 E-OPL

The Enterprise Ontology Pattern Language (E-OPL) (FALBO et al., 2014) is a core ontology defined in OntoUML, created with the purpose of providing a basis for a well-established pattern language to enterprise representation. It's organized in DROPs (Domain Related Ontology Patterns), which capture the general concepts about recurring modeling problems. DROPs represent fragments of core ontology and, together, can be extended to define specific domains, such as banking, military, government, and manufacturing, among others.

Besides the definition of a set of DROPs, E-OPL provides a process, which plays the role of providing a guide for users of the patterns (FALBO et al., 2014). An OPL supports the challenge of construction of domain ontologies with the indication of the appropriate portion of concepts with relevance to a specific problem. In addition, the associations between the DROPs are defined through specific relations, such as dependence, temporal precedence of application, or mutual exclusion among them.

E-OPL aims to cover five aspects of the enterprise domain: organization arrangement, team definition, institutional roles, human resource management and institutional goals. The last is outside our scope and is not treated in this section. The organization arrangement aspect encompasses the concepts related with how the organization is structured in terms of organizational units and other organizations (in the case of

complex organizations). The Figure 11 present a fragment of E-OPL related with the organization arrangement aspect.

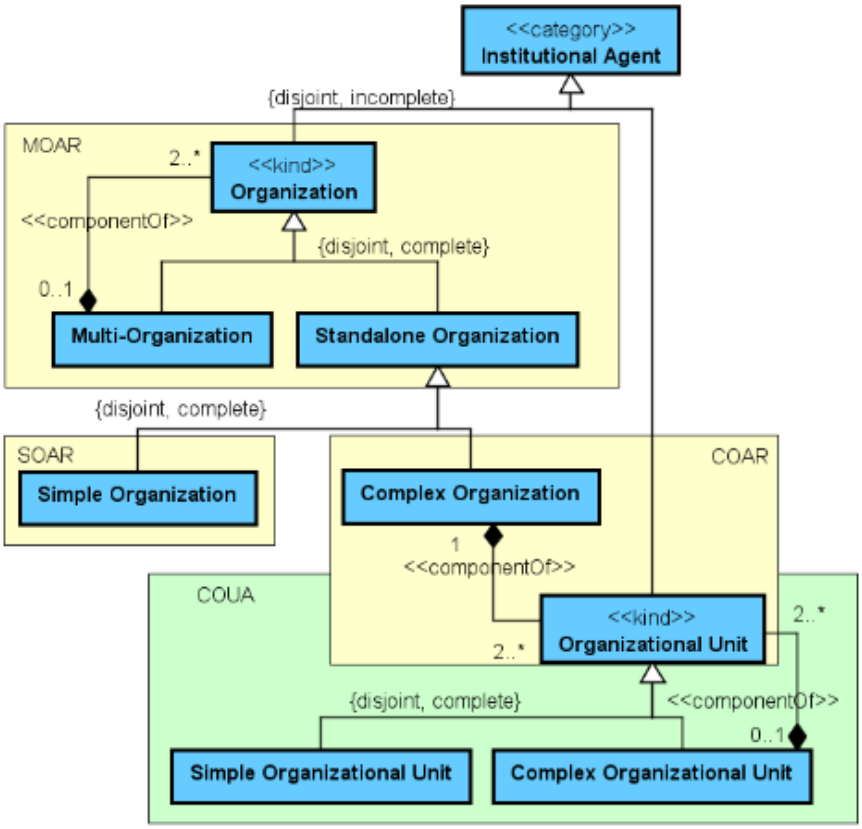

Figure 11. Organization arrangement patterns (FALBO et al., 2014)**.**

The top most concept “Institutional Agent” is a generalization of the “Organization” and “Organizational Unit” concepts. An “Organization” can be composed by others organizations (Multi-Organization) or exist independently (Standalone Organization). A composition of organizations can be seen, for example, in holdings or in international companies, with their branches dispersed geographically with some degree of autonomy.

A “Simple Organization” is a “Standalone Organization” with a trivial structure, without departments (Organizational Unit). In contrast, a “Complex Organization” represents the common organizational structure, composed by “Organizational Units”, which can have their own decomposition in another “Organizational Units” (Complex Organizational Unit) or not (Simple Organizational Unit).

Another aspect treated in E-OPL is related with the roles that a member of the organization can play in the context of its expected behavior. This kind of roles, in E-OPL, are second order concepts, i.e., its instances are types. The Figure 12 presents the concepts associated with the Organizational Positions (ORGP) and Organizational Roles (ORGR) patterns.

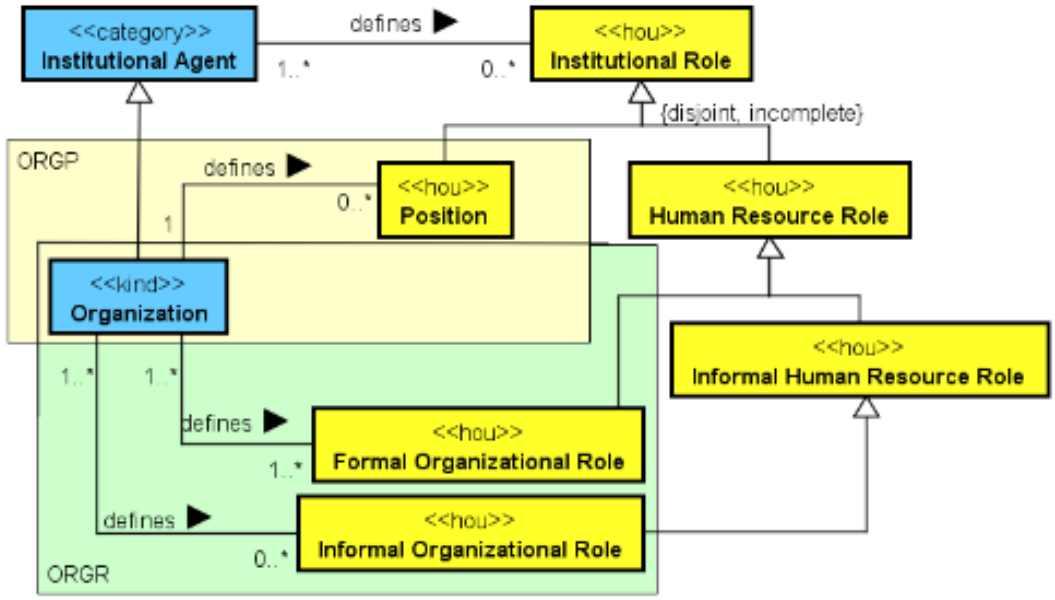

Figure 12. Organizational Positions (ORGP) and Organizational Roles (ORGR) patterns (FALBO et al., 2014)**.**

An “Institutional Agent” has the power to define “Institutional Roles”, which represent the most general concept for roles. A “Position” represents some formal position in the organization, such as “President”, “Sales Manager”, “Mayor” and “Private”. “Positions” are defined by the organization. In addition to the definition of positions, the functions that a person can assume as a member of the organization are defined as “Human Resource Roles”, such as “Programmer”, “Test Analyst” and “Snipe Observer”.

A role can have significance in the scope of the entire organization, an organizational unit or the organization environment. In E-OPL, the distinction between formal and informal roles is expressed in its recognition scope. Formal roles are recognized by the whole organization and its environment. In contrast, informal roles are recognized only on the scope of the corresponding “Institutional Agent”. Team roles and organizational roles are types of informal roles and are recognized, respectively, in the scope of a team or an organizational unit (FALBO et al., 2014). Organizational roles can be formal

or informal, being the first associated with the employment relationship between a person and the organization. A human resource playing a “Formal Organizational Role” can assume many informal roles during its lifetime as a member of the organization. “Formal Organizational Roles” and “Informal Organization Roles” are defined by the organization.

The OMEM and EMPL patterns (presented in Figure 13) illustrate the link between the organization and its agents. A “Human Resource” is a member of one or more “Organizations” and its membership is formalized by an employment relationship (FALBO et al., 2014). When a person becomes employee (Human Resource) of an organization, an employment is created and the human resource is associated with a “Formal Organizational Role”, which describes its expected behavior.

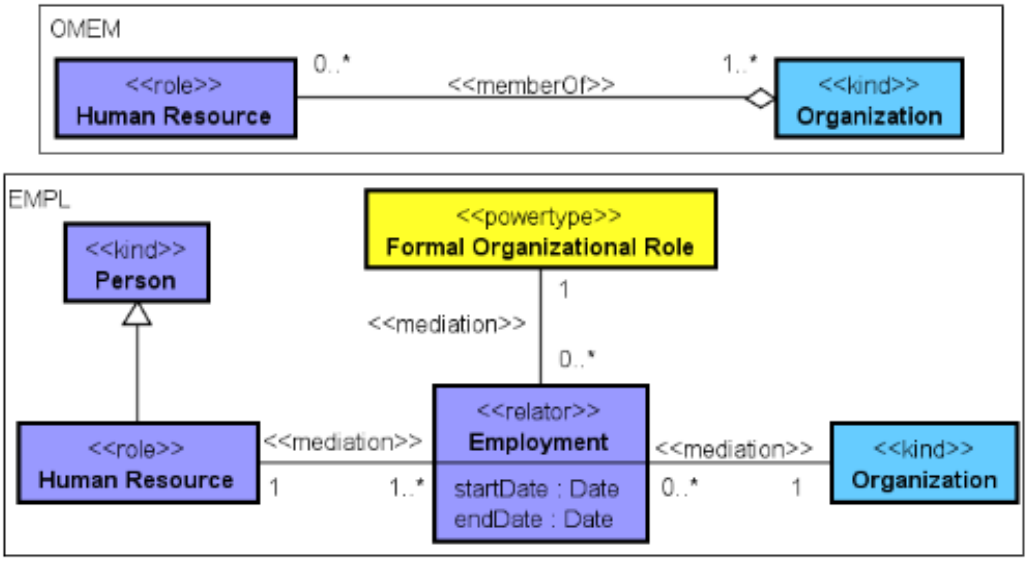

Figure 13. Employment variant patterns: OMEM and EMPL (FALBO et al., 2014)**.**

2.3.2 Enterprise Ontology

The Enterprise Ontology (EO) is a comprehensive collection of terms and definitions relevant to business enterprises. Developed as part of the Enterprise Project [10], it is defined in natural language and has the purpose to act as a communication medium to support system integration, sharing of meaning between different people and facilitate the understanding of system terms by users.

The ontology is defined in parts, namely Informal EO, Formal EO and Meta-Ontology. The last introduces the most fundamental terms, such as entity, relationship, role, among others. The first aims to present the ontology terms defined in natural language in a glossary format. Finally, Formal EO represents the formalization of the Informal EO in Ontolingua (GRUBER, 1993), with the definition of the terms based on the Meta-Ontology terms.

As an ontology developed with the purpose of enterprise definition, the Enterprise Ontology provides definitions of several business aspects, such as activity, plan, capability, resource, organization, strategy, marketing and time. An overview of the terms defined in EO is presented in Figure 14. We will discuss only the meta-ontology and the organization aspect of the Informal EO, related with the description of the organizational structure and business relationships, like management link and ownership.

ACTIVITY etc.	*ORGANISATION*	*STRATEGY*	*MARKETING*	TIME
Activity	Person	Purpose	Sale	Time Line
Activity Specification	Machine	Hold Purpose	Potential Sale	Time Interval
Execute	Corporation	Intended Purpose	For Sale	Time Point
Executed Activity Specification	Partnership	Purpose-Holder	Sale Offer	
T-Begin	Partner	Strategic Purpose	Vendor	
T-End	Legal Entity	Objective	Actual Customer	
Pre-Condition	Organisational Unit	Vision	Potential Customer	
Effect	Manage	Mission	Customer	
Doer	Delegate	Goal	Reseller	
Sub-Activity	Management Link	Help Achieve	Product	
Authority	Legal Ownership	Strategy	Asking Price	
Activity Owner	Non-Legal Ownership	Strategic Planning	Sale Price	
Event	Ownership	Strategic Action	Market	
Plan	Owner	Decision	Segmentation Variable	
Sub-Plan	Asset	Assumption	Market Segment	
Planning	Stakeholder	Critical Assumption	Market Research	
Process Specification	Employment Contract	Non-Critical Assumption	Brand	
Capability	Share	Influence Factor	Image	
Skill	Shareholder	Critical Influence Factor	Feature	
Resource		Non-Critical Influence Factor	Need	
Resource Allocation		Critical Success Factor	Market Need	
Resource Substitute		Risk	Promotion	
			Competitor	

Figure 14. Overview of the Enterprise Ontology's concepts (USCHOLD et al., 1998)**.**

First of all, a brief discussion about the basic terms of the Meta-ontology is necessary to clarify the foundational concepts used in the Informal Enterprise Ontology relevant for this work. As defined in (USCHOLD et al., 1998), the EO is composed of a set of Entities and a set of Relationships between Entities. Entities can play Roles in Relationships. As a fundamental concept, an Entity is a thing in the domain being modeled, such as a document, a human being and a schedule. Entities are associated by Relationships creating a network of Entities, Roles and relational entities

(Relationships). A Role, in turn, is the way that an Entity participates in a Relationship working as an intermediate.

The central elements in EO are Legal Entity and Organisational Unit. A Legal Entity is legally recognized by its external environment and includes a Corporation and Person. A Corporation is a social grouping of Persons (human beings) that are “recognized in law as having existence, rights and duties distinct from those of the individual Persons who from time to time comprise the group” (USCHOLD et al., 1998). The formalization of a Person as a member of a Corporation is an Employment Contract. In addition, Corporation can be composed by Organisational Units, that can relate with others Organisational Units through Management Links, describing the organizational structure.

Similar to Corporation, an Organisational Unit represents a grouping of Persons and possesses identity, but only is recognized in the scope of a Corporation. An Organisational Unit is characterized by the facts that it performs Activities and pursuits Purposes, which can be of interest of many Persons, called Stakeholders in EO. Besides the allocation of Persons, resources can be assigned to Organisational Units. On a resource assignment, both Corporation and Organisational Unit assume the role of Owner on the Ownership relationship created. If the Owner is a Legal Entity (like a Corporation), the Ownership relationship is considered a Legal Ownership. In contrast, if the Owner is an Actor recognized within a Legal Entity then the Ownership is considered a Non-Legal Ownership. An Entity that is legally owned and that has monetary value is denominated Asset. An Entity may be both an Asset and a resource, but some Assets are not resources and some resources are not Assets.

As a coordinated entity, a Corporation must have its management relations well-defined. The Manage concept describes the activity of assigning purposes and monitoring their achievements. This includes resource allocation and power to give authority, managing of people (Person) and Organisational Units. In addition, it may be necessary transfer something to somebody (an Actor) in the Corporation, like an activity to perform. This kind of transfer its denominated Delegate in EO and figures as a type of Managing Activity. Although EO define the term Delegate, a precise definition is left to the user, such as what may be delegated.

The union of a group of Persons pursuing common goals is a basic characteristic of Corporations and Organisational Units. This union configures a Partnership, which different from its Partners, does not have a legal identity and is not recognized by the external environment. Finally, some Corporations are owned by many Legal Entities, like the SA Companies. In this case, a group of Legal Entities shares the ownership of the Corporation. Each “part of ownership” is denominated Share and the Legal Entity that possesses one or more Shares becomes a Shareholder.

2.3.3 TOVE

The TOVE ontology is part of the TOVE Project, acronym to Toronto Virtual Enterprise Project. Developed at the University of Toronto, it was built to provide a common sense enterprise model to support the modeling of both commercial and public enterprises. TOVE can be viewed as a set of integrated ontologies divided in Foundational Ontologies and Business Ontologies. The Foundational ontologies provide the basis to the definition of some aspects of the Business Ontologies. Despite the idea of “foundational” ontology, there is a limitation about the amplitude of the foundation, which covers only activity and resource aspects. Regarding Business Ontologies, each Business Ontology is concerned with a particular enterprise subdomain, including the organization, products and requirements, quality (ISO9000 standard) subdomains, among others. In this work we are interested only in the organizational aspect defined in the Organization Business Ontology.

The terms of the TOVE ontology are structured into taxonomies and defined in natural language presented in a glossary format. The description in natural language of a term is followed by logical axioms that define the relationships with other terms and add constraints to its use. This set of axioms provides a declarative specification for the various definitions and constraints on the terminology (FOX, 1992). Figure 15 presents the organizational object taxonomy with the organizational terms and their relationships.

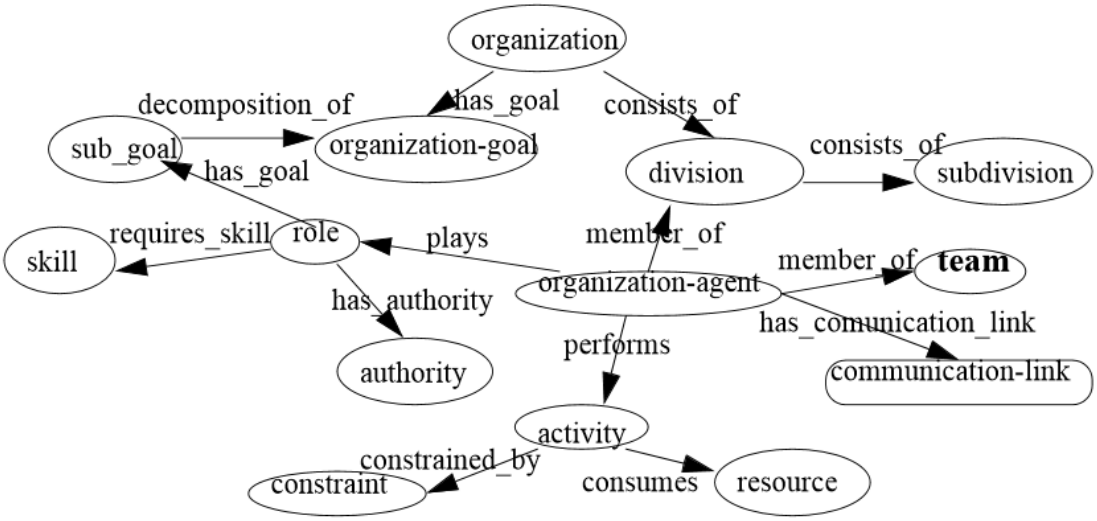

Figure 15. Overview of TOVE's concepts (FOX, 1992)**.**

An organization consists of a set of divisions and subdivisions (recursively defined), goals, roles and constraints. Indirectly, it also consists of organization agents (persons) that are members of working groups (divisions and subdivisions). In other words, an organization represents a group of persons that individually assume roles and are committed to pursuing goals. The members of the organization are distributed in divisions, which can be decomposed in others divisions, creating subdivisions. As a coordinated entity, the behavior of its members is limited by constraints that direct the actions of the members to an expected behavior.

An organization agent (or just agent) is a human being associated with an organization and can play one or more roles while member of the organization. Despite being defined as a human being, the concept of organization agent can be extended to include machine agent or software agent if needed. When assigned to a role, an agent commits to pursue the specific goals related with its role, called here subgoals. To achieve these goals, the agent performs activities, which may consume resources (e.g. materials, labors, tools, etc.). The activities performed by the agents requires some degree of skills, which constrain the roles that a specific agent can assume in organization (e.g. to became a chef an agent must have a cooking skill). An agent can be assigned to one or more divisions (or subdivisions) and teams in the organization. A team is a working group with temporary nature, differently from divisions, that are

usually setup for the long-term within the organization. The members of a team belong to different divisions.

As a social entity composed of people, the agents of an organization are involved in many interactions. When performing his/her activities, in many cases an agent may need interact with other agents, these interactions came in the form of an authority or a communication link. The authority is a control relationship between two agents, in which one agent has the power to obtain commitments from the other. The assignment of authority to an agent is called empowerment. It is not personal and is related with the role that an agent plays in the organization. In contrast, a communication link is a personal relationship established among agents in various roles. Communication link is a unidirectional link used to communicate information from one agent to another. This exchange does not create obligations for any agent (FOX, 1992).

2.3.4 SUPER Project

The SUPER project (Semantic Utilized for Process Management with and between Enterprises) aims to provide an organizational semantic contextualization for business process automation. This context embraces information like used resources, strategies, enterprise structure, as well as roles and functions (ABRAMOWICZ et al., 2008). The use of semantic models to support business process content description is a notion presented in SUPER project and named SBPM, acronym to Semantic Business Process Management. Figure 16 illustrates the SBPM stack. As a final product, the SUPER project presents a set of ontological models “expressed in a formal and machine readable form” (ABRAMOWICZ et al., 2008).

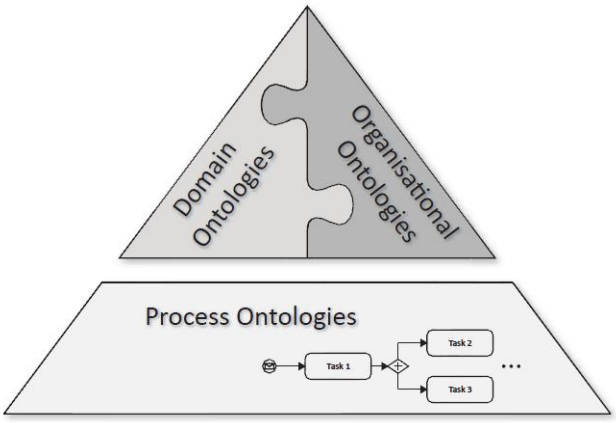

Figure 16. SBPM Ontology Stack (ABRAMOWICZ et al., 2008)**.**

In order to fulfill the SBPM view, the SUPER project is structured in four ontologies, namely: (i) Organisational Structure Ontology, related with the general structure of the organization, (ii) Organisational Units Ontology, concerned with the definition of the many types of organizational units, (iii) Business Functions Ontology, provides foundation for structuring and defining business functions, and (iv) Business Roles Ontology, introduces the vocabulary needed to describe roles of both internal and external actors as performers of process tasks. Since business functions are outside our scope, the Business Functions Ontology is left out of our discussion. Figure 17 presents the Organisational Structure Ontology (OSO).

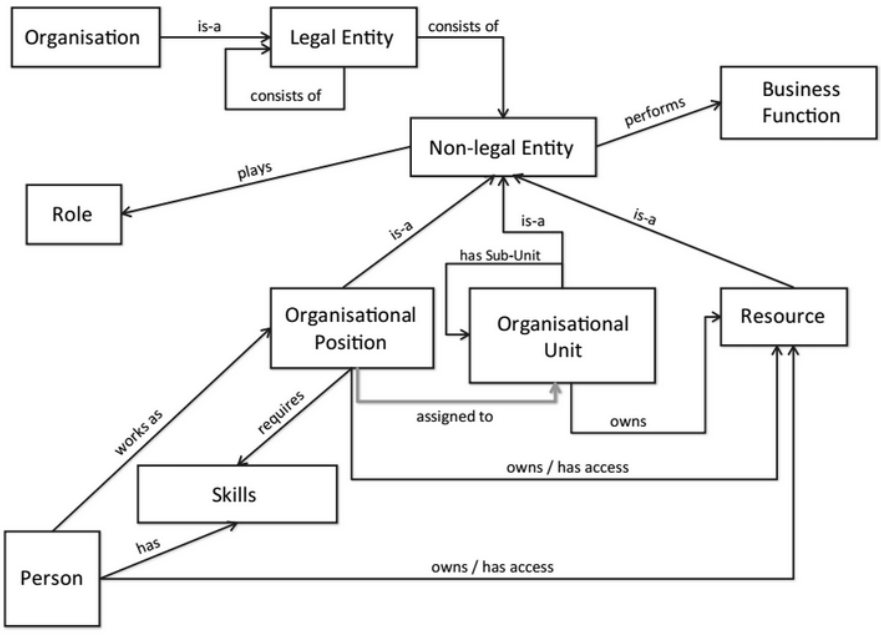

Figure 17. Organizational Structure Ontology (ABRAMOWICZ et al., 2008)**.**

An organisation is a social arrangement that pursues collective goals and controls its own performance. Organisations are legal entities that may be composed by other legal entities and non-legal entities. A legal entity is recognized by its external environment. In contrast, a non-legal entity is an entity internal to a legal entity with a role and business function assigned. This kind of entity encompasses organisational units, organisational positions and resources.

An organisational unit is a formal social group, built in the context of an enterprise, which in association with other organisational units define the hierarchical structure. It may be a corporation, a division, a team, a group, a class and so on. An organisational position defines the role of one or more people in an organisational unit, such as sales assistant and secretary (ABRAMOWICZ et al., 2008). An organisational position is assumed by a person, through a “work as” relationship. In addition, a person playing an organisational position meets the skills requirements and may own or access resources. The assignment of a person (member of the legal entity) to an organisational unit is performed indirectly through his association to an organisational position. A resource is an entity that can be used or consumed by persons (playing or not an organisational position) when performing their activities.

Finally, a role defines a set of expected behavior, prerogatives and obligations played by an actor. The role concept describes a supertype for all roles in the organisation, including organisational position, despite the lack of a formal definition. Figure 18 presents the Organisational Unit Ontology.

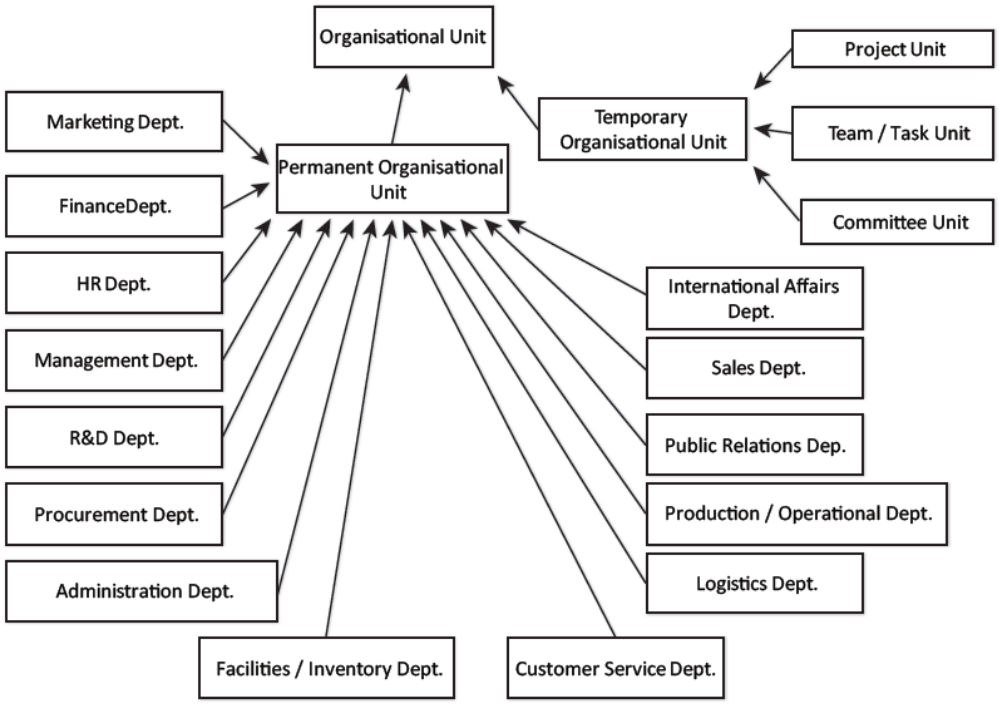

Figure 18. Organizational Units Ontology (ABRAMOWICZ et al., 2008)**.**

The main concepts in Organisational Unit Ontology (OUO) are the permanent and temporary organisational unit concepts. A permanent organisational unit is specialized in many units chosen as a result of analysis of different organizational structures of existing companies and organizations available in the internet and in the SAP Solution Maps (ABRAMOWICZ et al., 2008). In contrast, temporary organisational units are task driven units and are created in order to carry out a task. Their existence in the organizational structure is related with the status of the task, ceasing to exist when the task is complete.

In turn, the Business Role Ontology (BRO) introduces terms needed to describe roles of both internal and external participants of a process, called actors. The concepts internal role, external role and internal role type are presented. Despite the absence of definition, an internal role seems to be a role played by actors (persons) that are member of the organisation, while an external role seems to be a role played by an actor external to the organisation. In addition, an internal role type seems to define a kind of “more generic” role that is capable of typifying a set of roles, such as engineer and professor. Note that the definitions provided here are the result of an analysis of the labels of the concepts as there are no definitions for the terms in the original work.

2.3.5 W3C Organization Ontology

The W3C Organization Ontology is an ontology (ORG) for organizational structures. Defined by the W3C consortium, it aims to provide support for linked data publishing of organizational information across many domains (W3C, 2014). To achieve this purpose in the Semantic Web, the ORG ontology is defined in OWL. In addition, to facilitate human understanding, it also is presented visually in UML class diagram notation. Figure 19 illustrates the W3C Organization Ontology.

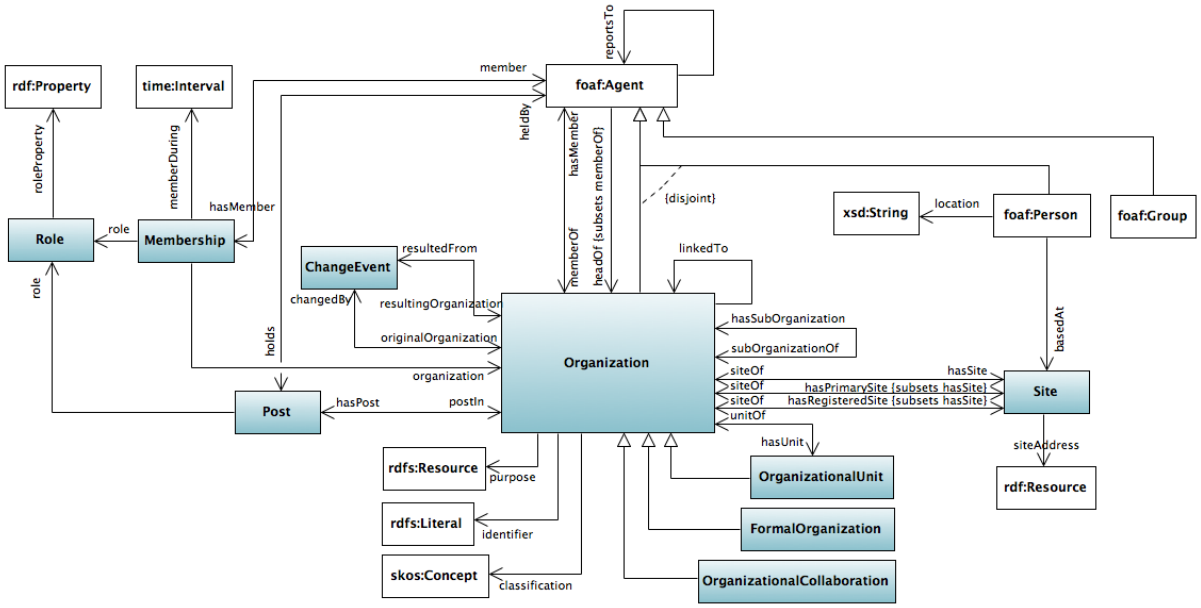

Figure 19. W3C Org Ontology overview.

An organization is a social agent composed of people organized in a community, political, commercial or other social structure. The individual agents belonging to the organization pursue a common goal and the existence of an organization is beyond the set of people composing it. Organizations are located in a specific site and usually have a hierarchical structure and consist of organizational units, posts and roles. ORG define three types of organizations, namely formal organization, organizational unit and organizational collaboration. A formal organization is a legal entity, recognized by its external environment, the world at large. Examples include a corporation, charity, government or church. In contrast, an organizational unit only has full recognition within an organization (W3C, 2014). Finally, an organizational collaboration describe a cooperation engagement at legal of organizations, like a project and a consortium.

Despite the fact that it has identity and defining purpose independent of its member, an organizational collaboration is neither a formally recognized legal entity nor a sub-unit within some large organization (W3C, 2014). Organizational collaborations may have limited lifetime, but not necessarily.

The agents that compose an organization can hold posts and play roles. A post represents some position within an organization that exists independently of the person or persons filling it (W3C, 2014). A post may be held by many member of the organization and define the roles that any holder of the post plays. On other hand, a role, as defined in (W3C, 2014), denotes a role (in its general sense) that a person or other agents can play in an organization. The assignment of an agent to a role is performed by the membership concept. Note that there is not a clear conceptual difference between a post and a role.

Organizations are adaptable entities and respond to environment changes. During the lifetime of an organization, many arrangements of working groups, roles, among others are experienced. A change event represents a great impact event in an organization or complete restructuring, like a merge. It is useful to differentiate organization's arrangements that result in an organization sufficiently distinct from the original organization that it has a different identity.

2.3.6 ArchiMate

ArchiMate is a specification for EA definition, maintained by the Open Group industry consortium. Currently in version 2.1, it is structured in several organizational aspects and layers. One of the aspects dealt with in ArchiMate is related to the representation of the active structure of organizations. For the purposes of our analysis in this work, we focus only on the business layer of the active structure, highlighted in Figure 20.

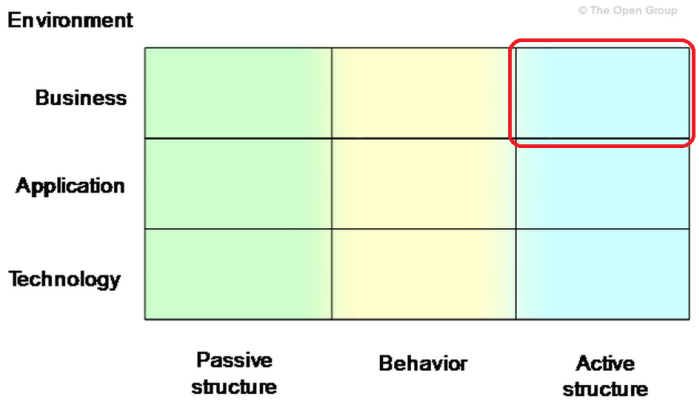

Figure 20. ArchiMate aspects and layers.

The Figure 21 presents a fragment of ArchiMate metamodel related with active structure at organizational domain.

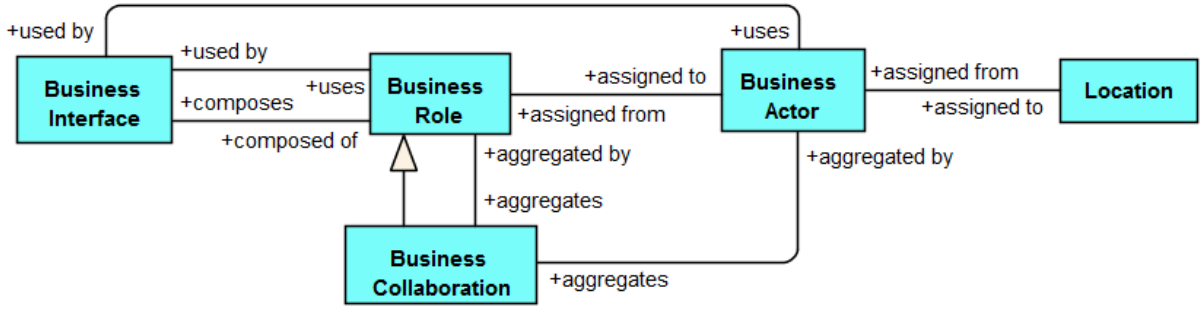

Figure 21. Fragment of ArchiMate metamodel related with active structure at organizational domain (THE OPEN GROUP, 2012)**.**

The main structural concepts at the business layer are business role and business actor. Business role specifies the responsibility to perform some behavior (business function or business process). In turn, business actor are those entities capable to perform behavior. “A business role is typically assigned to a business actor. Business actors may be individual persons (e.g. customers or employees), but also groups of people and resources that have a permanent (or at least long-term) status within the organizations” (LANKHORST; VAN DRUNEN, 2007). Business actor are assigned to a location, which “is defined as a conceptual point or extent in space” (THE OPEN GROUP, 2012).

A business collaboration can be used to model a business transaction (LANKHORST; VAN DRUNEN, 2007). It describes an aggregation of business roles (possibly

temporary) which together perform a collective behavior. A business interface may be used by a business collaboration, while a business collaboration may have business interfaces (through composition) (THE OPEN GROUP, 2012). Finally, a business interface “exposes the functionality of a business service to other business roles (provided interface), or expects functionality from other business services (required interface). It is often referred to as a channel (telephone, internet, local office, etc.)” (THE OPEN GROUP, 2012).

Figure 22 presents an example of an ArchiMate model concerning business active structure. In this example, two Business Actors (“Insurance Department” and “Customer”), playing the Business Roles of, respectively, “Insurance Seller” and “Insurance Buyer”, interact through a telephone interface.

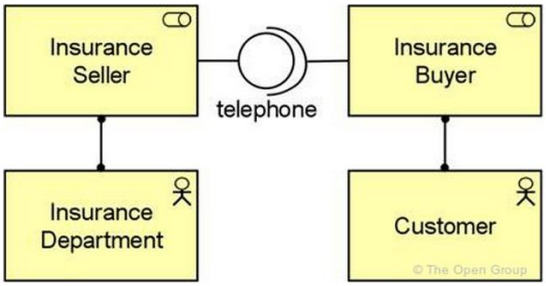

Figure 22. Examples of ArchiMate model with active structure elements (THE OPEN GROUP, 2012)**.**

2.3.7 UPDM

The UPDM language is a product of the Object Management Group (OMG) that aims to support both DODAF and MODAF framework. Currently in version 2.1, the main motivation for the development of UPDM is related with the shared need of the USA Department of Defense and UK Ministry of Defense to develop a modeling standard to DODAF and MODAF frameworks. As defined in (OMG, 2014), UPDM 2.1 specifies two compliance levels corresponding to supporting a UML-based profile and a UML + OMG SysML profile. The compliance Level 0 is an implementation of UPDM extending UML 2 and importing several SoaML stereotypes, while the compliance Level 1 includes

everything in Level 0 and imports the SysML profile (with all its sub profiles). Figure 23 illustrates compliance levels of UPDM 2.1.

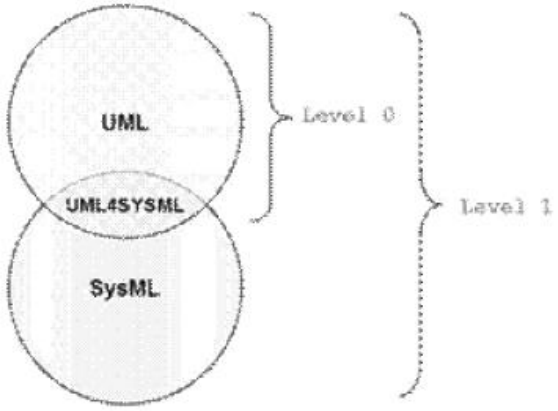

Figure 23. UPDM Compliance Levels 0 and 1 (OMG, 2014)**.**

UPDM provides support for DODAF and MODAF viewpoints by allowing the modeling of operational capabilities, services, system activities, nodes, system functions, ports, protocols, interfaces, performance, and physical properties and units of measure. In addition, the profile enables the modeling of related architecture concepts such as DoD's doctrine, organization, training material, leadership & education, personnel, and facilities (DOTMLPF) and the equivalent UK Ministry of Defense Lines of Development (DLOD) elements. For the purpose of this work, we are interested only in the organization concepts. Figure 24 illustrates the viewpoint support of UPDM.

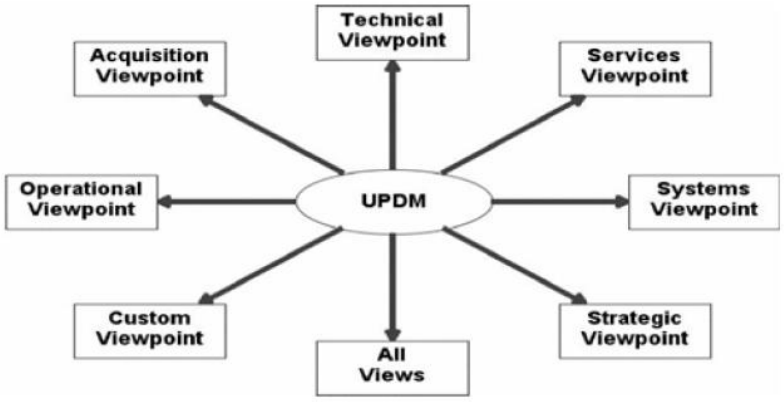

Figure 24. UPDM Viewpoint Support Illustration (OMG, 2014)**.**

Figure 25 presents the Organizational Structure diagram. This diagram represents only a fragment of UPDM and also of the organizational domain. The nature of the

description of UPDM is modular, so the concepts are distributed in many “cross-domain” partial views. For the sake of simplicity, we do not present all the partial visions of UPDM. The elements named with “actual” prefix represent a specific “thing”, while elements without the prefix represents types of “something”. For example, the concept ActualOrganization describes a specific organization, while the Organization concept represents a type of organization.

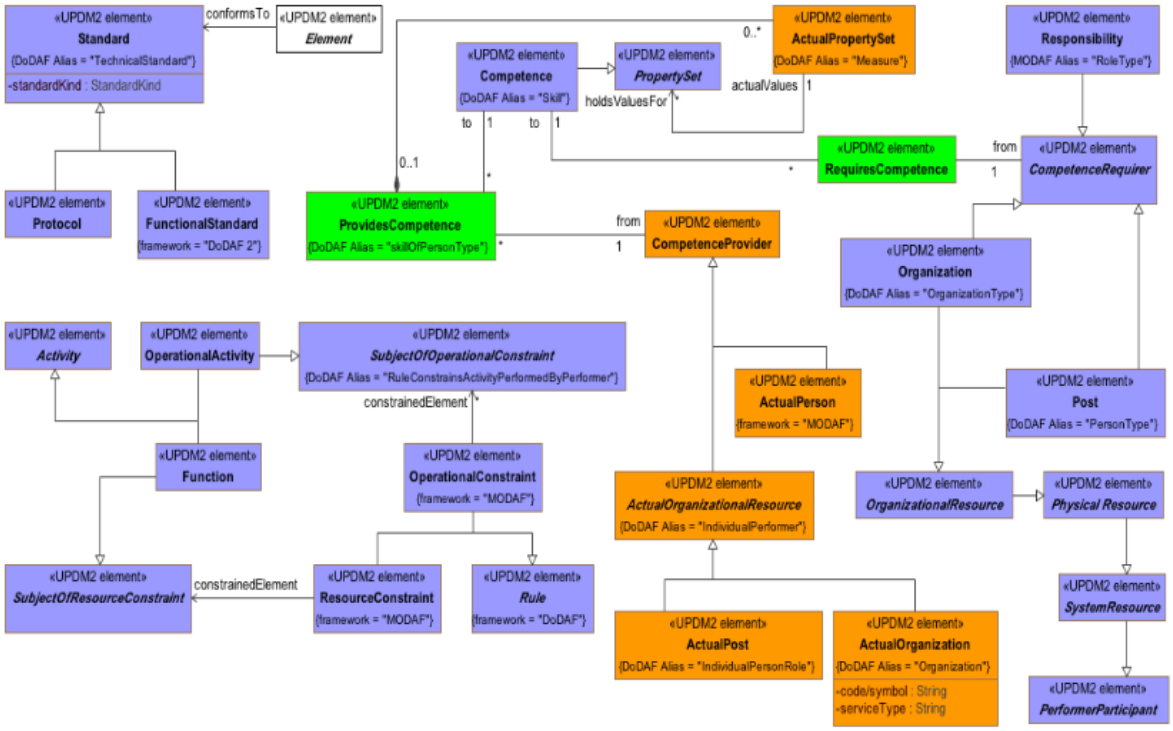

Figure 25. Organizational Structure - DM2 (OMG, 2014)**.**

An organization describes a group of persons associated to pursue a particular purpose. A person, in turn, is a type of human being recognized by law as the subject of rights and duties. A specific person (actual person) may fill a post and assumes responsibilities in the organization. Both specific organizations and persons are location holders, i.e., are situated in some location. For being part of an organization and to play its roles, a person, as member of the organization, must meet some competence requirements. A competence represents a specific set of abilities defined by knowledge, practice, aptitude, etc., to do something well. Organization and post are competence requirers, while a person is a competence provider (has competence).

The organizational activities, in a macro sense, can be eventual or unique, e.g., an audit may be necessary in the case of suspected fraud. The temporary collective effort to attack specific issues/problems/demands figures as a project. As defined in (OMG, 2014), a project represents a time-limited endeavor to create a specific set of products or services (resources or desired effects). The relation between a project and a specific organization is formalized by an organizational project relationship. As an input to activities or as an output to projects, in UPDM, resources are defined as abstract elements placeholder to indicate that resources can be exchanged in Operational and Systems views. UPDM describes many types of resources including resource artifacts, which represent the concrete sense of something that is used or consumed to accomplish a task or function. As organizations and persons, resources are also location holders. Examples of resources include data, information, fuel, car, among others.

2.3.8 RM-ODP

The Reference Model of Open Distributed Processing (RM-ODP) is an international standard built with the purpose of providing a common language (set of terms and structuring rules) for capturing the organizational context of an Open Distributed Processing (ODP) system. It is a set of ITU-T and ISO standards (ITU-T Rec. X.901-X.904 and ISO/IEC 10746), comprising five organizational viewpoints, called enterprise, information, computational, engineering and technology. For each viewpoint, a viewpoint language is described, which defines the concepts and rules that provide the elements to specify ODP systems from the corresponding viewpoint. Although RM-ODP provides abstract languages for description of its viewpoints, it does not specify a notation to support the modeling activity. In this work, we analyze only the enterprise viewpoint of RM-ODP. Because of its intent, many basic distinctions of the organizational domain are not present in the RM-ODP specification, such as how the members of the organization are distributed in working groups. Figure 26 presents the community and behavior concepts.

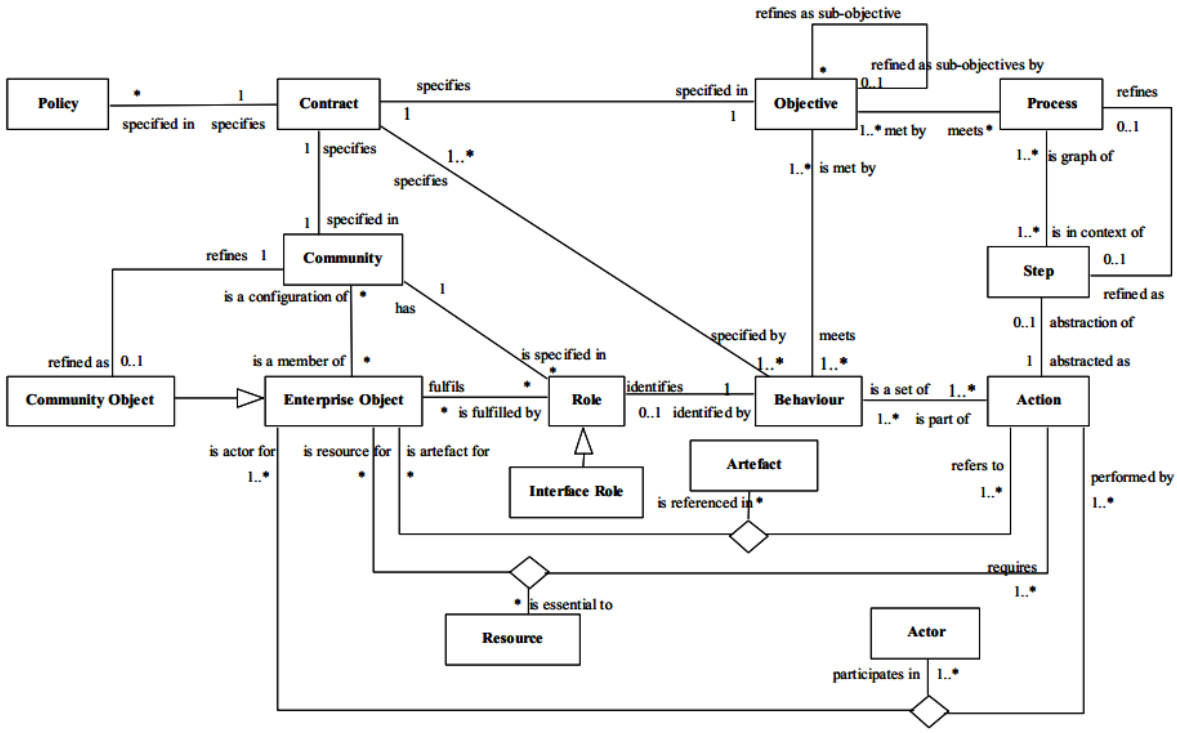

Figure 26. Community and Behavior Concepts (RM-ODP-ISO-ISO/ITU-T, 1995)**.**

An enterprise object describe an entity in its broader sense and can refer to the sort of entities defined in an enterprise specification, such as a person, a system, a book, among others. A community, in turn, represents a collection of entities formed to pursue an objective, like a hospital, a library and a factory. The objectives of a community are expressed in a contract, which specifies the policies that constraints the behavior of the member of the community. As defined in (RM-ODP-ISO-ISO/ITU-T, 1995), a community object is a composite enterprise object that represents a community. Components of a community object are objects of the community represented. Objects that represent an entity legally recognized are called party (a legal person, an organization).

A community may specify a set of roles, which enterprise objects can fulfill. A role defines the expected behavior of an enterprise object without reference to a particular object. Roles, in combination, specify the behavior of the objects in a community. In some cases, an object of a community must interact with objects that do not belong to the community. When performing this kind of interactions, an enterprise object fulfills an interface role. Examples of interface role include supplier, customer, and consultant, among others.

An enterprise object may perform actions in order to meets its expected behavior. When participating in an action an enterprise object is called actor. An actor is a role in which the enterprise object fulfilling the role participates in the action. Also in the context of actions we have artifacts and resources. Artifacts are roles that represent enterprise objects referenced in the action. In contrast, a resource is a role in which the enterprise object fulfilling the role is essential to the action.

A party, in exercising its power, may delegate authority, responsibility, functions, among others, to an enterprise object. An enterprise object that has been delegated by and acts for a party is called agent. An agent may be a party or may be the ODP system or one of its components. Another system in the environment of the ODP system may also be an agent of some party (RM-ODP-ISO-ISO/ITU-T, 1995).

2.3.9 ARIS

The Architecture of Integrated Information Systems (ARIS) is an enterprise architecture framework to support the documentation of existing business process types, blueprints for analyzing and designing business processes, and support for the design of information systems (LANKHORST, 2013). Initially developed by Prof. Scheer as part of academic research, it has been widely adopted by industry and today ranks as a profitable commercial product (LANKHORST, 2013). ARIS provides not only a method for analysis and design of organizational aspects, but also provides a language for its representation, which is supported by a software tool.

ARIS is organized in four views: organization, data, control and process/functions (LANKHORST, 2013). These perspectives encompass the main enterprise aspects and are defined in three different levels of interest: concept, data processing concept and implementation. Figure 27 presents the structure of ARIS.

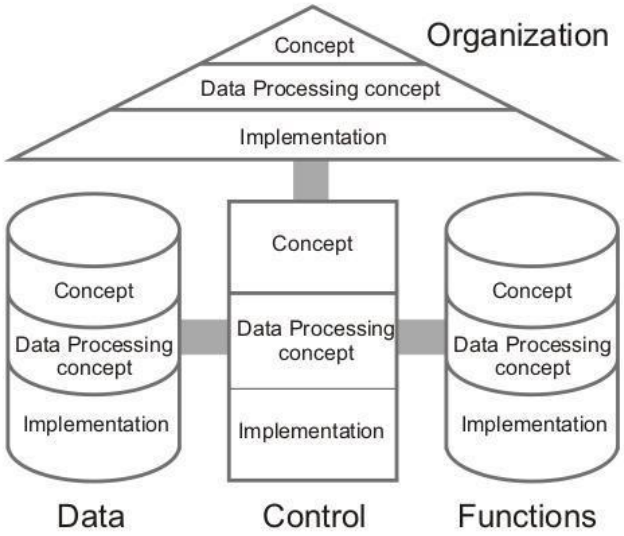

Figure 27. ARIS structure overview.

In this work we are interested only in the organization view, whose metamodel is presented in (SANTOS, 2009) as result of analysis of the original (now outdated) metamodel in combination with the current concrete syntax. The organization view treats the business contextualization for business process and data. Organization, in ARIS, includes the definition of its structure, roles and actors. The main set of metaclasses covered in the organization view includes, Organization Unit Type, Organization Unit, Position, Location, Person, Person Type and Group.

An organization unit is a social entity compromised in pursues organizational goals, includes enterprises as a whole or departments. The common characteristics of a group of organization units can be defined as a general type of organizational unit, called organizational unit type. A specific organization unit instantiates an organizational unit type through the relationship “is type of”. An organization unit can be composed by other organization units. As a social entity, organization units are composed by persons, who “occupy” some position in the organization. The smallest organization unit is defined by a position. An organizational unit can have multiple positions associated with it (through the “composed” relationship), according to its business rules and organizational structure (SANTOS, 2009). Positions specify the expected behavior of a person inside the organizational context and include, e.g., seller and sales manager.

Similarly, person type also defines expected behavior when grouping general characteristics of persons. It is possible to specify that just a group of persons (or type of a person type) may play a certain role or have access to certain information from the organization (SANTOS, 2009). Person types are instantiated by persons and can be associated to organization units or groups through the “belongs” relationship. Examples of person type include department manager, group leader and project manager. As defined in (SANTOS, 2009), the advantage of use of “types” (like organization unit type and person type) is the possibility of grouping of entities, which are governed by common business rules.

Some social entities are defined to pursue a specific goal during a determined period of time. These types of social entities are called groups. Examples include demand evaluation group, financial audit group and product project. A group can be related to organizational units through the “is assigned” relationship. Finally, as defined in (SANTOS, 2009), a location element represents a geographical location of an organizational unit, a person, a position or a resource of the organization. It can define a location in many levels of precision, starting from a workstation to a country. Using the location element its possible specify for instance that the Software Development Unit of organization is located in Rio de Janeiro, while its Human Resources Department is located in Brasília.

2.3.10 Conclusion

In this section we presented a set of approaches to represent the active structure domain. In addition to the approaches discussed in this section, there are other reference models and ontologies in use in organizations and / or specific governments. This is the case of the ontology proposed by the Brazilian Ministry of Planning, Budget and Management (*Ministério do Planejamento, Orçamento e Gestão* - MPOG) (MPOG, 2011), a government ontology used by the Brazilian Government, which is object of study in Chapter 6.

The organizational structure domain has been the focus of a number of ontologies since the end of the 90s. The Enterprise Ontology (EO), e.g., includes a fragment that

addresses the organization structure domain (USCHOLD et al., 1998). It is described in natural language and is based on formalized meta-ontology, with good coverage of concepts related to organization structure. Differently from O3, it makes no distinction between staff, line and missionary units. EO also includes a direct relationship between a “person” and an “organisation unit” (“working for”), without the intermediary of roles or positions they play in the scope of an “organizational unit”. In case a person plays multiple roles, it’s not possible to define which role is played in the context of each “organisation unit”. The organization ontology for the TOVE enterprise model (FOX, 1992) chooses for a fixed structure with three levels: organization, division and sub-division. It has a notion of team that is independent of these levels of decomposition. It does not distinguish staff and line units as well as the different categories of roles individuals may play. Roles are also not related to organization units (only indirectly through authority). The Organizational Structure Ontology of the SUPER project (OSO) (ABRAMOWICZ et al., 2008) is aimed at providing organizational context for the execution of business processes. Differently from O3, OSO is not specified using a well-defined language and is not based on a foundational ontology. Further, it does not include some important distinctions done in O3 (line vs. staff units, different sorts of roles). The W3C Org Ontology (W3C, 2014) concerns the description of organizational structure for Semantic Web applications. It is defined in OWL and, given its focus on Semantic Web data, it is less suitable for meaning negotiation, which is required in our intended application (semantic analysis and language revision). It does not make fine distinctions in the sorts of roles that can be played in an organization, as well as the different kinds of organizational units (staff, line, missionary). The W3C Org Ontology is further not grounded in a foundational ontology. Finally, E-OPL (FALBO et al., 2014) aims to provide a basis for an enterprise pattern language whose fragments can be selected flexibly. It is grounded in UFO and is defined using OntoUML, however it does not cover missionary and staff units, which is important to the representation of organograms in EA descriptions. We intend to add patterns to E-OPL that reflects the distinctions in O3 as part of our future work.

In a broader scope, some approaches aim to provide languages for representation of EA aspects in general, including the organizational structure aspects. UPDM (OMG, 2014), e.g., is a profile for DoDAF and MODAF frameworks focused on representation of EA aspects in UML, including active structure elements. It is grounded on the IDEAS

foundational ontology. UPDM lacks expressivity, since it does not differentiate types of organizational units and types of business roles. ARIS, in turn, has the primary purpose of support the ARIS Method modeling activities. ARIS has less coverage if compared to UPDM, once does not describes aspects related to the allocation of resources (employees), skills, authority and location. Finally, RM-ODP (RM-ODP-ISO-ISO/ITU-T, 1995) does not provides a notation for support modeling activities, however it defines abstract languages for specification of open distributing systems. Regarding the organizational domain, RM-ODP does not have sufficient expressivity. Among its shortcomings we can mention the lack of concepts for describing basic organizational aspects like organizational units and physical agents (employees of the organization).

2.4 ONTOLOGY ENGINEERING

The term ontology, in its broader sense, figures as the branch of metaphysics that studies the nature of existence or being as such. In technology, the term is used to represent a formal conceptualization of the real world. A conceptualization, in a broader sense, is an abstract, simplified view of the world that we wish to represent for some purpose (GRUBER, 1995). We all have different conceptualizations formed in our mind. When we think about school immediately the terms teacher, class, student, discipline, classroom come to our minds. Moreover, we are an intuitive sense of what these terms mean and how they are related, e.g., a teacher may be allocated in a classroom to teach a discipline.

For the purpose of communication, sharing or machine reasoning it is important to represent an abstract conceptualization in a formal way. The formal representation of a conceptualization is performed through the identification and modeling of concepts, objects and relationships of some domain of interest. Thus, ontologies are an explicit specification of a conceptualization (GRUBER, 1995), i.e., a means to explicitly specify conceptual models with logic-based semantics (OBERLE, 2006).

As defined in (VRANDECIC, 2009), ontologies in computer science are used in order to specify in a standardized way the knowledge which is shared and exchanged between different systems and within systems, by the various components. Ontologies

are engineering artifacts that define the formal semantics of the terms used and the relationships between these terms. An ontology ensures that the meaning of the data that is exchanged between and within systems is consistent and shared - for both computers (expressed in formal models) and humans (through its conceptualization). Ontologies ensure that all participants "speak a common language".

Despite the basic common nature of ontologies, there are several classifications of ontologies. Each of them focused on different dimensions in which ontologies can be classified (ROUSSEY et al., 2011). Here, we will focus only on the classification of ontologies regarding their abstraction level. Figure 28 presents the layers of abstraction and its classification, which are defined in details above.

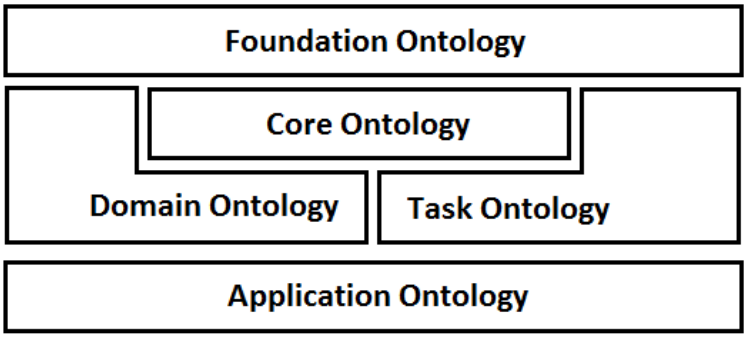

Figure 28. Overview of ontology classification.

- **Top-level (Upper, Foundation) ontologies** describe very general concepts like space, time, matter, object, event, action, etc., which are independent of a particular problem or domain: it seems therefore reasonable, at least in theory, to have unified top-level ontologies for large communities of users (GUARINO, 1998).
- **Core ontologies** have more specific concepts than foundation ontologies, but contain fundamental concepts of a domain or task. Core ontologies are used by different group of users. This type of ontology is linked to a domain but it integrates different viewpoints related to specific groups of users. A core reference ontology is often built to catch the central concepts and relations of the domain (ROUSSEY et al., 2011).
- **Domain ontologies and task ontologies** describe, respectively, the vocabulary related to a generic domain (like medicine, or automobiles) or a

generic task or activity (like diagnosing or selling), by specializing the terms introduced in the top-level ontology (GUARINO, 1998).

- **Application ontologies** describe concepts depending both on a particular domain and task, which are often specializations of both the related ontologies. These concepts often correspond to roles played by domain entities while performing a certain activity, like replaceable unit or spare component (GUARINO, 1998).

The practical potential of ontologies include its use as a reference ontology to support the communication among stakeholders, systems integration and evaluation of modeling languages. The use of reference ontologies for evaluating and revising enterprise modeling languages has shown to be promising, as observed in (AZEVEDO et al., 2011)(ALMEIDA, 2009)(SANTOS; ALMEIDA; GUIZZARDI, 2013)(ALMEIDA; GUIZZARDI, 2013). The efforts related with UFO include: a semantic analysis of fragments of ArchiMate (more specifically the motivational layer (AZEVEDO et al., 2011) and the active structure aspect (PEREIRA; ALMEIDA, 2014)); a semantic analysis of the notion of role in ArchiMate and other EA description techniques (ALMEIDA, 2009); and an analysis and revision of the ARIS capabilities for organizational structure modeling (SANTOS; ALMEIDA; GUIZZARDI, 2013).

In addition, ontologies has a clear technology potential. Ontologies can be applied to semantic annotation (ARNDT et al., 2009) to solve terms ambiguity and implement context awareness (POVEDA VILLALON et al., 2010). Despite the discussions about the qualification as ontology of artifacts modeled in OWL, the use of OWL to specify ontologies has an important role in the implementation of the called semantic web (ZHANG, 2007). The application of ontologies on web can improve the quality of search engines increasing the precision of the returned information.

2.5 UFO-A, UFO-C AND ONTOUML

The need to produce conceptual models with well-defined semantics has inspired the creation of well-founded philosophically foundational ontologies. In (GUIZZARDI, 2005), Guizzardi introduces the Unified Foundational Ontology (UFO), which has

played an important role on domain ontology engineering (GUIZZARDI; FALBO; GUIZZARDI, 2008), harmonization of semantic models (ALMEIDA; CARDOSO; GUIZZARDI, 2010)(CARDOSO et al., 2010) and evaluation and revision of enterprise modeling languages (SANTOS; ALMEIDA; GUIZZARDI, 2013)(ALMEIDA; GUIZZARDI, 2013)(PEREIRA; ALMEIDA, 2014).

In order to represent our reference ontology, we employ OntoUML, a UML profile that incorporates the foundational distinctions of the Unified Foundational Ontology (UFO-A) using UML stereotypes. Thus, our domain ontology employs and extends the more general domain-independent notions of objects, types, events, social entities, etc. (See (GUIZZARDI, 2005) and (GUIZZARDI; FALBO; GUIZZARDI, 2008) for thorough presentations.) Later in this thesis we will present a reference ontology that, by specializing UFO-C, provides an ontologically well-grounded view that covers the basic notions of the organizational domain.

2.5.1 Basic Entities

We start with the basic distinction in UFO between Individuals and Universals. Individuals are entities that exist in reality instantiating one or more universals and possessing a unique identity. Universals (more specifically first-order universals) are patterns of features that can be realized in a number of individuals. Universals specifies a set of characteristics common to a set of elements. Examples of universals include airplane, person, marriage, being married with, being taller than. Roughly speaking, individuals can be viewed as elements and first-order universals as their types.

Universals are refined in endurants universal, event universal and relations. The Figure 30 illustrates this setting.

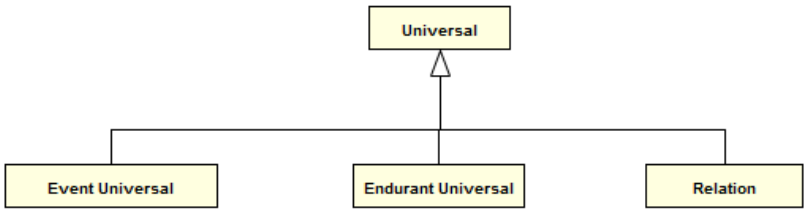

Figure 29. Basic distinctions of Universals.

“Endurants are said to be wholly present whenever they are present. Examples of endurants are a house, a person, the moon, a hole, an amount of sand” (GUIZZARDI; FALBO; GUIZZARDI, 2008). Relations, in turn, are entities that glue together other entities (GUIZZARDI; FALBO; GUIZZARDI, 2008) (e.g. smaller than, admitted in, superior to). Finally, Events are composed by temporal parts and may exist during a specific period in time. The features of the events are described in UFO-B, which is not including on the scope of this work. The Figure 30 detail the endurant universal’s specialization tree.

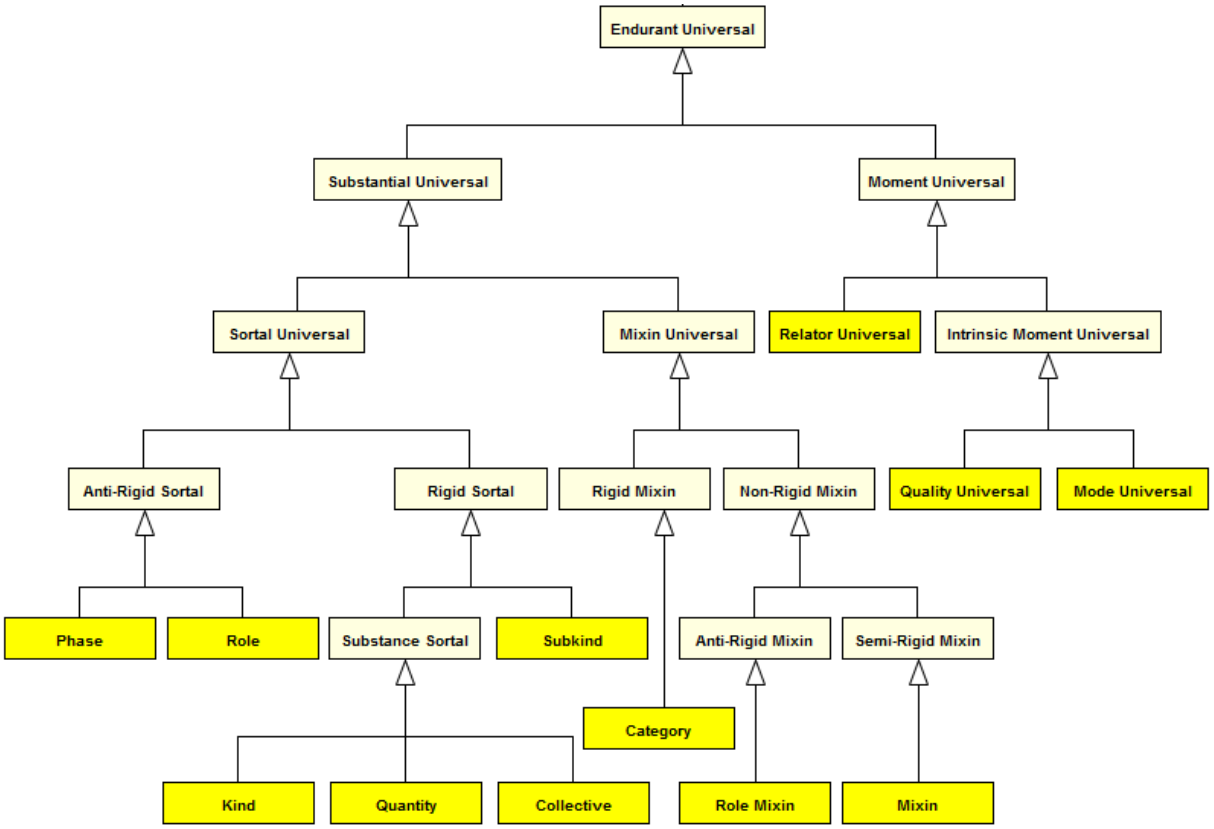

Figure 30. Endurant Universal complete taxonomy.

Substantials are individuals that do not need others individuals to exist, i.e., are existentially independent (e.g., a car, an apple, Bill Gates). Moments are particularized properties inherent to an individual and are existentially dependent on the individuals on which they inhere. Moments can be intrinsic or relational. Intrinsic moments apply to a single subject (e.g., an apple’s color, someone’s headache). Intrinsic moments are refined in quality and mode universals. “Qualities are objectification of properties that evaluate into a certain value space” (PRINCE, 2014) (e.g. mass, height, color). Modes,

in turn, represent unstructured intrinsic properties (PRINCE, 2014), such as a headache and a desire. Relational moments are called relators and depend on various relata. For example, an employment contract depends of an employee and an employer to exist. Similarly, a marriage contract depends of a husband and a wife (GUIZZARDI, 2005). Relators also play the role of truth-maker of material relations.

An important ontological distinction is the principle of identity. The perception of identity allow to us to precisely differentiate between two or more instances. Thus, we can state that an instance of some type (with principle of identity) maintain its identity (is the same instance) in every circumstance considered by the model (GUIZZARDI, 2005). An example is “Monique”, which is instance of “Natural Person”. Irrespective of whether she becomes a student, elderly, astronaut or an employee, she still preserve her identity.

Another important ontological distinction allows us to analyze the modal nature of the concepts. A universal is rigid “if its instances will continue to be so as long as they exist in the model” (GUIZZARDI, 2005). Examples of rigid types includes a person, a ship and a printed picture. In contrast, anti-rigid types are those that its characteristics are contingent to its instances. Take for example the anti-rigid concept Employee: for every x such that x is instance of Employee there is a counterfactual situation in which x is not an Employee (GUIZZARDI, 2005). Another example of anti-rigid concepts includes student, driver, living person, vehicle in transport and trip destination.

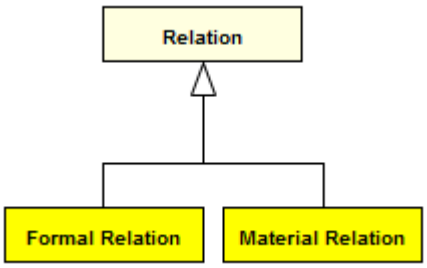

Figure 31. Relation complete taxonomy.

Relations are specialized into formal and material relations (Figure 31). Formal relation “is a meta-category applied to relations types that can hold between two individuals without the support of additional individuals” (PRINCE, 2014). In its turn, a material

relation requires the existence of an additional individual, the truth-maker of the relation (relator). For example, the relation between a student and a school is valid whilst exists the relator “enrollment” between them. “Taller than” and “instance of” are examples of formal relations. Examples of material relations include “being married to”, “studies in” and “works in”.

In addition to the formal and material relations, OntoUML provides support meronymic relations, i.e., part-whole relations. Part-whole relations describe the features established between a thing (whole) and its parts. Every part-whole relation obeys a set of additional axioms (PRINCE, 2014):

weak supplementation, which states that every whole must be composed by at least two parts;

- **irreflexivity**, individuals cannot be a part of themselves;
- **asymmetry**, if ‘a’ is part of ‘b’, ‘b’ cannot be part of ‘a’;
- **acyclicity**, an individual cannot be in its part-hood transitive closure (part of its parts, or parts of parts of its parts, and so on).

Moreover, all meronymic relations have the following additional Boolean meta-properties (PRINCE, 2014):

- **isEssential**, which implies an existential dependency from the whole to the part;
- **isInseparable**, which captures an existential dependency from the part to the whole;
- **isImmutablePart**, a specific dependency from the whole to the part;
- **isImmutableWhole**, a specific dependency from the part to the whole;
- **isShareable**, a boolean meta-property that, when set to true, forbids an individual to compose more than one whole of the same type.

UFO specifies four particular types of part-whole relations, namely *componentOf*, *memberOf*, *subcollectiveOf* and *subquantityOf*. Basically, the difference between them lies on its meta-properties and on the types of entities that may participate as whole and as part.

ComponentOf is a part-whole relation that stands between two functional complexes. Examples include an airplane and its wings, furniture and its doors and car and its engine. The *MemberOf* relation, in turn, “is a parthood relation between a complex or a collective (as a part) and a collective (as a whole)” (GUIZZARDI, 2005) (e.g. Football Team-Player, Deck-Card and UN Security Council-Nation). Furthermore, SubCollectiveOf stands between collectives, more precisely between collections and their sub-collections (e.g. The Brazilian part of the Amazon Forest, the reserve team of Brazil Football Team). Finally, the *SubQuantityOf* relation “stands for part-whole relations that hold between quantities (e.g. Beer-Water; Concrete-Sand). By default, the SubQuantityOf relation is inseparable and non-shareable” (PRINCE, 2014).

2.5.2 OntoUML

During the process of ontology development, the modeler demands means to formalize a conceptualization about a particular domain. A common mean to formalize conceptualizations is through the use of modeling languages. A modeling language has the role of providing elements for model specification.

Modeling languages are compliant with a conceptualization, i.e., a modeling language should have expressivity enough to cover the aspects with respect to a specific conceptualization. Here, we have to pay attention to the difference between what is on mind of the modeler and what is formalized on a model specification. “Conceptualizations and models are abstract entities that only exist in the mind of the user or a community of users of a language. In order to be documented, communicated and analyzed, these entities must be captured in terms of some concrete artifact. The representation of a conceptual model is named here a model specification” (GUIZZARDI, 2005). Figure 32 illustrates these relationships.

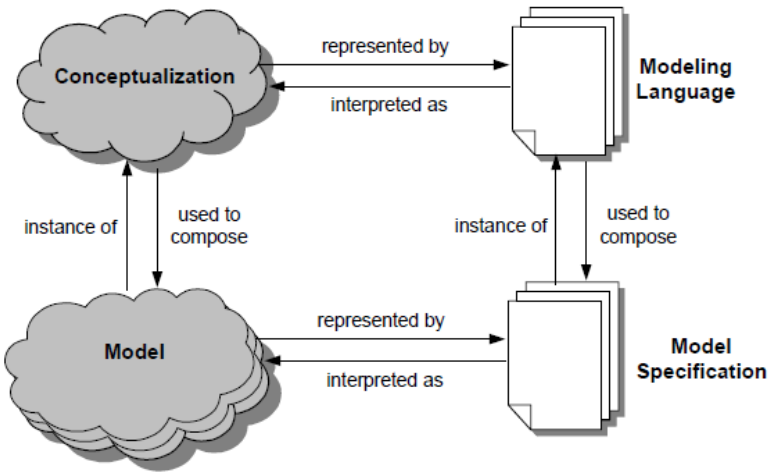

Figure 32. Relation between conceptualization and formal artifacts (Model Specifications) (GUIZZARDI, 2005).

In the context of ontological engineering, OntoUML plays an important role on ontology formalization. The stereotypes in OntoUML correspond to foundational ontological distinctions, enabling us to use class diagrams to represent ontologies that employ the distinctions of UFO-A. It provides building blocks with particular ontological features for ontological foundation support on developing ontologies. For instance, a class stereotyped as <<kind>> represents an instance of UFO's "kind". Thus, OntoUML models instantiate UFO-A, as illustrated in Figure 33 (PRINCE, 2014). Note that some UFO concepts (presented in UFO-B or UFO-C) are not supported by OntoUML at its meta level, thereby these concepts are on the same level of model concepts (model level).

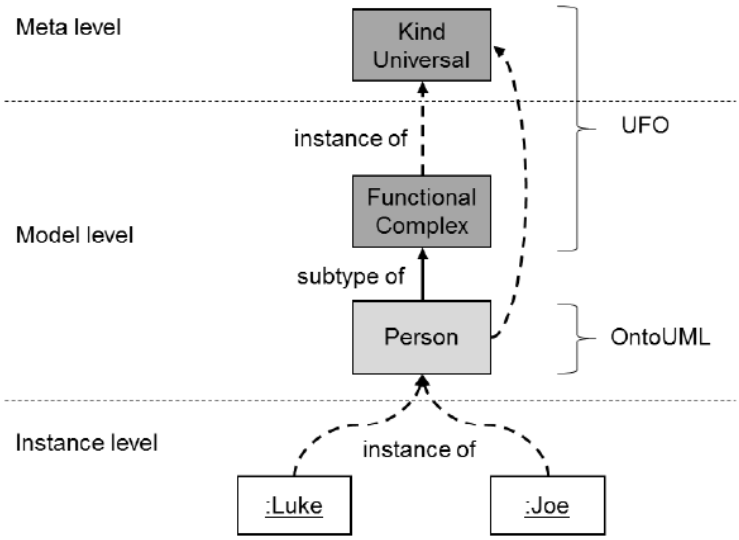

Figure 33. Instantiation of UFO-A by OntoUML models (PRINCE, 2014)**.**

The elements of OntoUML are mainly characterized by rigidity, identity principle and dependence (described earlier). The Table 1 presents a resume of the features of the OntoUML elements.

Table 1. Summary of OntoUML stereotypes.

Stereotype	Rigidity	Identity Principle (Supplier)	Dependence
Kind	Rigid	x	
Subkind	Rigid		
Category	Rigid		
Collective	Rigid	x	
Quantity	Rigid	x	
Role	Anti-Rigid		Externally
RoleMixin	Anti-Rigid		Externally
Mixin	Semi-Rigid		
Phase	Anti-Rigid		
Quality	Rigid		Existentially
Mode	Rigid		Existentially
Relator	Rigid		Existentially

A concept categorized as Kind is a rigid type, supply identity and is independent existentially. Examples of kind include “natural person”, “clock” and “car”. An instance of “natural person” possesses an identity and will not cease to be a “natural person”. Collective and Quantity also are rigid types, but with some particularities. A collective represent a collection of elements, such as a deck of cards (composed of cards) and a forest (composed of trees). Quantity, conversely, stands for elements “that are

maximal amounts of matter. It encompasses individuals with defined identity principles but undefined counting principles" (PRINCE, 2014). Examples of quantity include wine, hot lava and atmosphere.

Anti-rigid types must always have an identity supplier type (kind, collective, quantity) as supertype. Role and Phase are examples of Anti-rigid types. The former only can be defined in the context of a relator (at least its most refined subtype). Examples of Role include teacher, customer and inquirer. The latter, conversely, is existentially independent and characterized by changes on intrinsic properties of its supertype (e.g., the phases adult and elderly are characterized by the age of a person).

Relators are existentially dependent types which hold two or more mediations. This multiple dependence is result of its role as "truth-maker" of material relations. RoleMixin and Mixin are types that "aggregate" elements with heterogeneous foundational features. RoleMixin allows the specification of a role which its instances may have different identity principles. Thus, RoleMixin is defined as a supertype of role types. This pattern is illustrated on Figure 34. Mixin describes types which its subtypes has different rigidity characteristics. The Figure 35 presents application examples of RoleMixin and Mixin.

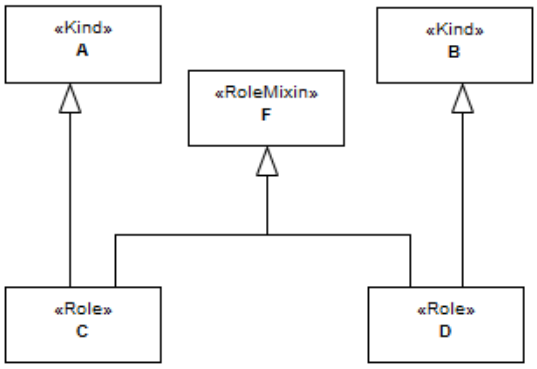

Figure 34. RoleMixin pattern.

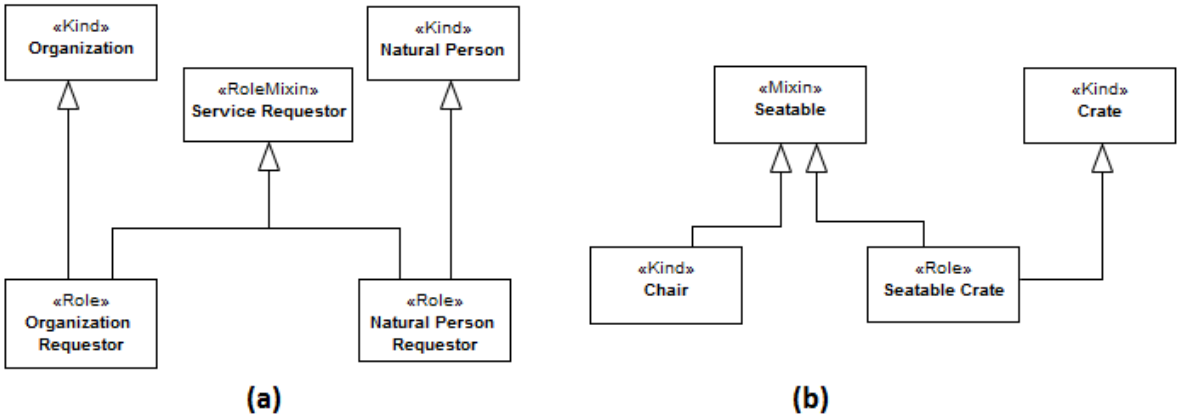

Figure 35. Example of application of RoleMixin and Mixin: (a) RoleMixin example; (b) Mixin example.

2.5.3 Qualities in OntoUML

OntoUML provides a set of constructs semantically well-defined for the development of ontologies. Despite its benefits on providing semantic ground for ontological models, OntoUML still has limitations regarding describing datatypes (among others). In this section we briefly present an extension of OntoUML for providing semantic ground to datatypes. We do not intend to discuss extensively all aspects of semantic foundation of datatypes. Instead, we only discuss the concepts relevant to this work.

In (ANTOGNONI, 2013), Antognoni discuss the semantic problem of datatypes and explores the theoretical foundations for value spaces associated to attributes in conceptual modeling languages, in particular OntoUML, giving an ontological interpretation for datatypes. The main contribution of his work is an extension for OntoUML to improve the foundations concerning value spaces. Figure 36 presents the hierarchy of quality universals.

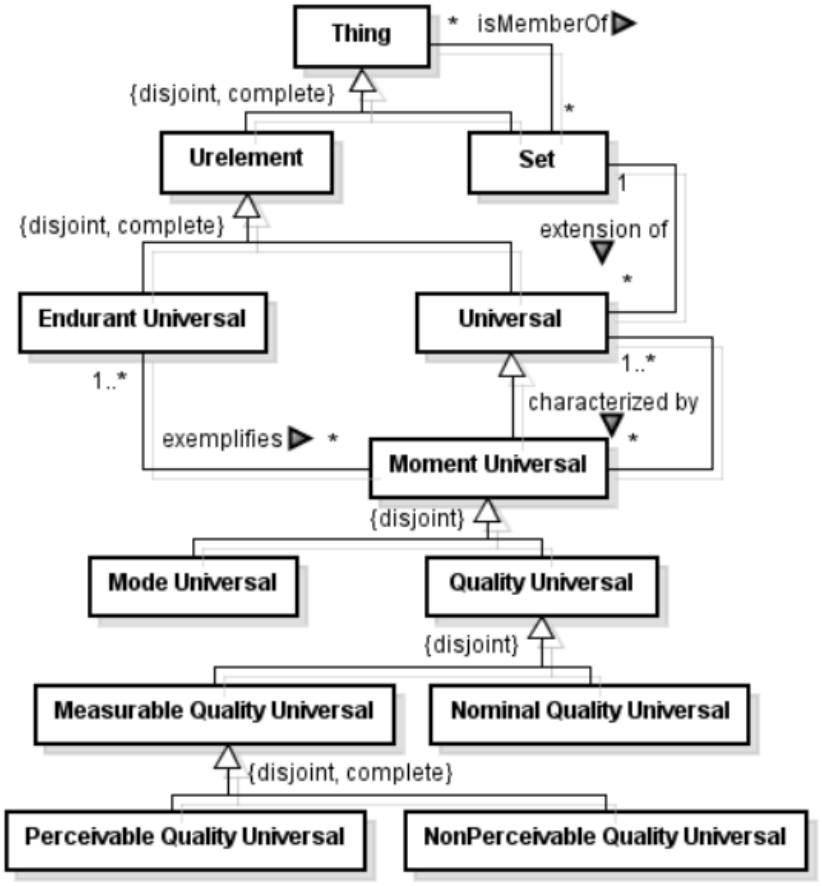

Figure 36. The hierarchy of Quality Universals (ANTOGNONI, 2013)**.**

A quality describes the nature of a particular property of a thing. For example, the color of an apple is a quality. Note that we are not referring to the value of the color (such as “red”) which is called quale (GUIZZARDI, 2005). The nature of a quality differs according to their perception by cognitive agents. The qualities which can be objectively measured i.e. associated to a value in a quality structure by cognitive agents and measurement devices are referred to as measurable qualities (ANTOGNONI, 2013). A perceivable quality originates from observation and measurement. In turn, a quality universal which its qualia originates from conception processes is called non perceivable quality (ANTOGNONI, 2013). Finally, nominal qualities are based in social conventions and describes qualities such as name, national security number and zip code. “The values of such abstract structures can be referred and denoted by lexical elements composed by alphanumeric characters following specific composition rules” (ANTOGNONI, 2013). Table 2 presents the relevant quality constructs for our thesis.

Table 2. Summarization of quality constructs (ANTOGNONI, 2013)**.**

Classes	Description
<<PerceivableQuality>>	A quality universal which its qualia originates from observation and measurement. Examples: Height, Weight, Temperature. Constraints: (1) Should always be associated to a **measurable reference structure** by structuration relation. (2) Should always be associated to a **universal** by a characterization relation.
<<NonPerceivableQuality>>	A quality universal which its qualia originates from conception processes. Examples: Currency Value. Constraints: (1) Should always be associated to a **measurable reference structure** by structuration relation. (2) Should always be associated to a **universal** by a characterization relation.
<<NominalQuality>>	A quality universal which its qualia originates from social conventions. Examples: Name, Postal Code, National Security Number. Constraints: (1) Should always be associated to a **nominal reference structure** by structuration relation. (2) Should always be associated to a **universal** by a characterization relation.

2.5.4 Intentional and Social Aspects

UFO includes a social layer that extends its core with distinctions to account for intentionality and social reality, namely UFO-C (GUIZZARDI; FALBO; GUIZZARDI, 2008). As shown in Figure 37, an important distinction in this layer is that between agentive and non-agentive objects. Agentive objects (**Agents**) can perform actions and have mental/intentional moments. Agents are differentiated in physical agents (e.g., a person) and social agents (e.g., an organization). Intentionality, here, means “the capacity of some properties of certain individuals to refer to possible situations of reality” and does not limits to the notion of “intending something” (GUIZZARDI; FALBO; GUIZZARDI, 2008). Situations are the state of the reality at some moment of time and may satisfy (in the logical sense) one or more propositions. Propositions, in turn, refer to mental/intentional moments (intentions, desires and beliefs) as it propositional content. Figure 38 presents the relationships inherent to metal/intentional moments.

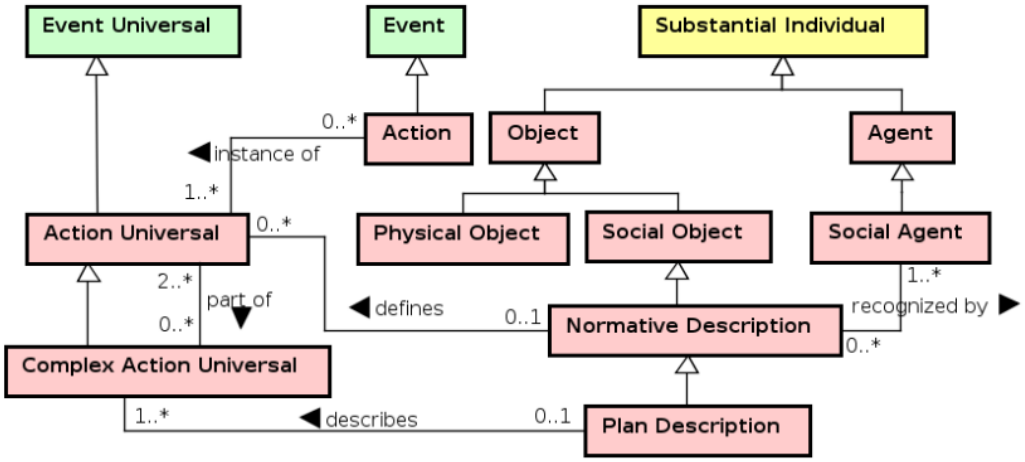

Figure 37. Agents, Objects and Normative Description (NARDI et al., 2013)**.**

Beliefs can be justified by situations in reality. Examples include the belief of somebody that Vitória is the capital of Espírito Santo, and the Belief that at some moment in the past the dinosaurs dominated the planet; Desires and Intentions can be fulfilled or frustrated. Whilst a desire expresses a will of an agent towards a state of affairs in reality (e.g., a Desire that Brazil wins the Next World Cup), intentions are desired state of affairs for which the agent commits at pursuing (internal commitment) (e.g., the Intention of graduate in the university) (GUIZZARDI; FALBO; GUIZZARDI, 2008).

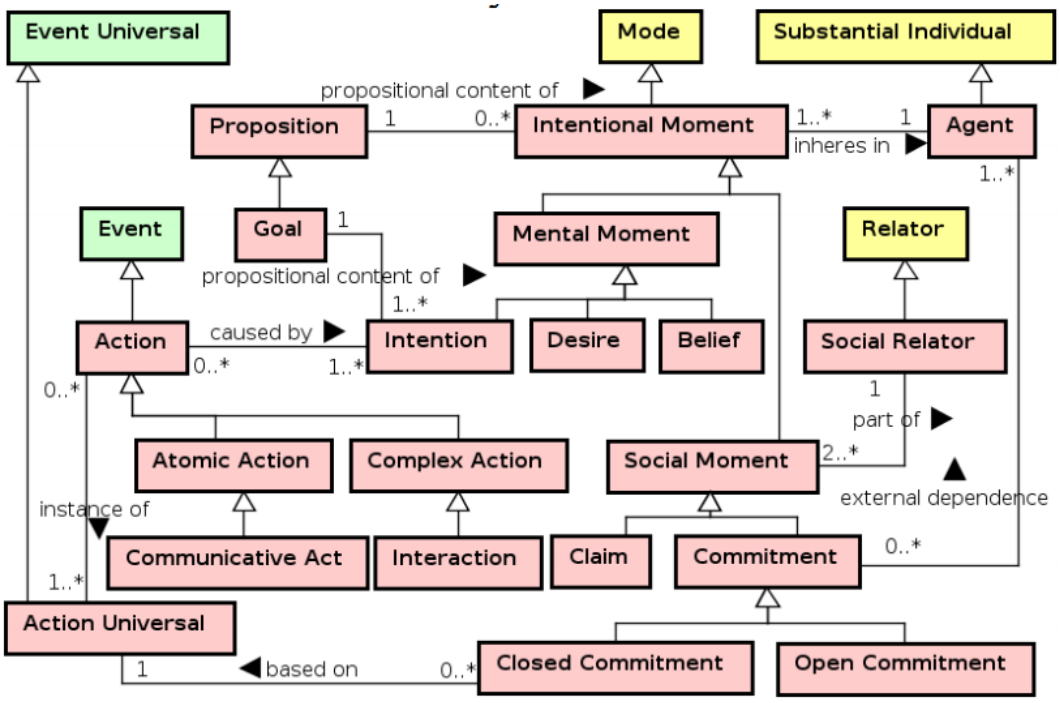

Figure 38. Action, Mental Moments and Social Moments (NARDI et al., 2013)**.**

Objects are passive entities that can be used, consumed, destructed, modified and created by agents (Figure 37). Objects are partitioned into physical objects (e.g., a computer, a pen) and social objects (e.g., a piece of legislation, a language). Actions are intentional events which has the purpose of achieve some situation in reality. Actions can be atomic (**Action**) or complex (**Complex Action**). Complex actions has two or more participations. Participations can be intentional or non-intentional events. For example, the attack of Caesar by Brutus includes the intentional participation of Brutus and the unintentional participation of the knife. In other words, not every participation of an agent is considered an action, but only intentional participation, here called action contributions (BRINGUENTE, 2011).

Normative descriptions are social objects that define rules/norms recognized by at least one agent. Normative descriptions can define nominal universals, such as social objects (e.g., the crown of the King of Spain) and social roles (e.g., IT Analyst, surgeon) (GUIZZARDI; FALBO; GUIZZARDI, 2008).

Despite internal commitments (**Intentions**), there is also social commitments. Social commitments are maintained between two agents “A” and “B”, which “A” has a social commitment with “B”. In this case, the social commitment is inherent to “A” and externally dependent of “B”. When a social commitment is created, both participants has different roles. At example of the social commitment between “A” and “B”, “A” have the role of satisfy the propositional content referred by the commitment, for this, he acts in order to fulfil its internal commitment. “B”, conversely, has the role of claim (**social claim**) to “A” the fulfilling of the intended proposition content of the social commitment.

Delegation is a special type of material relation derived by a social relator (**delegatum**). When an agent “A” (**delegator**) delegates a goal to an agent “B” (**delegatee**), “B” compromises himself (**social commitment**) with “A” (BRINGUENTE, 2011). The agent “A”, in turn, gain the right to claim the fulfilling of the goal. The pair commitment/claim composes the **delegatum** which the delegation is derived (BRINGUENTE, 2011).

Commitments and claims always form a pair that refers to the same propositional content. A social relator is an example of relator composed by two or more pairs of associated commitments/claims (BRINGUENTE, 2011).

2.5.5 Conclusion

This section showed the main ontological elements relevant to this thesis. Here, we point out the various ontological features (identity, rigidity, dependence) and introduce UFO-A, OntoUML and UFO-C. These elements provide the basis for further discussion about the reference ontology to be presented in subsequent chapters.

In this work, OntoUML plays the role of provide a well-founded modeling language for ontology specification. Our reference ontology takes advantage of its basic ontological distinctions in its formalization. In addition, UFO-C is extended for defining more specific social concepts related to the organizational domain.

3 ONTOUML ORGANIZATIONAL ONTOLOGY - O3

The industry's need for enterprise architecture description has been supported by many approaches that include ontologies and languages (as seen in Section 2.3). Despite the alternative solutions, some approaches have specific purpose and shortcomings with consequences in precision and coverage. The OntoUML Organizational Ontology (O3) is a well-founded core ontology, built with the purpose of serving as a reference ontology for organizational definition. It is intended to support the creation of domain ontologies through the specialization of its concepts and relationships, as well as to support the analysis and revision of EA languages.

In this chapter we present our reference ontology and its development approach. This chapter is structured as follows: Section 3.1 discusses the requirements of our reference ontology; Section 3.2 presents the approach applied in its development; Section 3.3 discusses in details the reference model. The discussion about O3 reference model is partitioned in many perspectives, each of them concerned with a specific aspect of the active structure domain.

3.1 REQUIREMENTS FOR AN ORGANIZATIONAL ONTOLOGY

During the process of ontology development, one of the challenges is associated to its validation. The goal of covering the selected portion of reality (scope of interest) must always be taken into account. The quality of an ontology is associated with the achievement of an acceptable degree of some characteristics. In (PRINCE, 2014), are described some key criteria that we consider relevant to this thesis, which are listed below.

- **Precision:** measures if the ontology has problems of under-constraining, i.e., if it allows instantiations that were not intended by the modeler;
- **Coverage:** measures if the ontology has problems of over-constraining, i.e., if it does not allow desired instantiations;

- **Scope:** measures if the ontology formalizes every concept, property and relationship required to explain a domain, and only them;
- **Classification:** measures if the modelers choose the appropriate categories of the foundational ontology to describe the domain entities;

Basically, the discussion about the quality of ontologies comes down to the match between the intended conceptualization and the conceptualization that is captured in the modeled ontology. The intended conceptualization reflects our goal as modelers when representing a real world domain or a portion of reality. In the ontology modeling process some problems may arise when we “translate” a conceptualization into an ontology. Some aspects we would like to represent may have been left out of the ontology. Moreover, certain unwanted aspects (non-scope concepts, unwanted possible instantiations, among others) may be present in the modeled ontology.

The coverage and scope constitute important characteristics for expressivity evaluation. When defining the scope of an ontology we limit the range of its concepts, which are related with the portion of reality being modeled. A comparison between the scope of the created ontology in opposite with the scope of the intended ontology is important to identify if all relevant concepts are covered. “As an example, consider a common sense ontology about cars. The ontology would have scope problems if it describes a car having only wheels as parts, leaving out the bumper, the windshield, the engine and so on” (PRINCE, 2014). Figure 39 illustrates the quality degrees of an ontology based on precision and coverage criteria levels. The blue and gray areas represent, respectively, the modeled ontology and the intended portion of reality to be modeled.

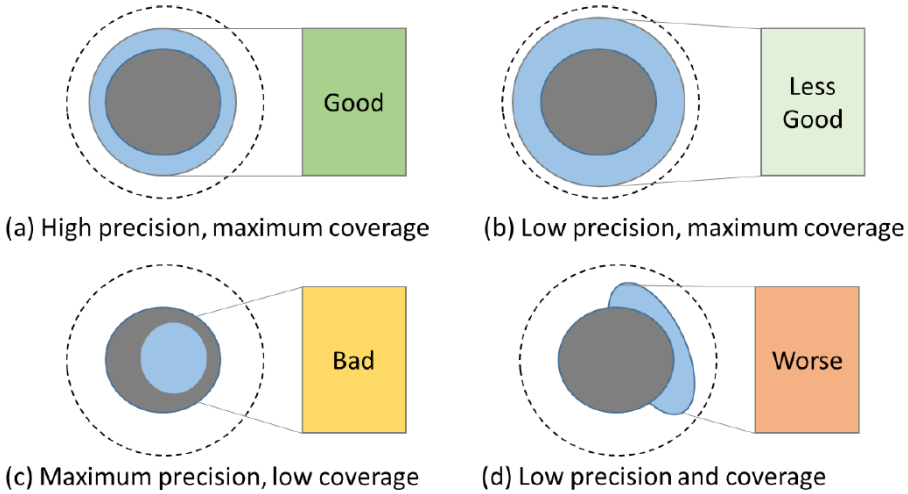

Figure 39. Intended and possible model instantiations (PRINCE, 2014).

We can observe that a good ontology (a) fits well with the portion of reality being modeled. On the other hand, the worse ontology (d) does not cover all the relevant concepts and allows for unintended instantiations. Another set of quality criterias for ontologies is presented in (FOX, 1992), which also takes into consideration the use of ontologies for reasoning.

- **Generality:** To what degree is the representation shared between diverse activities such as design and troubleshooting, or even design and marketing?
- **Competence:** How well does it support problem solving? That is, what questions can the representation answer or what tasks can it support?
- **Efficiency:** Space and inference. Does the representation support efficient reasoning, or does it require some type of transformation?
- **Perspicuity:** Is the representation easily understood by the users? Does the representation “document itself?”
- **Transformability:** Can the representation be easily transformed into another more appropriate for a particular decision problem?
- **Extensibility:** Is there a core set of ontological primitives that can be partitioned or do they overlap in denotation? Can the representation be extended to encompass new concepts?
- **Granularity:** Does the representation support reasoning at various levels of abstraction and detail?
- **Scalability:** Does the representation scale to support large applications?

Among the set of quality characteristics presented in (FOX, 1992), we consider competence and extensibility as important criteria for the purpose of this work. We can evaluate the competence of an ontology through questions that can be answered by the representation (FOX, 1992). When we define a question like “Who has administrative authority over whom?”, we are building queries that we expect to be covered by the ontology. A well-built ontology can “execute” all the specified queries. These queries are called competency questions, which can be used in competence evaluation of an ontology. Note that the competence and the scope criteria are very similar. We consider here that the different terms correspond to the same quality characteristic.

On the following sections, we formally specify our scope and define our ontology requirements through the definition of competency questions. These will support the formalization of the ontology evaluation presented in Chapter 4.

3.1.1 Basic Organizational Aspects

In this chapter, we have revised a variety of active structure perspectives, each of which covering a set of concepts aligned with specific purposes. Because of the focused vision of the various approaches, some concepts are left out of their coverage affecting their expressiveness. Our reference ontology should represent the active structure domain accurately and with greater expressiveness possible. Thus, the design decisions of each approach should be abstracted to not impact the generated ontology.

In this section, we specify some “organizational aspects” that we judge of high relevance to the active structure domain, taking as base the union of the set of approaches and also the analysis performed on the organizational representation literature. Table 3 presents all the analyzed concepts organized by approach. Note that the table only shows the concepts considered within the scope of active structure domain.

Table 3. Elements of active structure modeling approaches.

UPDM	EO	E-OPL	RM-ODP	SUPER P.
Organization ActualOrganization Post ActualPost Resource ResourceArtifact SystemResource PhysicalResource Competence ActualPerson Location PhysicalLocation Project ActualProject Function OrganizationalProjectRelationship Responsibility IsCapableOfPerforming MapsToCapability CompetenceProvider ProvidesCompetence CompetenceRequirer LocationHolder PerformerParticipant	Corporation Legal Entity Organisational Unit Role Actor Role Resource Machine Person Actor Potential Actor Partnership Employment Contract Partner Owner Purpose Management Link Stakeholder	Institutional Agent Organization Organizational Unit Human Resource Role Informal Human Resource Role Informal Organizational Role Institutional Role Position Formal Organizational Role Person Human Resource Team Employment Multi-Organization Standalone Organization Simple Organization Complex Organization Simple Organizational Unit Complex Organizational Unit Allotment	Community Party Role CommunityObject Resource Artefact Party Agent Interface Role Delegation Authorization Policy Violation Obligation Permission Prohibition Declaration Evaluation Commitment Prescription Principal	Organisation Legal Entity Non-Legal Entity Role Internal Role Internal Role Type Organisational Position Organisational Unit Permanent Organisational Unit Resource Skills Person Temporary Organisational Unit External Role

W3C OO	Archimate	ARIS	TOVE
Organization FormalOrganization OrganizationalUnit Role Post Resource Person Agent OrganizationalCollaboration Site Membership Group	Business Actor Business Role Business Collaboration Location Business Function Business Interface	Organizational Unit Organizational Unit Type Position Person Type Person External Person Internal Person Location Group	Organization Role Division Subdivision Resource Skill Organization-Agent Team Authority Communication-link

Table 4 describes the organizational aspects that specify the core of the scope of our ontology. We hope with this effort to support the ontology evaluation process. To achieve this result, we perform an analysis grouping similar concepts of different approaches (same meaning, but different label) and observing the frequency with which they occur among the set of approaches (presented in Table 5). We also keep in mind the observed concerns on organizational representation literature analysis.

Table 4. Organizational aspects.

ID	Organizational Aspect	Description
A01	Organizations	Organizations as a whole. Administratively independent organizations and also organizations formally recognized by their external environment.
A02	Organizational Working Groups	Working groups recognized only within the organization. Organizational working groups may have general (e.g., a functional department) or specific purpose (e.g., a task force) character.

A03	Organizational Members	The physical agents that are member of the organization and its working groups.
A04	Organizational Roles	The roles that organizational members play when pertaining to the organization. Organizational roles specify the expected behavior of organizational members.
A05	Authority	Specification of superior and subordinate. The superior has the power to control some behavior of the subordinate.
A06	Capabilities	Knowledge, skills, and other characteristics that a human resource has.
A07	Responsibility	A commitment between an organization member and the organization to do something in order to achieve an expected result.
A08	Resources	Objects that participate or support the activities performed in the context of the organization.
A09	External Collaborations	Collaboration between organizational members (or organizational working groups) with agents external to the organization.
A10	Internal Collaborations	Collaboration between organizational members with the purpose of performing some joint actions in the context of the organization.
A11	Geographical Location	Geographical location of organizational entities, including groups, members, resources, etc.
A12	Organizational Assignment	Formal acts of assignment of organizational members to organizational working groups. An assignment specifies that an organizational member belongs to a working group and perform tasks pertinent to it.

The specified organizational aspects aggregate similar concepts as well as define themes related with active and passive organizational structure. We understand that passive structure is out of the primary scope of our work, however similar ontology approaches cover this aspect. Thus, we choose to consider it for the purpose of

evaluation. Table 5 presents the mapping of the organizational aspects with the concepts of the analyzed set of approaches.

Table 5. Organizational aspects analysis.

Asp.	UPDM	EO	E-OPL	RM-ODP	SUPER P.	W3C OO	Archimate	ARIS	TOVE
A01	Organization ActualOrganization	Legal Entity Corporation	Organization Institutional Agent Multi-Organization Standalone Organization Simple Organization Complex Organization	Party Community	Legal Entity Organisation	FormalOrganization Organization	Business Actor		Organization
A02	Project ActualProject	Organisational Unit	Organizational Unit Team Simple Organizational Unit Complex Organizational Unit		Non-Legal Entity Permanent Organisational Unit Temporary Organisational Unit	Organizational Unit	Business Actor	Organizational Unit Organizational Unit Type Group	Division Subdivision Team
A03	ActualPerson	Person Actor Potential Actor	Person Human Resource		Person	Person Agent	Business Actor	Person External Person Internal Person	Organization-Agent
A04	Post ActualPost	Role Actor Role Partner	Human Resource Role Informal Human Resource Role Informal Organizational Role Institutional Role Position Formal Organizational Role	Role Interface Role	Role Internal Role Internal Role Type Organisational Position External Role	Role Post	Business Role	Position Person Type	Role
A05	Competence IsCapableOfPerforming MapsToCapability CompetenceProvider ProvidesCompetence CompetenceRequirer	Management Link		Delegation					Authority
A06					Skill				Skill
A07	Responsibility	Purpose		Delegation					
A08	Resource ResourceArtifact SystemResource PhysicalResource	Resource Machine			Resource	Resource			Resource
A09		Partnership				Organizational Collaboration	Business Collaboration		
A10									Communication-link
A11	Location PhysicalLocation					Site	Location	Location	
A12	OrganizationalProjectRelationship	Employment Contract	Employment Allotment			Membership			

3.1.2 Competency Questions

For the purpose of driving our effort, we defined a set of competency questions starting from the basic requirements identified in the organizational representation literature and the analysis of enterprise architecture approaches. The specified competency questions directed the construction of the ontology as well as the definition of the boundaries of its scope. These questions will be revisited and answered in the evaluation section (Chapter 4).

- CQ01. How is the organization structured?
- CQ02. Which roles a specific employee can assume?
- CQ03. Which functions a specific employee must perform?
- CQ04. Which competences are necessary to perform a function?
- CQ05. Which resources are allocated in the organization?
- CQ06. Who are the members of the organization?
- CQ07. To which organizational group is a particular employee assigned?
- CQ08. What is the location of an organization?
- CQ09. What is the location of a particular employee?
- CQ10. Over which employees does a particular employee have authority?
- CQ11. With which employees does a particular employee have communication interface?
- CQ12. What are the organizations with which an organization interacts?
- CQ13. Which people interact with the organization?
- CQ14. To which resources does a particular employee have access?
- CQ15. Does an organization own a particular resource?
- CQ16. Who does manage the organization?
- CQ17. Who does manage a particular organizational unit?
- CQ18. What are the roles associated with a particular working group?

Table 6 shows the relationship between the organizational aspects and the competency questions.

Table 6. Organizational aspects x competency questions.

ID	Organizational Aspect	Related Competency Questions
A01	Organizations	CQ01
A02	Organizational Working Groups	CQ01
A03	Organizational Members	CQ06, CQ07
A04	Organizational Roles	CQ02, CQ03, CQ18
A05	Authority	CQ10
A06	Capabilities	CQ04
A07	Responsibility	CQ03
A08	Resources	CQ05, CQ14, CQ15
A09	External Collaborations	CQ12, CQ13
A10	Internal Collaborations	CQ11
A11	Geographical Location	CQ08, CQ09
A12	Organizational Assignment	CQ07

Despite the lack of a method for **extensibility** evaluation, we present a proof-of-concept to demonstrate the **extensibility** of our ontology. The coverage, precision and classification criteria are evaluated through the application of anti-patterns analysis defined in (PRINCE, 2014).

3.2 APPROACH

Many methodologies have been proposed to address ontology development, such as Methontology (FERNANDEZ LOPEZ; GOMEZ PEREZ; JURISTO, 1997), NeOn (DEL CARMEN SUAREZ FIGUEROA; GOMEZ PEREZ; FERNANDEZ LOPEZ, 2012), Uschold and King's (USCHOLD; KING, 1995), Grüninger and Fox's (GRUNINGER; FOX, 1995) and Bernaras' (TH, 1996) methodologies. Existing methodologies differ in degree of detail, coverage of development steps, and strategy for building applications, among others (FERNÁNDEZ LÓPEZ; GÓMEZ PÉREZ, 2002). In order to guide the development of O3, we specify a variant of the Grüninger and Fox and Uschold and King methodologies. The approach adopted in this work focuses on development of an ontology as a conceptual model and not its use as a computational artifact. We chose to adapt existing approaches such that the resulting approach is suitable for the specific purpose of our work; we do not intend to propose a new general approach. Figure 40 presents an overview of O3's development process.

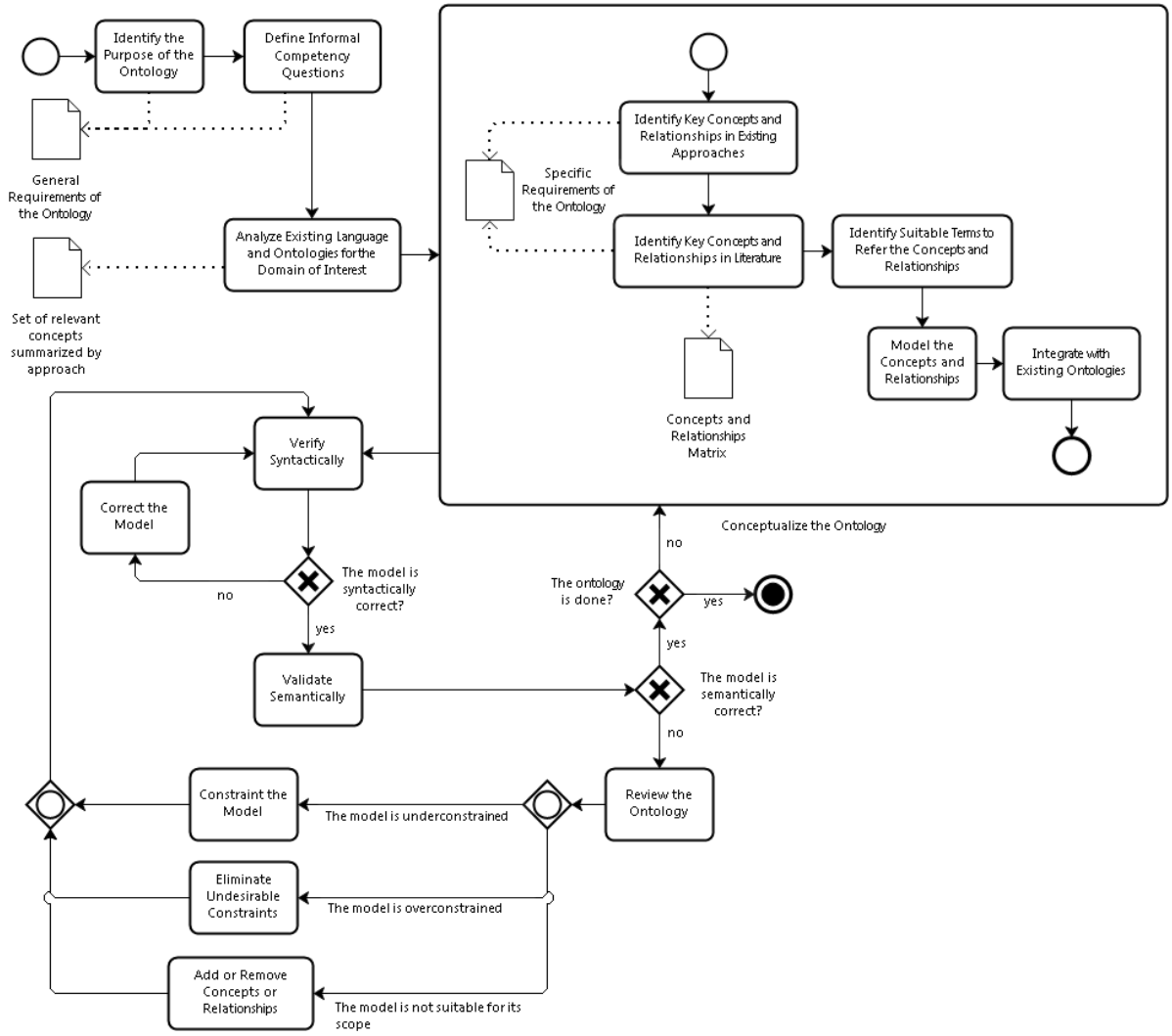

Figure 40. Adopted ontology engineering method.

The approach used to develop O3 conforms to following steps:

1. **Identify the purpose of the ontology.** It is important to be clear why the ontology is being built and what its intended uses are (FERNÁNDEZ LÓPEZ; GÓMEZ PÉREZ, 2002). Here, it is necessary to clarify the general scope of the ontology and its intended application. An output of this task is the draft of the “general requirements of the ontology”, which includes the description of the phenomena being modeled, the non-scope and the goal of the ontology (including its intended uses).
2. **Define Informal Competency Questions.** Given the motivating scenario, a set of queries will arise which place demands on an underlying ontology. We can consider these queries to be requirements that are in the form of

questions that an ontology must be able to answer. These are the informal competency questions, since they are not yet expressed in the formal language of the ontology (GRUNINGER; FOX, 1995).

3. **Analyze existing languages and ontologies for the domain of interest.** Generally, a lot of knowledge is already described in ontologies and modeling languages. These sources can provide a rich set of candidate concepts and relationships for the ontology being built. An output of this step is a “set of relevant concepts summarized by approach”, which provides a good basis for ontology specification. The summarization by approach is useful for evaluation purposes (comparison of coverage, for example).

The task of conceptualize the ontology is a sub process that comprises the following steps. The ontology development occurs in an iterative way, i.e., the development is partitioned and each partition represents an increment to the results of the earlier phases:

4. **Identify key concepts and relationships in existing approaches.** With the set of relevant concepts and relationships in hand, the modeler must select the relevant elements to the portion being modeled. The selected subset should be studied in the light of the various settings (for each approach). As a result of this study, the modeler must understand the real semantic of the element and identify possible construct overloads (and term overloads). An output of this step is the “specific requirements of the ontology”, which contains a refinement of the informal competency questions specified earlier.
5. **Identify key concepts and relationships in literature.** In order to restrict the ontology for existing approaches coverage and provide a formal basis for analysis, the literature study is needed. The study must focus on formalization of the selected set of elements and on the identification of related concepts and relationships. The “specific requirements of the ontology” should be updated. An output of this step is the “concepts and relationships matrix”, whose lines contain the approaches and whose columns describe the concepts and relationships covered. The concepts and

relationships discovered in this step must be represented in the matrix, even if not supported by the existing approaches.

6. **Identify suitable terms to refer the concepts and relationships.** One of the challenges of building ontologies is to choosing the terms to refer to the concepts and relationships. The terms should not aggregate too much meaning to not intent the users of the ontology to a misinterpretation. In contrast, the term should be familiar to increase the share of meaning, its adoption and to establish a common vocabulary. The columns of the “concepts and relationships matrix” must specify the chosen terms.
7. **Model the concepts and relationships.** Since we have an understanding of the domain, we must represent our conceptualization on a formal language. One of the dangers of this task is related to the modeler's ability to accurately represent the real-world phenomenon. Despite the flow described in our process, this task requires a revisiting of the literature and existing approaches. In addition, the modeler must keep the specific requirements in mind not to extrapolate the scope, which would lead to modelling unnecessary phenomena.
8. **Integrate with existing ontologies.** Existing ontologies can make the task of building an ontology even easier. Reuse can speed up development, and increase their semantics. As an example, foundational ontologies can be extended to create core ontologies or domain ontologies.

The subsequent steps treat for verification and validation of the ontology being built:

9. **Verify syntactically.** In order to represent our ontology, it is necessary to adopt a modeling language. Syntactic check consists in the activity of checking if a specific ontology is following all the syntactic constraints of the adopted modeling language.
10. **Correct the model.** If the modeler finds syntax mistakes in the previous task, it is necessary to perform corrections, adjusting the model to follow the language rules.
11. **Validate semantically.** While the syntax verification concerns whether the modeling language is correctly used, semantic validation concerns whether the model is a faithful representation of reality. Here, the modeler must

perform a careful analysis of the model semantics. The model semantics must be balanced against the intended semantics, so the modeler should have deep knowledge of the modeled domain (documentation or consult experts can assist in this process). To support this task, a number of anti-patterns are described in (PRINCE, 2014). These patterns help the modeler to identify potential semantic issues.

12. **Review the ontology.** If the modeler finds semantic mistakes in the previous task, it is necessary to perform corrections. First of all, the modeler needs to develop an understanding about the identified problem. For this, one must understand the existing semantic gap between the model semantics and the intended semantics and correctly classify the problem. The model might be underconstrained or overconstrained. Further, the model may not represent some relevant aspect or it may exceed the model intended scope.
13. **Constrain the model.** If the model is underconstrained, the modeler must add constraints to ensure the models rules out unintended interpretations. In this work we indicate model constraints in natural language.
14. **Eliminate undesirable constraints.** If the model is overconstrained, the modeler must adjust the set of constraints of the model to allow for the intended interpretations. For this, OCL constraints might be eliminated or edited. In addition, the modeler might perform adjustments in the model arrangement itself (tapping the potential of the modeling language).
15. **Add or remove concepts or relationships.** In some cases, the scope is exceeded or the model does not describe some relevant aspects of reality. When the latter occurs, the modeler must identify the relevant concepts lacking in the model and add the new set of concepts in the model. When the former occurs, the modeler must select the concepts that exceed the ontology scope in order to eliminate them.

When adjustments are necessary, a new cycle of analysis is necessary to guarantee that the model remains syntactically and semantically correct. The earlier steps (3 - 14) are repeated until the ontology is considered stable and has acceptable quality.

3.3 THE REFERENCE MODEL

O3 has been defined by extending the social concepts of UFO-C (highlighted in green and orange in O3's diagrams), such as social role, social agent and physical agent. In this section we present the concepts of O3 described contextually in partial models. We discuss the ontology following the viewpoints defined in O3, namely: (i) organizational structure, (ii) allocation, (iii) organizational roles, (iv) social relationships, (v) capability, (vi) resource and (vii) business collaboration. Figure 41 presents an overview about how O3 is organized. Figure 42 details O3's structure and its dependencies.

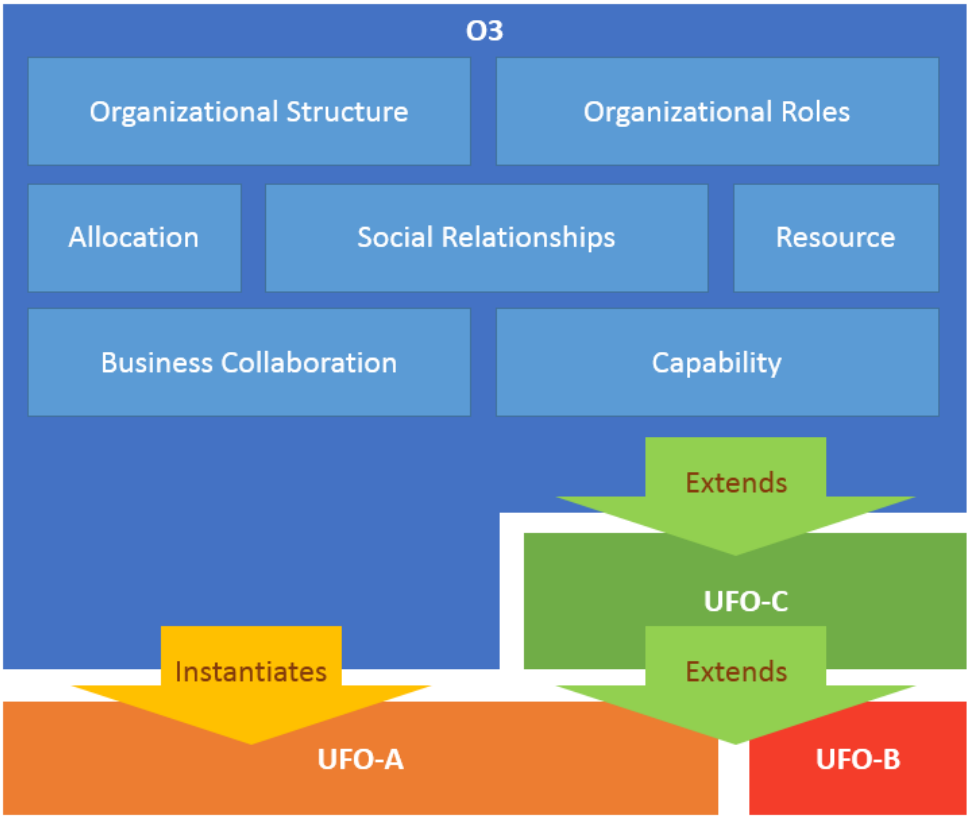

Figure 41. O3 overview.

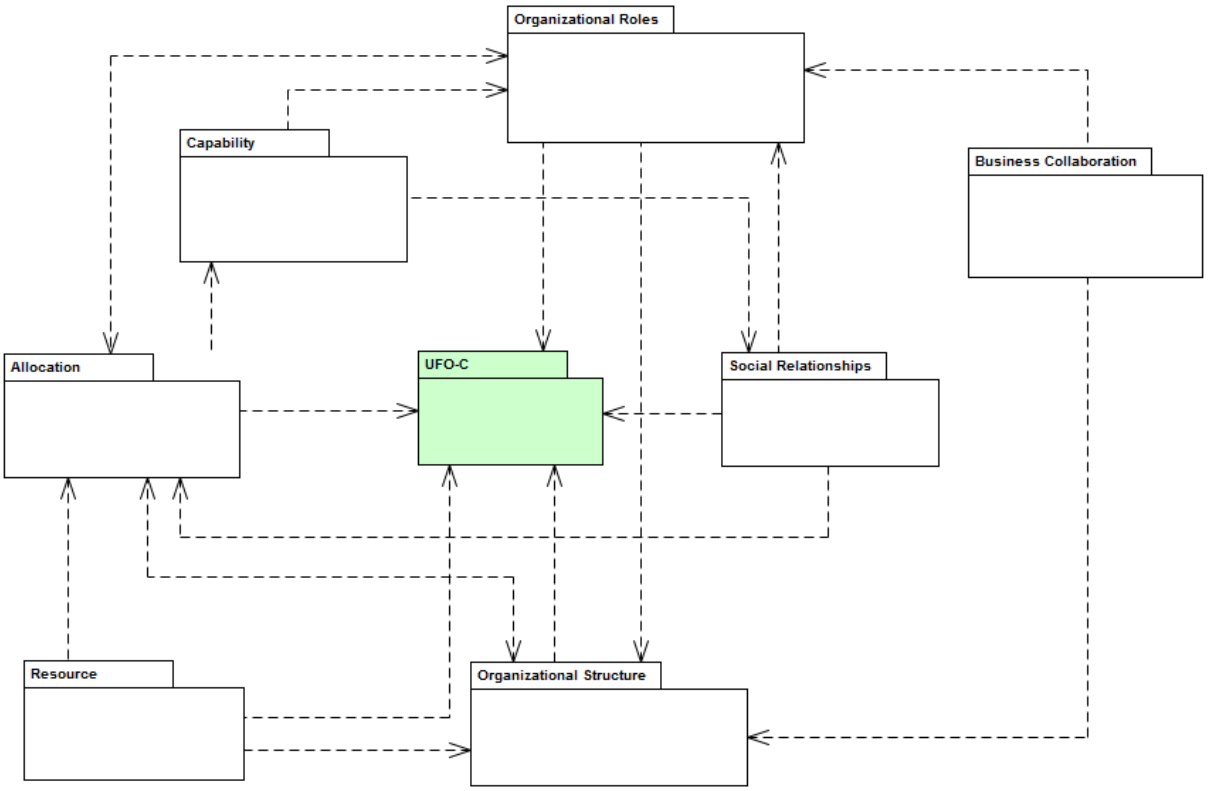

Figure 42. O3's general structure and dependencies.

Each view presents a coherent set of ontology elements which conform to a specific aspect of interest. The modularization adopted is based on the organizational aspects (previously defined in Section 3.1.1). The definition of each viewpoint was held by aggregating similar or complementary organizational aspects. Table 7 provides a mapping between the established viewpoints and organizational aspects addressed by it.

Table 7. Organizational aspects covered by viewpoint.

Viewpoint	Organizational Aspect
Organizational Structure	Organizations Organizational Working Groups Authority Geographical Location
Organizational Roles	Organizational Roles External Collaborations Internal Collaborations
Allocation	Organizational Roles Organizational Members

	Organizational Assignment Geographical Location
Social Relationships	Authority Responsibility
Business Collaboration	External Collaborations Internal Collaborations
Capability	Capabilities
Resource	Resources

The following sections describe in detail each viewpoint of the reference ontology.

3.3.1 Organizational Structure View

The organizational structure view describes the structure of organizations, more precisely how organizations are structured in other organizations and working groups. It concerns the definition of social agents that together composes the abstract concept of organization. Figure 43 presents an overview of the decomposition of an organization in specific social agents.

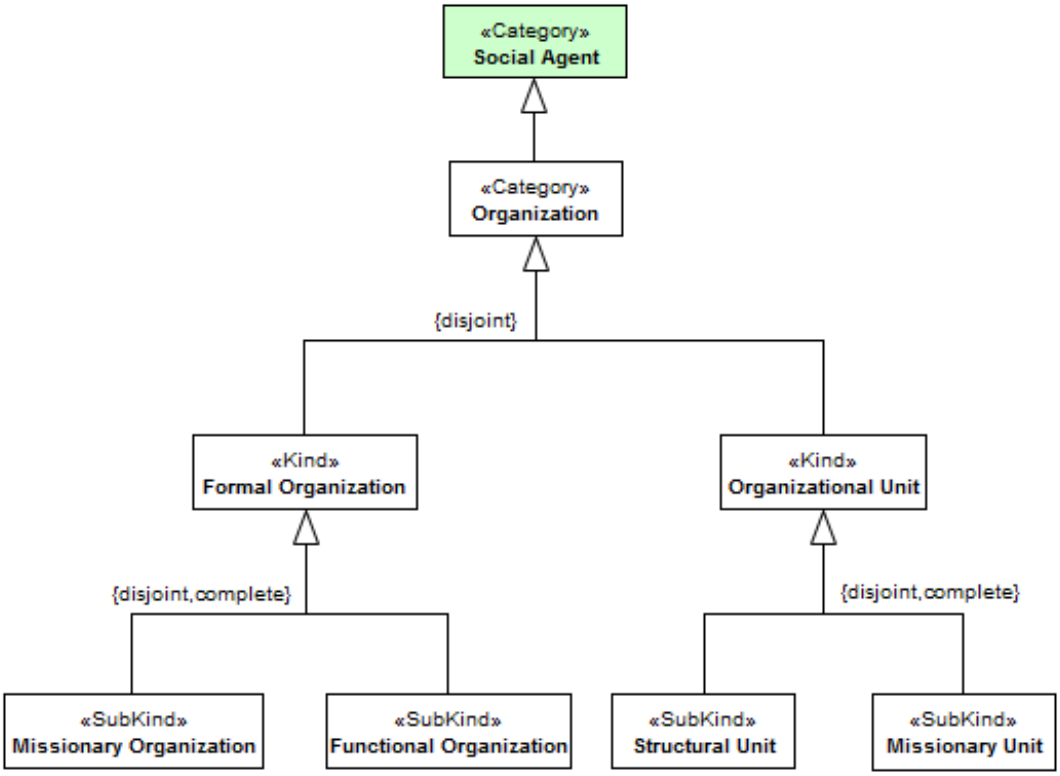

Figure 43. Basic organizational structure arrangement.

The top-most concept is Organization, specializing the UFO notion of Social Agent. As defined in (FOX, 1992), organizations are (artificial) social units built with the explicit intention of pursuing goals. Organizations include corporations, armies, hospitals and churches, but exclude tribes, ethnic groups, families and groups of friends. Organizations are characterized by division of labor, presence of one or more power centers that control the combined efforts of the organization and coordinate activities to achieve goals. Members of an organization can be replaced or relocated to other functions without the organization ceasing to exist. An organization may be structured into other social agents that together contribute to the operation or behavior of the whole, defining thus what is called a functional complex in (RADNER, 1990). See (WEBER; ROTH; WITTICH, 1968) for a discussion on the whole-part relation of UFO applied at the organizational context.

We refine organizations into formal organizations and organizational units. Formal organizations are formally recognized by the external environment. Their creation is determined by normative descriptions or speech acts which are recognized by the normative context in which formal organizations exist. Work groups and human agents

playing the roles that define the behavior of the organization (called here employee types, described in organizational role structure) constitute the formal organization. Examples of formal organization include Microsoft Inc., the UK Government and the Federal University of Espírito Santo. Figure 44 presents the detailed description of formal organizations.

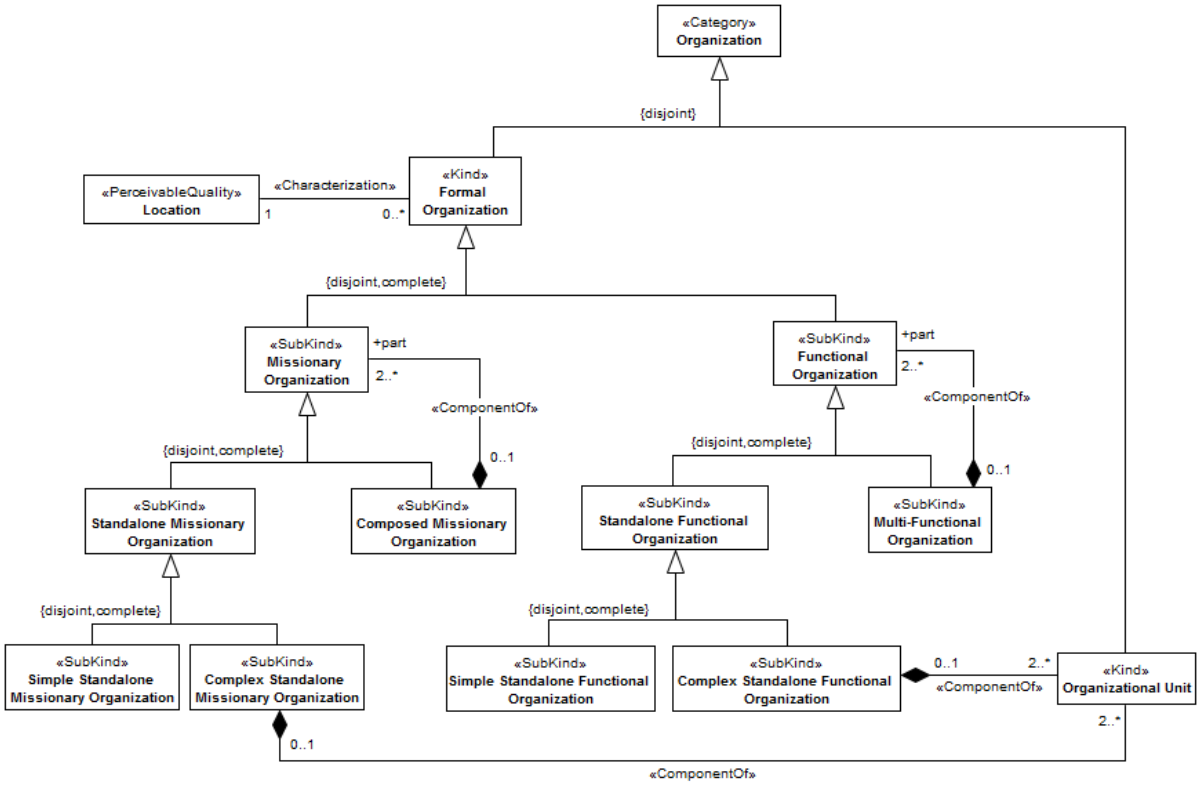

Figure 44. O3 fragment - Formal organizations.

Formal organizations that have as their main purpose the provision of services or products (functional purpose) are called functional organizations. On the other hand, organizations that have a temporary, deliberative or that are designed to perform a specific task without the figure of a customer order are namely missionary organizations. Examples of missionary organizations include United Nations (UN), World Trade Organization (WTO) and W3C consortium.

Activities in its highest abstraction level are treated by formal organizations, which by division of labor principle decompose the activities to their parts. Formal organizations can be decomposed in other formal organizations, configuration very common in multinational companies. Missionary organizations that are composed by others missionary organizations are called complex missionary organization, in contrast

simple missionary organizations do not have subparts. Similarly, composed functional organizations are namely multi-functional organizations and describe a unified abstract representation of organizations with many formal branches. We have to be very careful in defining multi-functional organizations. This kind of organization is concrete in the meaning of recognition by its external environment and identity, but in practice represents the union of its representations (branches). On the other hand standalone functional organizations are not decomposed in others functional organizations. Finally, standalone functional organizations can be structured internally in organizational units. Standalone functional organizations decomposed in organizational units are denominated complex standalone functional organizations, while those that are not are called simple standalone functional organizations.

Despite the fact of some organizations are known and operate only in the virtual field, all formal organizations are located in some location as a requirement of recognition by their external environment. Figure 45 illustrates upper leadership in organizations.

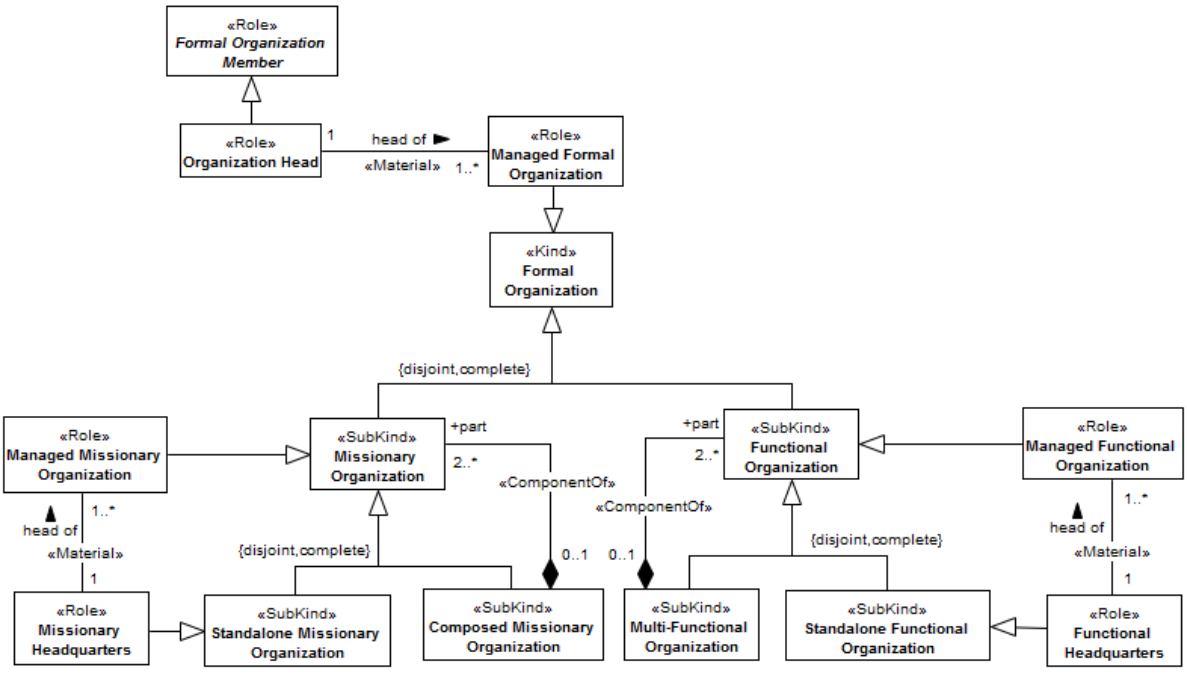

Figure 45. O3 fragment - Organization leadership.

Generally organizations are structured in hierarchical way with more or less levels. In the organizational domain, the top of the hierarchy is the head of the organization. In O3, the head of a formal organization is defined through the “head of” relationship. The

head is a member of the organization, namely formal organization member (described in detail in allocation view). In the same way, organizations may be led by their headquarters. In this case, a social agent plays the role of being headquarter (missionary headquarters and functional headquarters). Figure 46 defines in detail organizational units.

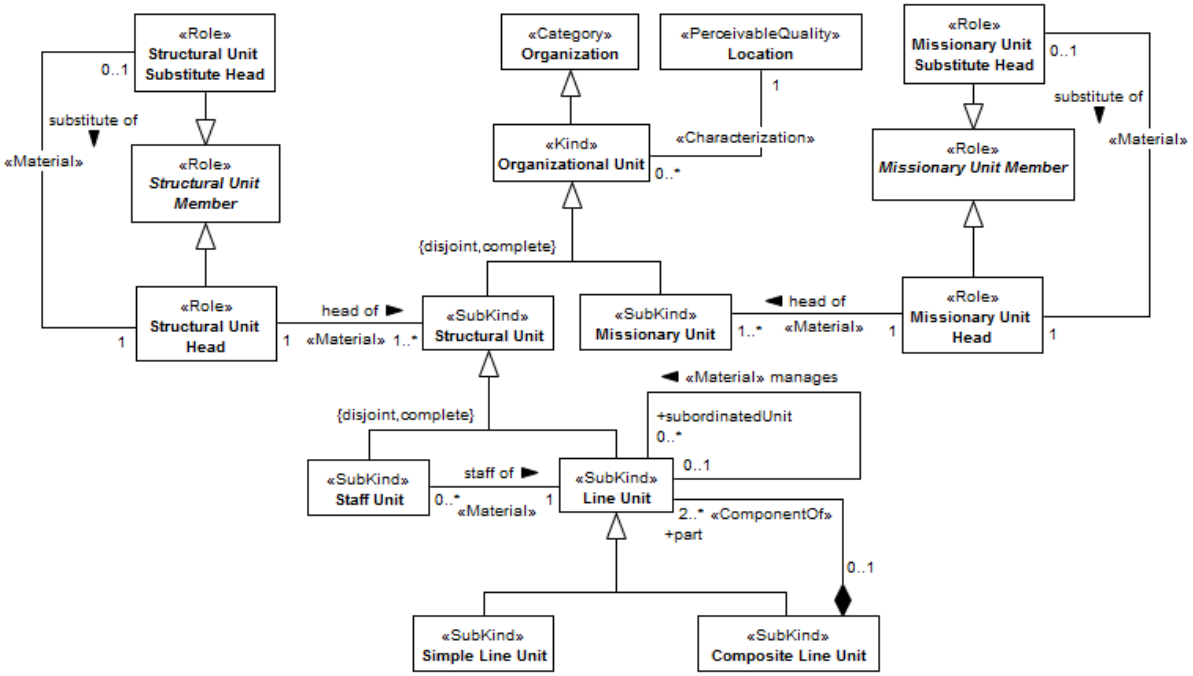

Figure 46. O3 fragment - Organizational unit.

Organizational units are those organizations that are only recognized in the internal context of a formal organization and represent the working groups of a formal organization. An organizational unit can be a structural unit or a missionary unit. Structural units are closely related to the functional structure of the organization. A missionary unit is related to the matrix structure of a formal organization and concerns to solve recurring or/and temporary problems. A feature of this type of work group is the aggregation of actors belonging to different line units, besides being able to have a limited lifetime. Examples of missionary unit include an ERP Project Team, an Audit Committee and a Financial Task Force.

Structural units include line units and staff units. A line unit has authority relationships with other line units (upper or lower). Such relationships result in a hierarchy of authority. Furthermore, it may be composed of other line units, resulting in a

relationship of authority (represented by the relationship “manages”) between parts. The justification for the structuring of line units through two distinct relationships (whole-part and authority) lies in the fact that the whole-part relationship (in the organizational domain) naturally implies power, but power does not imply a whole-part relation. Examples of line unit include a Marketing Department, a Board of Directors and a Sales Division. As seen in Section 2.2.3, a staff unit is a “counselor” unit, which has no administrative authority, thus it is not part of the line hierarchy composed by line units. Although they have no line authority, staff units relate to line units through the relation “staff of”, which determines the line unit to which a staff unit responds. Examples of staff unit: a Group of Financial Advisors and an Internal Audit Group.

Similarly to what happens on the upper level, organizational units are also headed. In this case, only members of an organizational unit may take a command post, named "Structural Unit Head" and "Missionary Unit Head" respectively for "Structural Units" and "Missionary Units". In organizations, it is common to define substitute leader. This stems from the fact that organizations are impersonal and beyond the composition of its members. Thus, the absence of a member cannot affect the operation of the organization. Substitute takes charge of an organizational unit in the absence of the titular leader.

Table 8 presents the constraints that must be observed when analyzing or instantiating the concepts of the Organizational Structure View.

Table 8. Organizational structure view constraints.

ID	Description
AXI01	An instance of "Multi-Functional Organization" cannot establish a relationship of composition with itself.
AXI02	An instance of "Composed Missionary Organization" cannot establish a relationship of composition with itself.
AXI03	An instance of "Composite Line Unit" cannot establish a relationship of composition with itself.
AXI04	If an instance "A" of Line Unit is composed of another instance "B" of Line Unit then "A" manages "B".
AXI05	A "manages" relationship cannot be maintained between two units (Line Unit) at different levels of composition.

AXI06	An instance of "Line Unit" cannot establish a relationship "Manages" with itself.
AXI07	An employee (Formal Organization Member) may only be head of a “Structural Unit” to which he/she belongs. In addition, the “Structural Unit” must be part of the organization to which it belongs.
AXI08	An employee (Formal Organization Member) may only be head of a “Missionary Unit” to which he/she belongs. In addition, the “Missionary Unit” must be part of the organization to which it belongs.
AXI09	An employee (Formal Organization Member) may only be head (Organization Head) of an organization (Formal Organization) to which he/she maintain an “Admission”.

3.3.2 Organizational Roles View

The organizational role view describes the roles that specify the expected behavior of the organizational members. As a consequence of the independent nature of organizations, the individuals (natural persons) that compose an organization can change over time. The defined set of roles has the purpose of keeping the organization on course of their goals while maintaining the uniformity of the expected behavior of its members. These roles are called social roles and are defined by normative descriptions. The establishment of social roles by a recognized authority is fundamental, once only the recognition of its act assigns validity to the characteristics inherent to the role. Figure 47 presents the social role hierarchy.

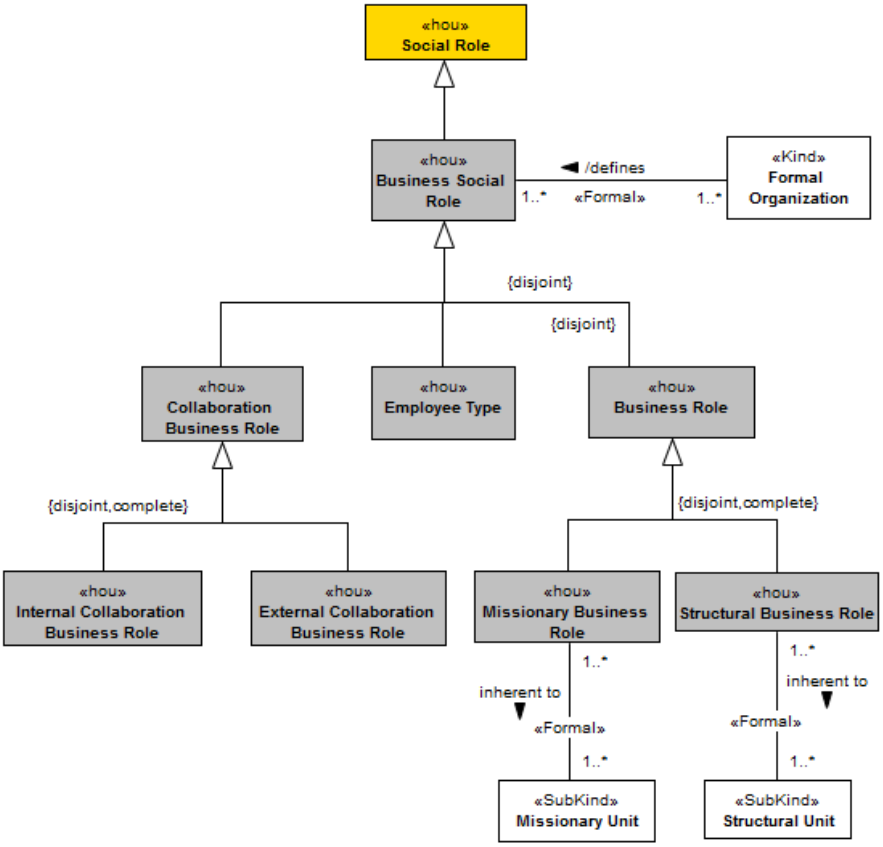

Figure 47. O3 fragment - Business Social Role taxonomy.

The main concept, business social role, describes a role defined and valid on the scope of an organization. It is refined in business role, employee type and collaboration business role. The complete specialization hierarchy of business social roles encompasses the roles presented in Figure 47. Here, we will not go into more detail about the taxonomy of business roles, as these concepts will be defined in later sections.

In an organizational structure description, it is important to define the relationship between the behaviors of the individuals with the collective behavior. In this context, we can describe the behavior of an organizational units by the specification of a set of business roles (through the “inherent to” relationship). For example, it’s very natural to say that the Sales Department is associated with the Salesman and the Sales Manager roles. This association does not bind the people with an organizational unit, but specify the behavior that the members of it have to assume. Figure 48 presents the recognition chain between organizations and their members, normative descriptions and social roles. The fragment presented in Figure 48 comprises an upper vision about

“recognition” relationships, which are extended to create specific relationships to the active structure domain.

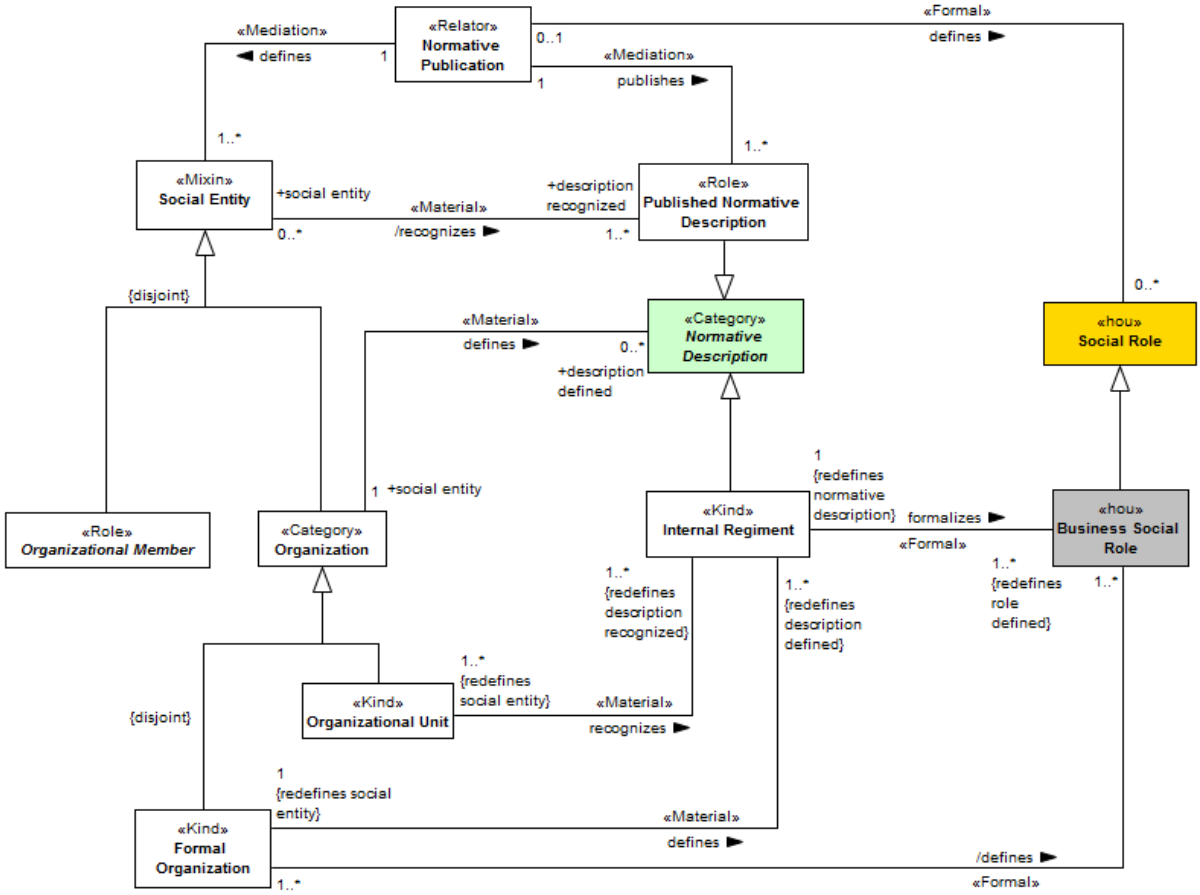

Figure 48. O3 fragment - Normative Description.

In organizational scope, we have a special type of social role, namely business social roles, which are formalized by internal regiments. An internal regiment is a specific type of normative description and has its scope limited to the organization. Formal organizations define internal regiments to describe formally their roles, which are recognized by their organizational units and members.

In an upper view of the “recognition” subject, we have normative descriptions as a central part. A normative description, as defined in (GUIZZARDI; FALBO; GUIZZARDI, 2008), defines one or more rules/norms recognized by at least one social agent. We extend here the notion of recognition defining social entity. The essence of organizations is social, but, as a social agent, an organization is composed by natural persons. Within the organization, a natural person assumes a social role against the

whole, becoming a social entity. The difference between organizations and organizational members as social entities lies in the fact that an organization always will be a social entity, while an organizational member may cease their role in the organization. At this level of analysis, normative descriptions may be defined by organizations. In a lower view, the “defines” relationship between formal organization and internal regiment is “redefined”. At this configuration only formal organization are entities with the right of defining normative descriptions. Figure 49 extends the concept of recognition illustrating the discussion about recognition contracts.

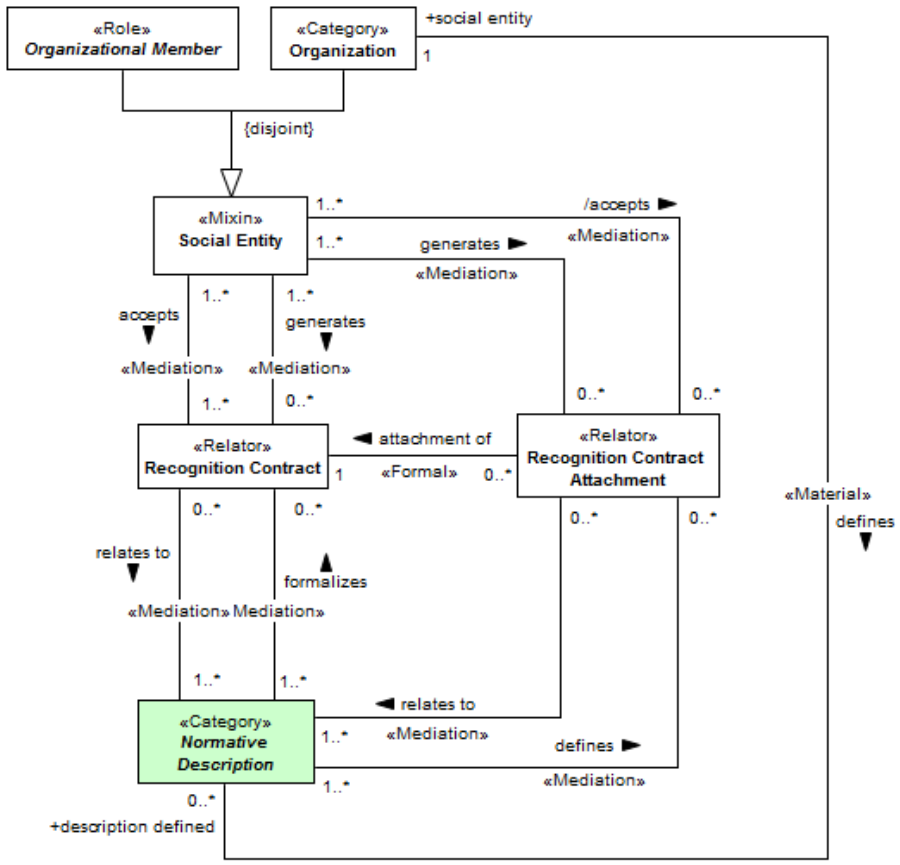

Figure 49. O3 fragment - Recognition contract.

Like living organisms, organizations adapt to changes in their external environment. Organizational evolution generally comes with changes in organizational structure (departments and roles). The maintenance of the formal environment is coupled with continuity of the formal recognition by the individual and collective agents against the organizational definitions. Here, we call definition every role defined, every organizational unit create. With this in mind, a recognition contract describes a formal

agreement between social entities. On one side, a social entity creates (generates) the recognition contract and its attachments (maybe at a later time). On the other side, the recognition contract and attachments are accepted and consequently the normative descriptions associated with the contract also are recognized.

Normative descriptions can be related with many recognition contract (and its attachments). In contrast, a specific recognition contract may be related with one or more normative descriptions.

To visualize this recognition arrangement, take the following example. A software development company decided to terminate the “mathematical models department”. For this, the organization has created new positions to meet the functional need and relocated former members of the “mathematical models department” to other departments. For such changes to be valid, it is necessary that all members of the organization recognize its legitimacy. We can observe this scenario as an update of an existing recognition contract. In this case, a recognition contract attachment is associated with the normative description that formalizes the creation of the new position. The “accepts” relationship between the social entity and the recognition contract attachment is derived by the specification of the relationship of “attachment of” between the recognition contract attachment and the recognition contract. Note that we not intent to enter in legal matter about additional agreements on updating an existing agreement. Our purpose here is to describe the continuous formal characteristic of organizational acts.

Table 9 presents the constraints that must be observed on analyzing or instantiating of the concepts of the Organizational Role View.

Table 9. Organization roles view constraints.

ID	Description
AXI10	A “Social Entity” that defines a “Normative Description” should compulsorily recognize it.
AXI11	If an “Organization” recognizes a “Normative Description”, automatically its members should also recognize it.
AXI12	A “Structural Business Role” inherent to a “Structural Unit” will result in a definition relationship between the organization as a whole and the business role.

AXI13	A “Missionary Business Role” inherent to a “Missionary Unit” will result in a definition relationship between the organization as a whole and the business role.
AXI14	If a social entity accepts (recognizes) a Recognition Contract then this entity must also recognize the Normative Descriptions associated with this contract.

3.3.3 Allocation View

The allocation view describes the establishment of the relation between the members of the organization and the organization itself, including its sub-organizations. Figure 50 presents the most basic arrangement for the definition of a member of the organization. Here, we are only concerned with human agents, and thus the physical agents we refer to are human beings, i.e., natural persons. The association of natural persons to an organization is an essential part of the definition of organizations, being defined by an organizational membership. By becoming an organizational member, a natural person is inserted among a group of agents that comprise the organization. An organizational member is the most generic denomination of a member of the organization is refined in more specific types of members, according to the allocation type (admission or assignment).

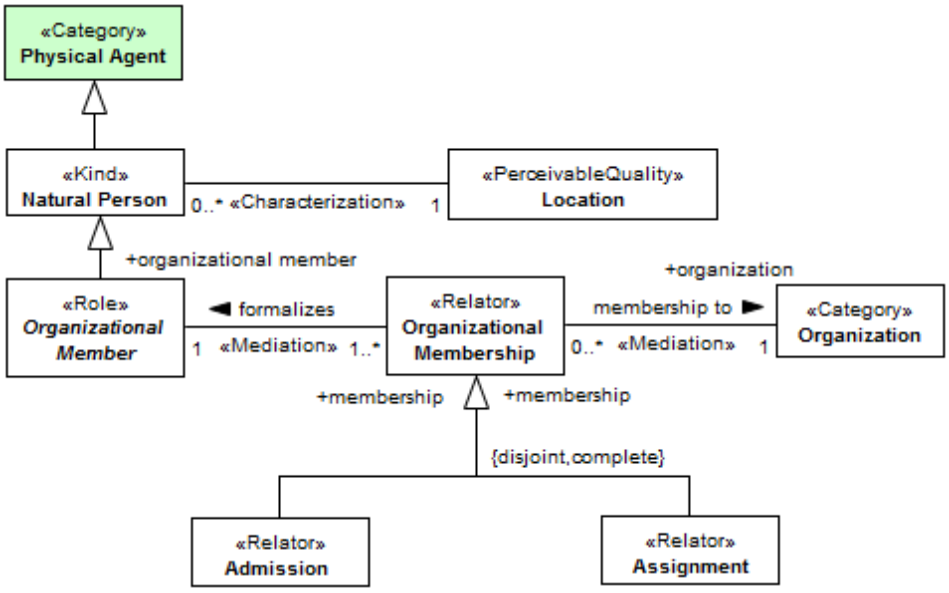

Figure 50. O3 fragment - Organizational membership.

In the scope of each organization, different specializations of these more general roles are required. For example, in a university, employee types such as “University Professor” and “Secretary” become relevant, while in a hospital employee types such as “Doctor” and “Nurse” may be defined. Therefore O3 includes the second-order notions of employee type and other business roles. They are to be instantiated in particular settings creating thus specific roles. The instances of employee type extend formal organization member, and the instances of business role extend either structural unit member or missionary unit member. We represent them by following the UML’s “powertype” representation pattern with the second-order concept stereotyped <<hou>> (for higher order universal), highlighted in gray. Due to this, the user of the ontology can develop an extension that includes specific roles to his/her domain of interest. Figure 51 illustrates this setting.

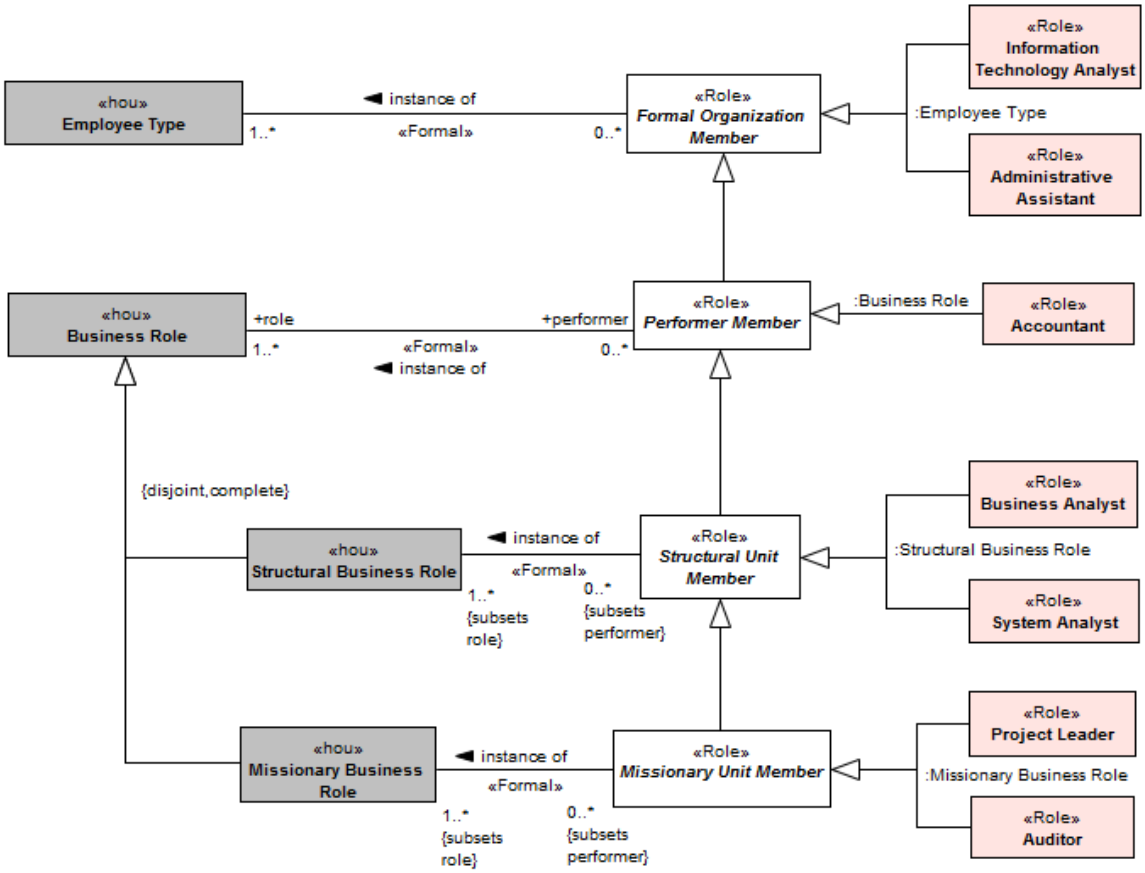

Figure 51. Instantiation examples of Employee Type, Structural Business Role and Missionary Business Role.

Figure 52 and Figure 53 present in details the concepts related with the agents that compose the organization and the types of roles they may play. In these fragments,

we are concerned with the specific roles that natural persons play, first of all as a member of a formal organization (Formal Organization Member), and then when they are given more specific places in the power structure, either in a structural (line or staff) unit (Structural Unit Member) or in missionary units (Missionary Unit Member). Note that in order to play a particular role in an organizational unit, a person needs to be a formal organization member first. Figure 52 defines in detail the existing formal relation between an employee and a formal organization.

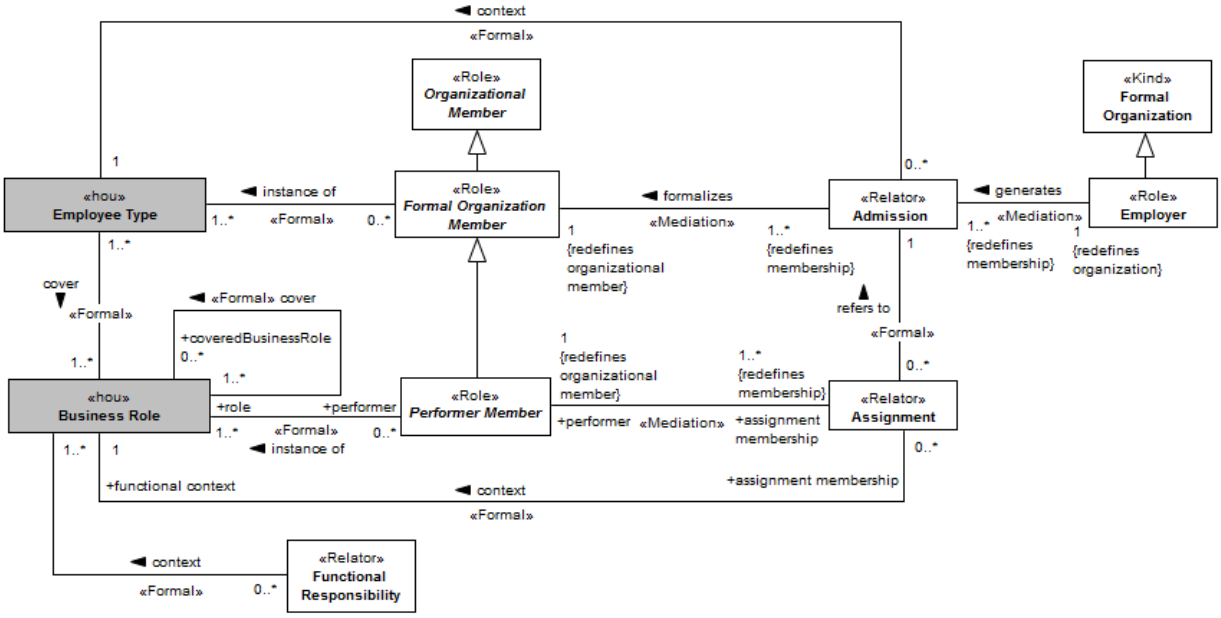

Figure 52. O3 fragment - Admission in organizations.

The association between an individual and an organization is accomplished through an admission or an assignment. When an individual becomes an employee (Formal Organization Member) of an organization, her formal “link” with the employer is the action of admission. The admission defines, in a general way, the expected behavior and constraints through the association of the individual with an employee type. In addition, an admission is recognized by the external environment, e.g., a real estate recognizes that Paul is a mechanical engineer (his profession) in a lease process.

Specific employee types define the set of roles (business roles) that a typified employee can occupy in the organization (through the “cover” relationship). Business roles define more specific capabilities, duties and prerogatives possibly in the scope of organizational units. Thus, business roles are more committed with the expected

behavior than employee types once aggregate functional responsibilities (see Figure 56 for detail about functional responsibility).

Formal organization members assigned to business roles are named performer member. In this scope, the allocation is limited to only the definition of functional responsibilities and does not extend to the allocation in organizational units. This setting fits perfectly with organizations that are not constituted by organizational units (simple standalone functional/missionary organizations). Figure 53 defines in detail the existing relation between an employee and organizational units.

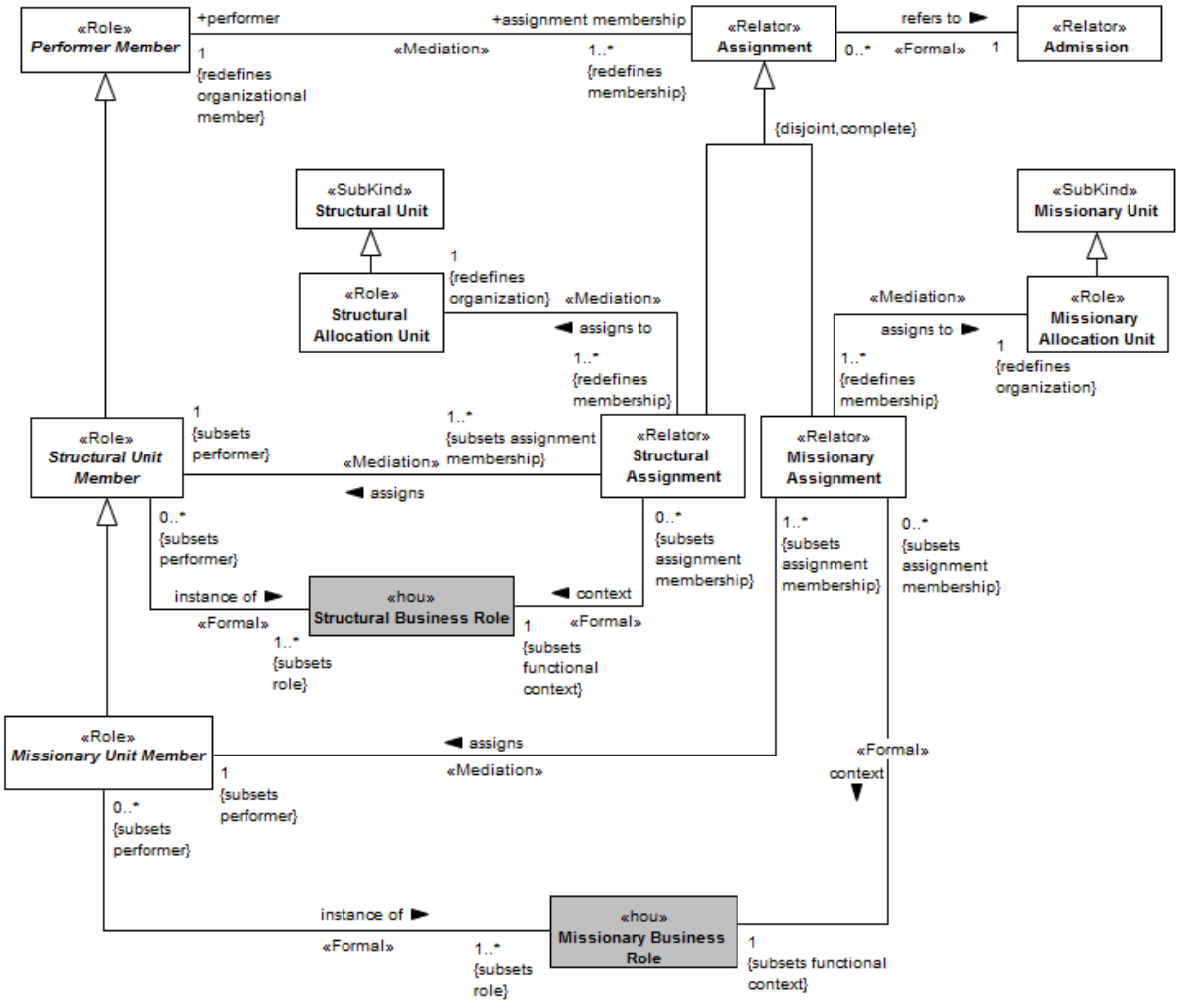

Figure 53. O3 fragment - Assignment in organizations.

Within the organization, an employee must be assigned to an organizational unit to assume a specific role and consequently a specific function. An assignment is recognized only in the internal context of the organization and can be structural

(structural assignment) or missionary (missionary assignment). When an assignment is related with the allocation of an employee to a structural unit, the individual becomes a structural unit member, whose subclasses are instances of structural business role. An employee allocated to a structural unit must play a structural business role; on the other hand, employees assigned to missionary units play missionary business roles. This type of assignment represents for example the association of John to the role of “system analyst” in the “IT department”.

Organizations that adopt the matrix structure can perform multiple assignments of “functions” to their employees. Generally, an employee is allocated to only one structural unit, but it is possible that the same employee is assigned to different missionary units, with different missionary business roles. When associated to a missionary unit, an employee becomes a missionary unit member. The specializations of the concept missionary unit member are instances of missionary business role.

When assigned to an organizational unit, an employee has a defined “function” formalized in the specification of the business role, which defines in detail its expected behavior and authority relationships. The accumulation of “functions” by an employee can be simultaneous or at different time periods. The assignments are only possible if the individual is member of the organization, not being possible, for example, that John is allocated (by an assignment) to an organizational unit if he is not a member of the organization or a member of another organization. Thus, the assignments are tied with the admission that made the individual a member of the organization, which is defined through the relationship “refers to”.

Admissions and assignments can be performed through many actions (e.g., an election, an appointment), each of these defining a different member. Figure 54 describe in detail the multiple membership forms.

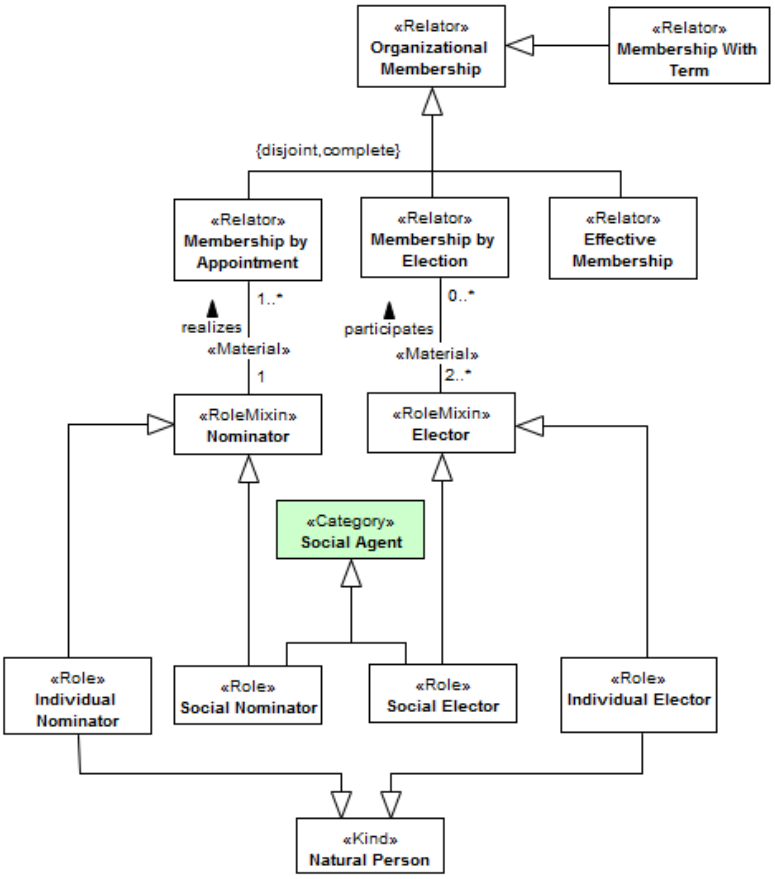

Figure 54. O3 fragment - Organizational membership complete taxonomy.

Before discussing the many forms of membership (admission and assignment), we need first to define election and appointment. An election is a process to select one among many candidates. In an election many electors participate with votes to a specific candidate. The candidate with the most votes is selected. In contrast, an appointment is performed by a nominator in favor of other.

In the organizational context, an employee may be admitted or assigned by different forms. An effective membership is the most common admission/assignment type and represents an admission/assignment following the usual process. Other forms of membership include appointments and elections. When an employee is admitted as consequence of an appointment, the resulted admission/assignment is a membership by appointment. An appointment need not necessarily be performed by members of the organization. In the case of O3, a natural person or a social agent can “realizes” an appointment. Finally, an employee can be elected by a group of natural person or social agents, which “participates” of its selection. The presence of social agents in

appointment process can be observed, for example, United Nations Council. The General Secretary is appointed by the General Assembly, after being recommended by the Security Council. The members of General Assembly are governments, which represents social agents.

Table 10 presents the constraints that must be observed on analyzing or instantiating the concepts of the Allocation View.

Table 10. Allocation view constraints.

ID	Description
AXI15	Every member of an organizational unit should be employee (Formal Organization Member) of the “Formal Organization” to which the “Organizational Unit” is related (component of relationship).
AXI16	An employee (Formal Organization Member) can only assume a “Business Role” inherent to the “Organizational Unit” to which he/she belongs.
AXI17	An instance of "Business Role" cannot establish a relationship "covers" with itself.
AXI18	Assignments should be performed in the context of a specific “Admission” in an organization (Formal Organization), i.e., an instance of "Formal Organization Member", which was admitted by an admission a1, cannot have a related assignment with an admission a2.

3.3.4 Social Relationships View

The social relationships view describes how the members of an organization are related. During the length of stay of an employee in an organization, he/she plays many roles that are internal to the same. These roles formalize the social contract between the employee and the organization, defining the expected behavior and social relationships, like authority and communication. Figure 55 presents the social relationships that permeate organization members.

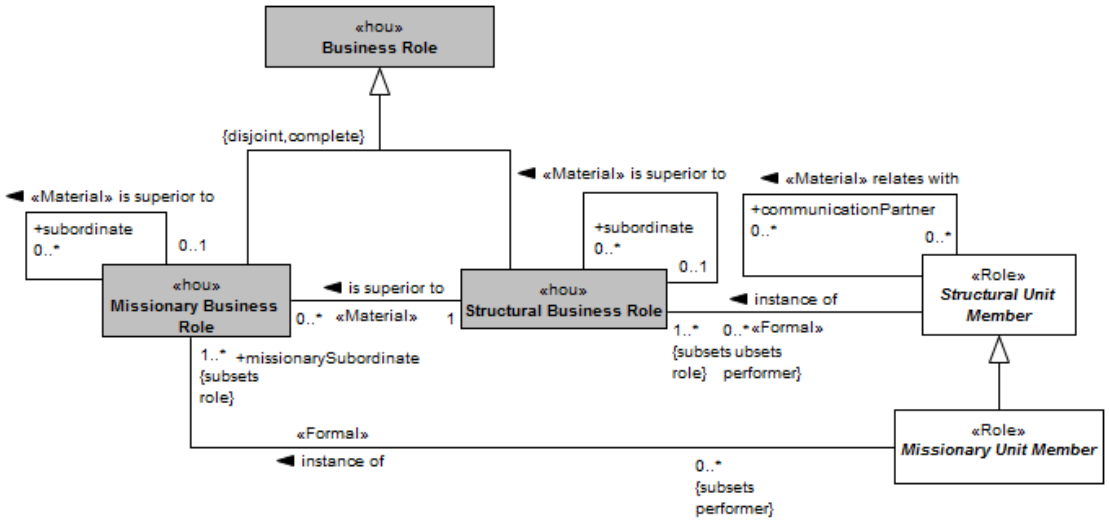

Figure 55. O3 fragment - Social relationships.

As a coordinated environment, authority constitutes a fundamental aspect for organizations. Authority is related with the formal assignment of power to an employee with respect to another. In terms of O3, a formal organization member “is superior to” another. Despite the fact of the “is superior to” relationship be used in many ways between structural business roles and missionary business roles, its meaning varies in according to each use. The reflective authority relationship “is superior to” that occurs between structural business roles and missionary business roles allows the differentiation between the command structure of a department and the command structure of a project, for example. In addition, in many organizations those responsible for projects, task forces and others, are not allocated in the associated missionary unit, but participate giving the directives, constraints and demanding results to the leader of the working group. The power relationship existing between structural business roles and missionary business roles also can be defined through the “is superior to” relationship.

The establishment of power relationships provides managers a way to achieve the coordination of the actions to fulfill goals. To support horizontalization, cooperation must also be present in social structure. Cross functional processes are performed by multidisciplinary participants in a cooperative way. Cooperation allows the interaction between the participants without the establishment of authority, describing that a

member “relates with” another. This relationship also can be viewed as a communication link between the participants.

In some cases, the rigid authority structure is not adequate for agile decision making. Usually, managers delegate part of their authority in favor of breaking down decision barriers. The authority delegation allows empowerment of a performer member to a specific duty (functional responsibility). E.g., a sales manager may delegate authority to a salesman to ensure that a particular sales process is followed. While the delegation is not revoked the salesman has authority over the staff related with the functional responsibility. Figure 56 illustrates organizational delegations, regarding of authority and functional responsibility.

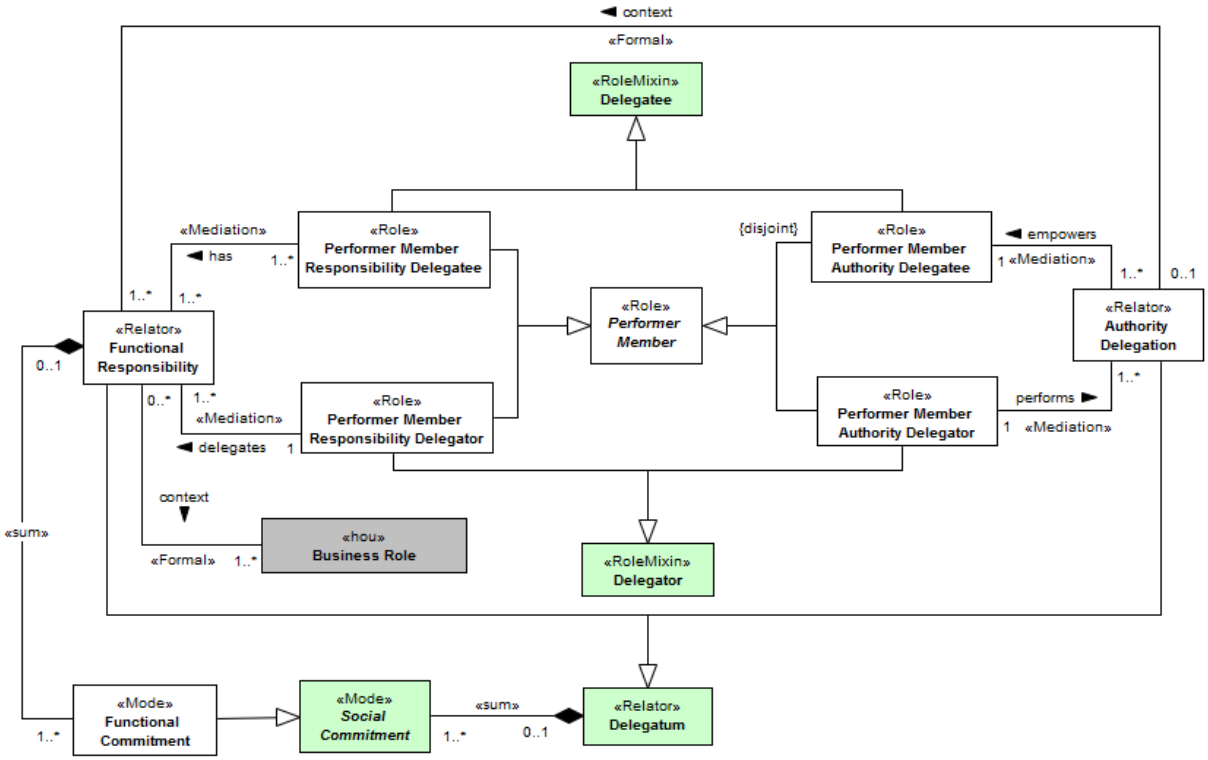

Figure 56. O3 fragment - Authority and functional responsibility delegations.

The goals pursued by an organization can be decomposed at its lowest level of decomposition into tasks (DO; FAULKNER; KOLP, 2003). The distribution of tasks is performed by the assignment of functional responsibilities to its members as duties (delegation). Performer members may have multiple functional responsibilities, carried out in the context of their business roles. Functional responsibilities aggregate many functional commitments. The difference between functional responsibilities and

commitments lies on the basic nature of these two concepts. The first represents the delegation of responsibilities to someone, while the last describes the tasks that must be performed. A functional commitment does not represent a specific task, but instead a predisposition to conduct tasks. We choose to not describe the activities related with a specific functional commitment, since behavioral aspects are out of our scope. The user of the ontology can alternatively integrate or extend the ontology to cover behavioral aspects. For this, we recommend the use of the functional commitment concept as a bridge.

Table 11 presents the constraints that must be observed on analyzing or instantiating the concepts of the Social Relationships View.

Table 11. Social relationships view constraints.

ID	Description
AXI19	A structural role (Structural Business Role) may be superior to structural roles defined by the same organization (Formal Organization) to which it belongs.
AXI20	A team role (Missionary Business Role) can only be superior to team roles defined by the same organization (Formal Organization) to which it belongs.
AXI21	A structural role (Structural Business Role) can only be superior to team roles (Missionary Business Role) defined by the same organization (Formal Organization) to which it belongs.
AXI22	An instance of "Structural Business Role" cannot establish a relationship "is superior to" with itself.
AXI23	An instance of "Missionary Business Role" cannot establish a relationship "is superior to" with itself.
AXI24	An instance of "Structural Unit Member" cannot establish a relationship "relates with" with itself.
AXI25	An instance of “Structural Business Role” cannot establish a relationship “is superior to” with someone that is transitively superior to it.
AXI26	An instance of “Missionary Business Role” cannot establish a relationship “is superior to” with someone that is transitively superior to it.

3.3.5 Business Collaboration View

The business collaboration view describes the external organizational interactions and their participants. Despite the effort to define organizations as a unit, the view that organizations are inserted in a broad collaborative and dependent environment is defended as the path to business survival. Organizations think of themselves as teams that create value jointly rather than as autonomous companies that are in competition with all others (DAFT, 2010). An organization interacts with suppliers to get its inputs, and, surely, interacts with its customers to sell its products or services. These interactions are called business collaborations. The knowledge about the context of the organizations is essential to business strategy, as a way to adapt the organizational behavior to the changes and opportunities (DAFT, 2010). Figure 57 presents the roles involved in business collaborations.

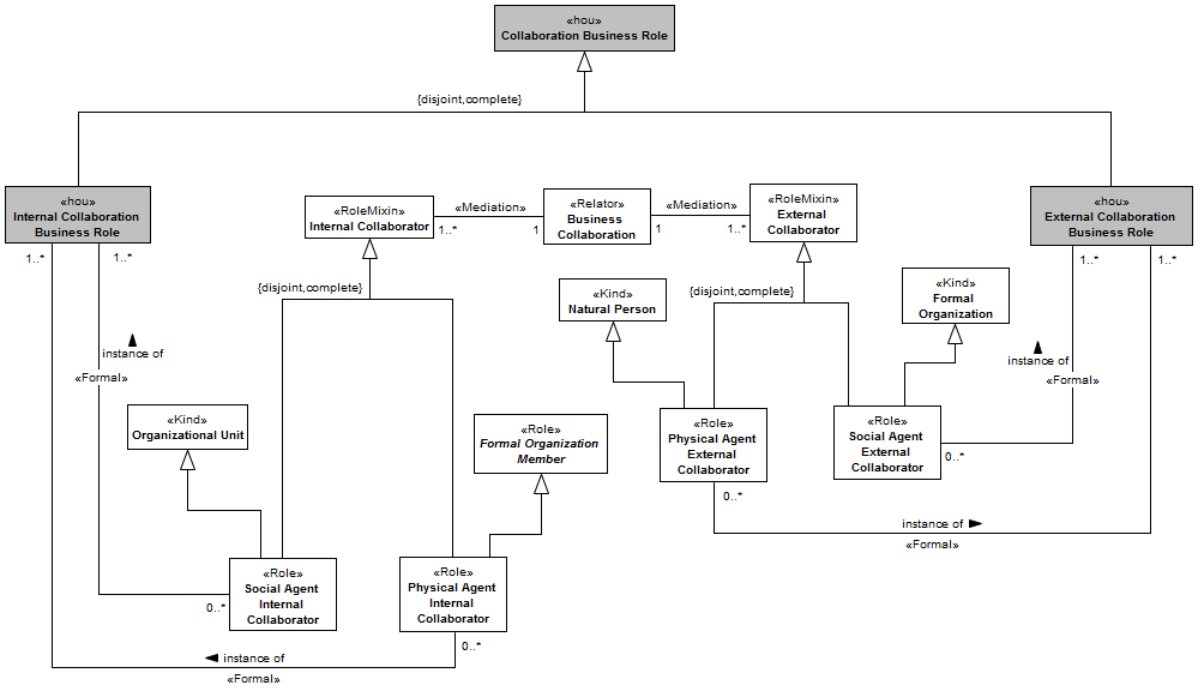

Figure 57. O3 fragment - Business collaboration view.

Business collaborations involve two distinct parts that work together to perform a collective behavior, an internal and an external part. Internal participants are namely internal collaborators and represent the organization as a whole (e.g., sales department, business agent). On the other hand, external participants are called external collaborators and represent the organizational environment (e.g., a supplier,

a customer, an audit organization). Social agents or physical agents may get involved in a business collaboration. When an organizational unit (social agent) becomes an internal collaborator it plays the role of social agent internal collaborator. Similarly, when a formal organization member (physical agent) becomes an internal collaborator she plays the role of physical agent internal collaborator.

An internal collaboration business role specifies the expected behavior of an internal agent when participating in a business collaboration. The specializations of both specializations of internal collaborator are instances of internal collaboration business role. This means that the specializations of both, social agent internal collaborator and physical agent internal collaborator, have as power type the internal collaboration business role concept. Due to this fact we can define types of roles explicitly in the model through specialization of these concepts, as shown in Figure 58.

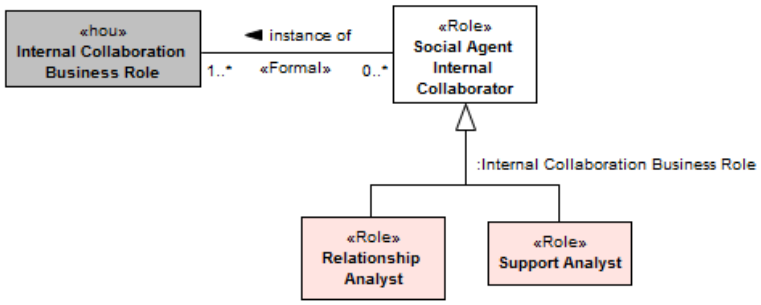

Figure 58. Example of instantiation of Internal Collaboration Business Role.

Finally, when an organizational unit (social agent) becomes an external collaborator, it plays the role of social agent external collaborator. In the same way, when a natural person (physical agent) becomes an external collaborator, he/she plays the role of physical agent external collaborator. An external collaboration business role specifies the expected behavior of an external agent when participating in a business collaboration. The specializations of both specializations of external collaborator are instances of external collaboration business role.

3.3.6 Capability View

The capability view describes the organizational members' characteristics relevant to performing their duties. Natural persons can be described by their physical and mental characteristics, like height, weight and temperament. These characteristics manifest themselves in the form of skills. In the organizational context, we are only interested in the subset of skills needed to carry out business tasks. Figure 59 presents the relationship between the required skills and the inherent skills of a natural person.

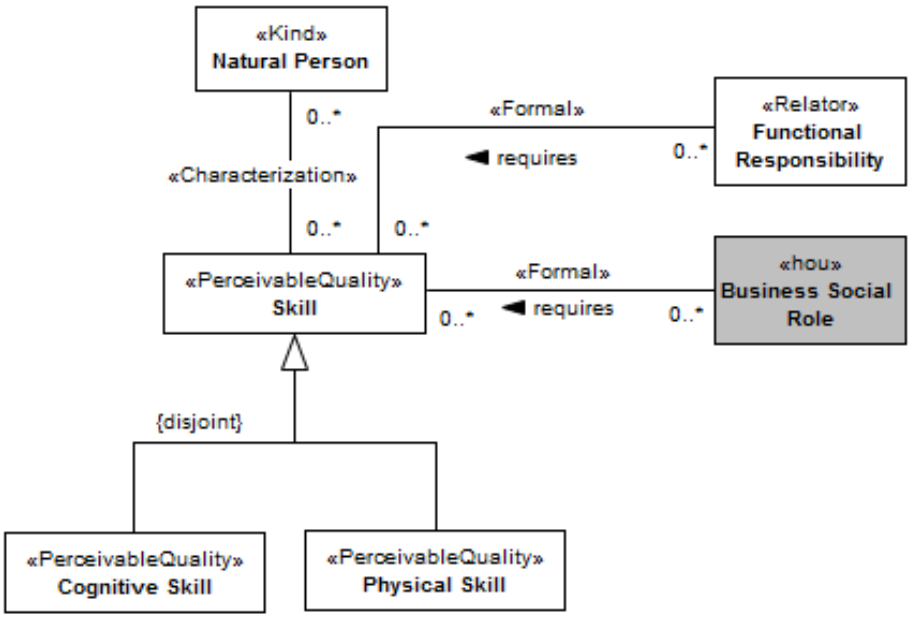

Figure 59. O3 fragment - Capability view.

As defined in (FAYOL, 1949), each group of operations or functions corresponds to a special ability (skill). There are technical abilities, commercial abilities, financial abilities, administrative abilities, etc. The set of essential qualities and knowledge comprises physical, intellectual and moral qualities, general knowledge, experience and certain special knowledge regarding with a function to perform. This set of skills represent the requirements to engage in business social roles. In the scope of this work, we cover only physical and intellectual qualities, here called respectively, physical skill and cognitive skill. Examples of skills includes UML modeling, java programing, bridge structural design, flying aircraft, fast running and carrying heavy weights.

3.3.7 Resource View

The resource view describes the organizational resources and their relationships with the organization and its members. Here, resources do not comprise human being as human resources, but only physical and social objects. A resource, in the sense of O3, follows rigorously the definition of resource in UFO-C. As defined in (GUIZZARDI; FALBO; GUIZZARDI, 2008), “only agents (entities capable of bearing intentional moments) can perform actions. An object participating in an action is termed a resource. Agents can be physical (e.g., a person) or social (e.g., an organization, a society). Objects can also be further categorized in physical objects and social objects. Physical objects include a book, a tree, a car; Social objects include money, language and Normative Descriptions”. In addition, we have also system objects, which represent software in general (e.g., an operational system, an ERP). A system object is not an agent, since we consider it cannot bear intentional moments, but have automated characteristics. Thus, this kind of objects participates as resources in actions. Figure 60 presents an overview of the definition of “resource” merging with UFO-C concepts.

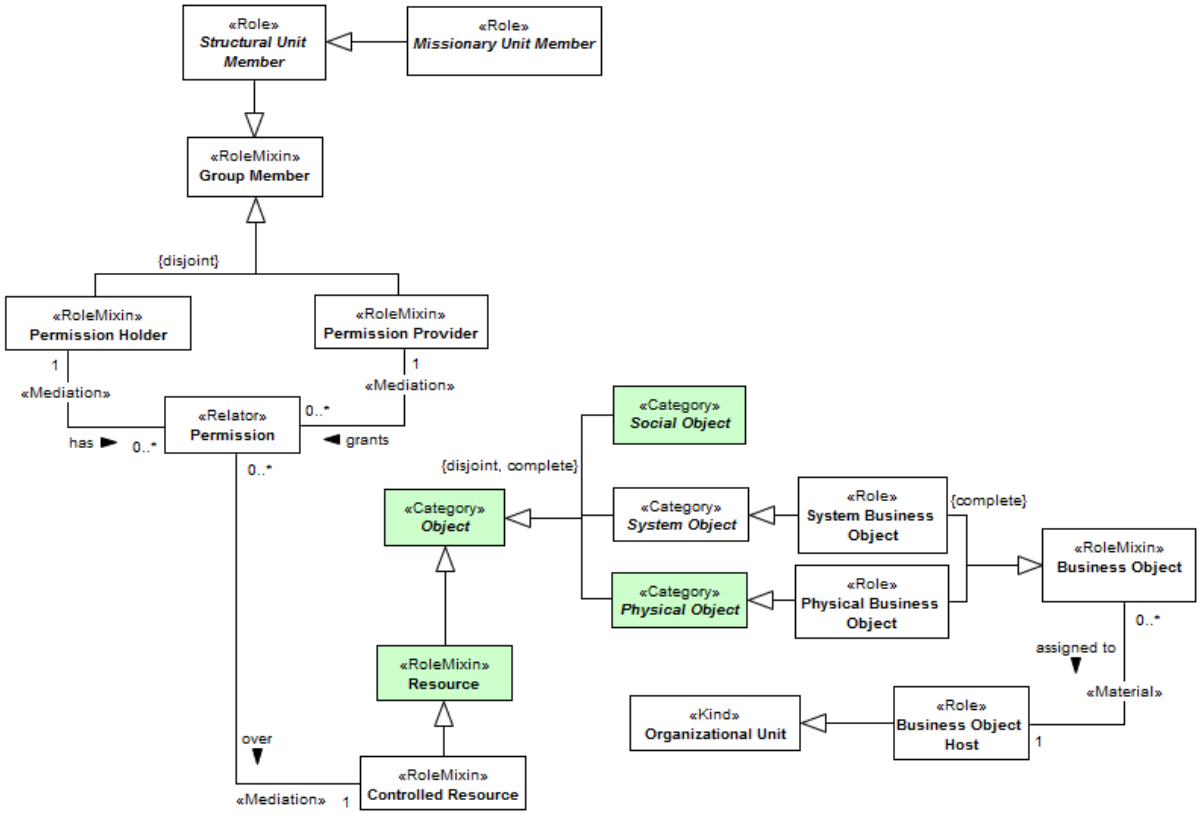

Figure 60. O3 fragment – Resource access and categorization.

In the organizational scope, we also have particular objects, which can be possession of someone (owner) and are assigned to some organizational unit (available to the use). These objects are namely business physical objects. Many actions performed in the business context have the participation of resources. When a call center attendant makes a customer service, the description of the process is a social object, the phone used is a physical object and the software that records the occurrence is a system object.

The access to a resource can be controlled by granting or revoking permissions. Group members (Figure 60) can maintain permissions over resources, as a permission provider or a permission holder. A permission holder can retain many permissions over many resources. On the other hand, as a permission provider, a group member can grant permission for many group members to access many resources. Note that the term “access” comprises use and consume.

Figure 61 presents the definition of organizational ownership and the roles involved.

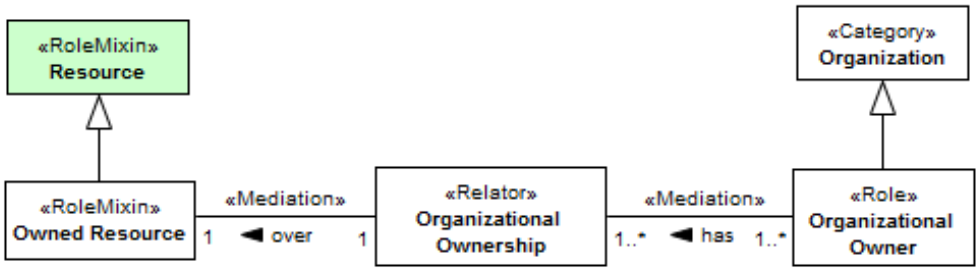

Figure 61. O3 fragment - Organizational ownership.

An organizational ownership relates organizations with business objects as a possession relationship. The owner in an organizational ownership has certain rights with respect to the object. An ownership can be transferred by sale or donation (the transfer of ownership is out of the scope of our ontology). Despite the abstract nature of social objects, this kind of objects can be visualized as a property. Further, social objects also may have commercial value. An example of social objects owned by organizations includes the TOGAF Framework, Brazilian Real (currency) and ArchiMate modeling language. Despite the fact that system objects are abstract, a registered software has a transferable license which symbolizes the object itself.

4 O3 EVALUATION

In this chapter we present the evaluation of O3 against the precision, coverage and scope quality criteria. Our evaluation takes as basis the organizational requirements defined earlier (Section 3.1 and a comparison with existing approaches). The extensibility criterion is evaluated in Chapter 6 through the development of a government ontology extending O3.

Section 4.1 presents a comparative analysis of O3 against existing approaches. Our purpose here is to provide an expressivity overview of O3. Section 4.2 demonstrates how the specified competency questions are answered by O3. Finally, Section 4.3 presents a discussion about the conclusion of our evaluation.

4.1 A COMPARISON WITH EXISTING APPROACHES

With the purpose of evaluating the scope of O3, we present in this section an analysis of the coverage of the analyzed approaches. This analysis comprises all the 9 approaches presented in Section 2.3. Also, we present a mapping of O3's concepts with concepts of the other approaches. This mapping is useful to identify semantic equivalences.

Before we perform our analysis, we need to classify the concepts of O3 regarding the organizational aspects. This classification has the goal of completing Table 5 presented on Section 3.1.1. Table 12 presents the result of this effort.

Table 12. O3 analysis against organizational aspects.

ID	Organizational Aspect	O3 Concepts
A01	Organizations	Organization Formal Organization Functional Organization Missionary Organization Multi-Functional Organization Standalone Functional Organization Simple Standalone Functional Organization

		Complex Standalone Functional Organization Composed Missionary Organization Standalone Missionary Organization Simple Standalone Missionary Organization Complex Standalone Missionary Organization
A02	Organizational Working Groups	Organizational Unit Structural Unit Missionary Unit Line Unit Staff Unit
A03	Organizational Members	Natural Person Organizational Member Formal Organization Member Structural Organization Member Missionary Organization Member
A04	Organizational Roles	Employee Type Business Role Structural Business Role Missionary Business Role Collaboration Business Role External Collaboration Business Role Internal Collaboration Business Role
A05	Authority	Authority Delegation Is superior to (Relationship)
A06	Capabilities	Skill Cognitive Skill Physical Skill
A07	Responsibility	Functional Responsibility Functional Commitment
A08	Resources	Resource System Object System Business Object Physical Object Physical Business Object Business Object
A09	External Collaborations	Business Collaboration
A10	Internal Collaborations	Relates With (Relationship)
A11	Geographical Location	Location
A12	Organizational Assignment	Admission Assignment Structural Assignment

		Missionary Assignment

Table 13 illustrates the coverage analysis of the selected approaches. Here, we present an analysis of the level of alignment between the approach's concepts with the organizational aspects. The columns represent the organizational aspects and the lines the analyzed approaches. The level of alignment is defined by the following rule.

- **No alignment** - Blank: There are not concepts that directly or indirectly describe the aspect.
- **Low alignment** - 1: There are concepts that indirectly describe the aspect.
- **Medium alignment** - 2: There are concepts that represent directly the aspect, but there are no specializations to provide more expressivity.
- **High alignment** - 3: There are concepts that represent directly the aspect and there are specializations that provide more expressivity.

We consider that a concept describes directly an aspect if its semantics is perfectly correlated with the description of the organizational aspect, without adjustments. On the other hand, we consider that a concept describes indirectly an aspect if its correlation only is possible with adjustments, like an assumption of some interpretation.

Table 13. Summary of organizational aspects analysis.

Approach	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12
O3	3	3	3	3	2	3	2	3	2	2	2	3
UPDM	1	1	2	2		3	2	3			3	1
Enterprise Ontology	2	2	3	3	2		2	3	2			3
E-OPL	3	3	2	3								3
TOVE	1	2	2	2		2		2		2		
Super Project	2	3	2	3		2		2				
W3C Org Ontology	2	2	2	3				2	2		2	2
ArchiMate	1	1	1	2				1	2		2	
ARIS		2	3	2							2	
RM-ODP	2			3	2		2					

1	Low alignment
2	Medium alignment
3	High alignment

Table 14 presents a mapping of the main concepts (and constructs) of existing approaches with the concepts of O3. For the sake of this work, we select only concepts related with the active structure domain.

Table 14. Summary mapping – O3 x Active structure approaches.

O3	UPDM	EO	E-OPL	TOVE	SUPER P.	W3C OO	Archimate	ARIS	RM-ODP
Organization	Organization, ActualOrganization	Corporation	Institutional Agent	Organization	Organisation	Organization	Business Actor		Community
Formal Organization		Legal Entity	Organization		Legal Entity	FormalOrganization			Party
Organizational Unit		Organisational Unit	Organizational Unit Human Resource Role, Informal Human Resource Role, Informal Organizational Role, Institutional Role		Non-Legal Entity	Organizational Unit		Organizational Unit, Organizational Unit Type	
Business Role		Role, Actor Role	Position, Formal Organizational Role, Institutional Role	Role	Role, Internal Role, Internal Role Type	Role	Business Role	Position, Person Type	Role
Employee Type	Post, ActualPost				Organisational Position	Post	Business Role	Position, Person Type Organizational Unit, Organizational Unit Type	
Structural Unit		Organisational Unit		Division, Subdivision	Organisational Unit, Permanent Organisational Unit	Organizational Unit	Business Actor		Community/Object
Resource	Resource, ResourceArtifact, SystemResource, PhysicalResource	Resource, Machine		Resource	Resource	Resource			Resource, Artefact
Skill	Competence			Skill	Skill				
Natural Person	ActualPerson	Person, Actor, Potential Actor	Person	Organization-Agent	Person	Person, Agent	Business Actor	Person, External Person, Internal Person	Party, Agent
Business Collaboration		Partnership				Organizational Collaboration	Business Collaboration		
Location	Location, PhysicalLocation				Organisational Unit, Temporary Organisational Unit	Site	Location	Location	
Missionary Unit	Project, ActualProject		Team	Team				Group	
Functional Commitment	Function						Business Function		Commitment
Admission		Employment Contract	Employment			Membership			
External Collaboration Business Role					External Role				Interface Role
Physical Agent External Collaborator		Partner							
Physical Agent Internal Collaborator		Partner							
Multi-Funcional Organization			Multi-Organization						
Standalone Funcional Organization			Standalone Organization						
Simple Standalone Funcional Organization			Simple Organization						
Complex Standalone Funcional Organization			Complex Organization						
Composed Missionary Organization									
Standalone Missionary Organization									
Simple Standalone Missionary Organization									
Complex Standalone Missionary Organization									
Simple Line Unit			Simple Organizational Unit						
Composite Line Unit			Complex Organizational Unit						
Owner		Owner							
Assignment	OrganizationalProjectRelationship		Allotment			Membership			
Functional Responsibility	Responsibility	Purpose							Delegation
Authority Delegation, Is superior to (R)		Management Link		Authority					Delegation
Relates with (R)				Communication-link					
Permission									Authorization
Organizational Member	Human Resource								

Some approaches provide support for concepts not supported by O3. Therefore, the resulting mapping does not include these concepts, once they do not have an appropriate correspondence in O3. We do not consider these expressivity shortcomings an issue, since many of concepts are too specific, and are considered thus outside the scope. The concepts not covered with a justification for their exclusion of O3 is described in Table 15.

Table 15. Concepts of other approaches that are considered outside the scope of O3.

Concept/Construct	Present in	Description	Justification
Stakeholder	Enterprise Ontology	A Role of a Legal Entity or Organizational Unit in a Relationship with an Organizational Unit whereby one or more Purposes of the Organizational Unit are included in the scope of interest of the Legal Entity or Organizational Unit.	Not described for simplification purpose.
IsCapableOfPerforming	UPDM	Links a Performer to the behavior that it can perform.	Is not direct represented, but can be derived through the **functional responsibilities** related with a **business role**. A **natural person** that can assume a specific role (**structural unit member**) transitively is capable of performing some behavior expected in the context of a **functional responsibility**.
MapsToCapability	UPDM	A disposition to manifest an Activity. An Activity to be performed to achieve a desired effect under specified [performance] standards and conditions through combinations of ways and means.	We choose to describe the capabilities required to assume the disposition to perform a set of activities by describing the **skills** required to assume a **functional responsibility**.
CompetenceProvider	UPDM	Abstract element used to group ActualPersons and	Not described for

		ActualOrganizationalResources.	simplification purpose.
CompetenceRequirer	UPDM	Abstract element used to group Organizations, Post, and Responsibilities.	Not described for simplification purpose.
LocationHolder	UPDM	Abstract grouping to capture elements that can have a location.	Not described directly. Can be inferred by selecting all elements that are related with a **location**.
PerformerParticipant	UPDM	Definition missing from documentation.	We select this concept as pertinent with our scope due to its related concepts and its label name. However, the definition is missing in the documentation.
Policy	RM-ODP	A set of rules related to a particular purpose. A rule can be expressed as an obligation, an authorization, a permission or a prohibition.	Not described for simplification purpose. We choose not to represent rules and relations explicitly.
Violation	RM-ODP	A violation is a behavior contrary to a rule. A violation of a rule that is part of a contract is a failure.	Not described for simplification purpose. We choose do not represent rules and its relations explicitly.
Obligation	RM-ODP	An obligation is a rule that a particular behavior is required. An obligation is fulfilled by the occurrence of the prescribed behavior. If that behavior does not occur as prescribed, then there is a violation. Some obligations are continuing: the behavior is required to be ongoing.	Not described for simplification purpose. We choose to not represent rules explicitly.
Permission	RM-ODP	A permission is a rule that a particular behavior is allowed to occur.	Not described for simplification purpose. We choose to not represent rules explicitly. We describe the

			concept **permission** (O3) at the sense of permission to access a **resource**.
Prohibition	RM-ODP	A prohibition is a prescription that a particular behavior shall not occur. A prohibition is equivalent to there being an obligation for the behavior not to occur. Occurrence of that behavior is a violation.	Not described directly on ontology. Can be inferred (in the case of access to resources) by absence of a permission between a **permission** holder and a **resource**.
Declaration	RM-ODP	Sometimes, when some person says something, the very fact of saying that causes a change in the world. The act of making such a statement may be represented as a declaration. The essence of a declaration is that, by virtue of the action of declaration itself and the authority of the object or its principal, it causes a state of affairs to come into existence outside the object making the declaration. An ODP system may be delegated by a party to participate in some action that is a declaration.	Described in UFO-C as a **speech act**. Is not described directly on ontology, but its semantic is covered by the extended ontology UFO-C.
Evaluation	RM-ODP	An action that assesses the value of something is an evaluation. In an evaluation, the ODP system assigns a relative status to something, according to estimation by the system of usefulness, importance, preference, acceptability, etc.	Not described for simplification purpose.
Prescription	RM-ODP	An action that establishes a rule.	Not described for simplification purpose. We choose do not represent rules and its relations explicitly, although we can extrapolate our interpretation to visualize

			a **speech act** as an action that establishes a rule.
Principal	RM-ODP	A party that has delegated (authority, a function, etc.) to another.	Not described directly on ontology. Can be inferred by selecting all **structural unit member** that performs **authority delegation**.
Group	W3C Org Ontology/foaf	A collection of individual agents. This concept is intentionally quite broad, covering informal and ad-hoc groups, long-lived communities, organizational groups within a workplace, etc.	We choose do not represent informal groups in our ontology, since we only focus on formal organizational structure.
Business Interface	ArchiMate	A business interface is defined as a point of access where a business service is made available to the environment.	Not described for simplification purpose.

4.2 REVISITING COMPETENCY QUESTIONS

The competency questions defined in Section 3.1.2 have the purpose of guaranteeing that the ontology fits with its purpose. Each competency question represents a possible use of the ontology. The ability to respond these content requirements demonstrates that the ontology covers aspects enough to satisfy its basic intended uses. For each competency question we present a “query” in natural language that indicates its answer and we indicate the model fragment related with the answer.

CQ01. How is the organization structured?

Regarding social composition, formal organizations can be structured in other formal organizations or organizational units. Organizational units comprise line units, staff units and missionary units.

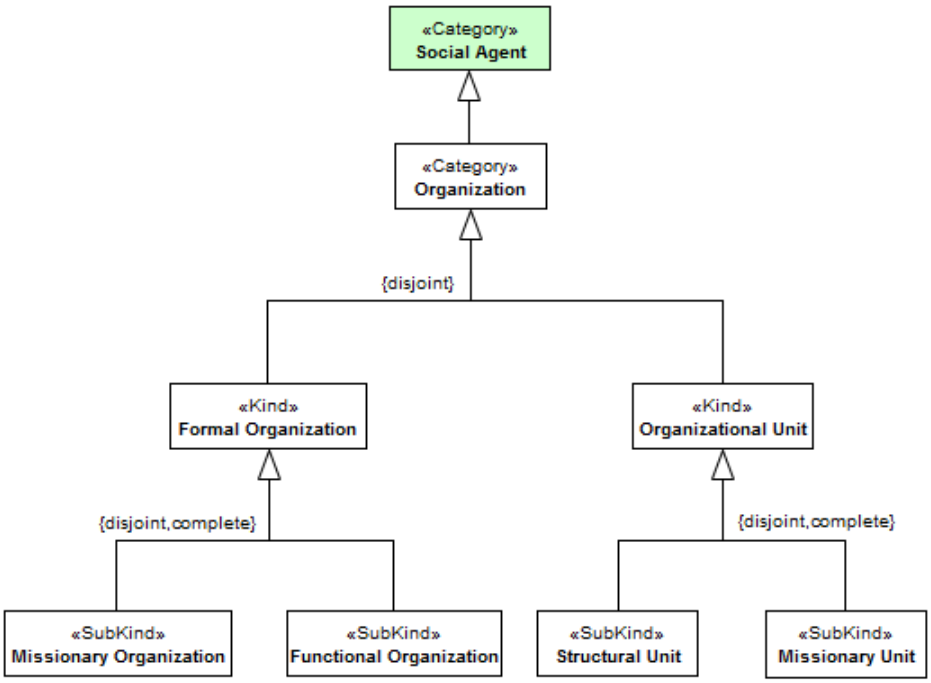

Figure 62. Fragment of O3 related with CQ01 (Organization).

Regarding the “roles”, the members of the organization are assigned to business roles which follow a specific authority structure.

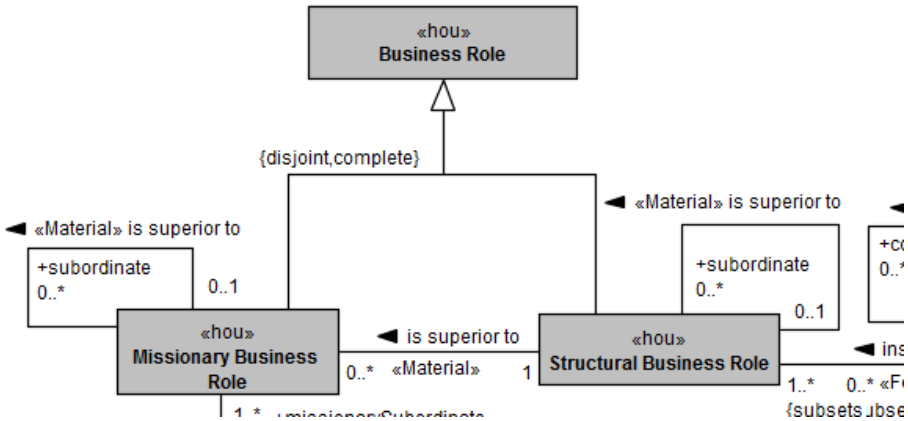

Figure 63. Fragment of O3 related with CQ01 (Business Role Taxonomy).

CQ02. Which roles a specific employee can assume?

Every employee assumes an employee type when admitted in the organization. The roles covered by its employee type are the business roles that an employee can

assume. Also, when assigned to a set of business roles, the employee can assume the business roles covered by them.

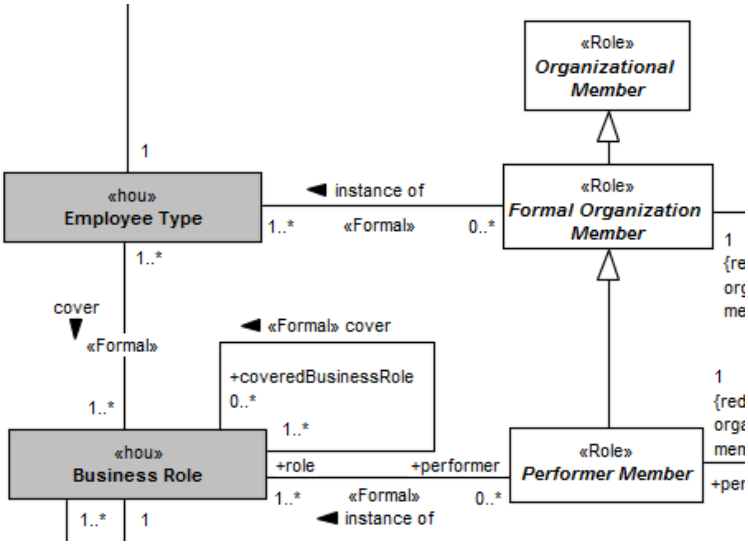

Figure 64. Fragment of O3 related with CQ02.

CQ03. Which functions a specific employee must perform?

An employee (performer member) must perform all the expected behavior of a delegated functional responsibility. A functional responsibility is delegated in the context of the business role that a specific employee plays.

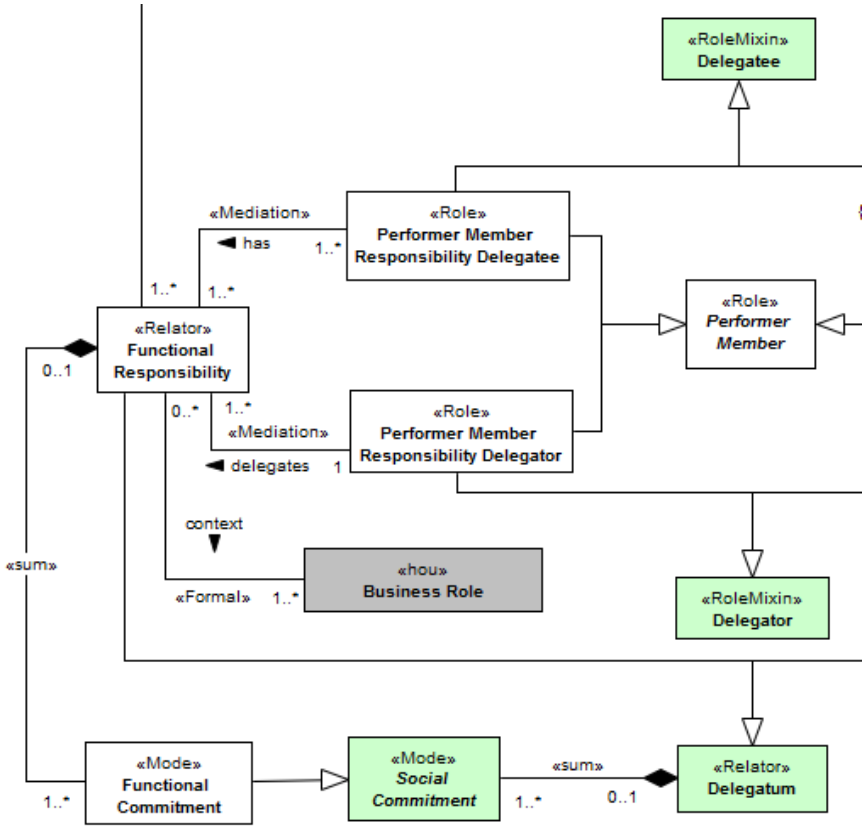

Figure 65. Fragment of O3 related with CQ03.

CQ04. Which competences are necessary to perform a function?

To play a functional responsibility, a natural person (as member of the organization) must fulfill its skill requirements. Generally, the skill requirements of a functional responsibility are a subset of the skill requirements of its associated roles.

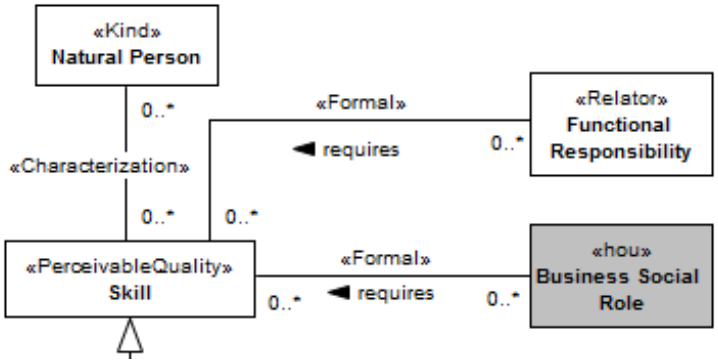

Figure 66. Fragment of O3 related with CQ04.

CQ05. Which resources are allocated in the organization?

Firstly, the term “resource” has to be carefully handle in O3. The concept resource present in O3 is the same concept of UFO-C. Resources are objects, which have some participation in an event. Objects are refined in social objects and physical objects. In O3 we define a new kind of object, called “software object”. In addition, we group physical objects and software objects to define business object. Business objects are those objects capable of deployment, and therefore traceable. Thus, the “resources” that are allocated in the organization are those business objects that are related to the organizational units (as business object host) of the organization through the "assigned to" relationship.

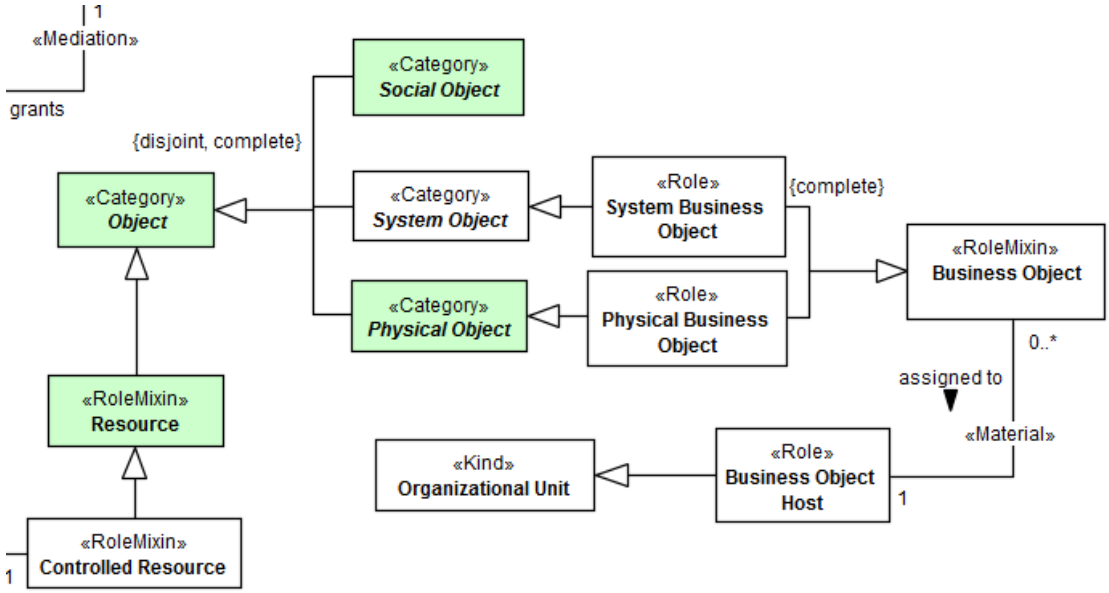

Figure 67. Fragment of O3 related with CQ05.

CQ06. Who are the members of the organization?

A natural person becomes a member of the organization through the establishment of an admission act. In O3, admissions relate the employer and the formal organizational member admitted (a natural person playing the role of formal member). Thus, the members of the organization are those natural persons that play the role of formal organization member pertinent to the organization.

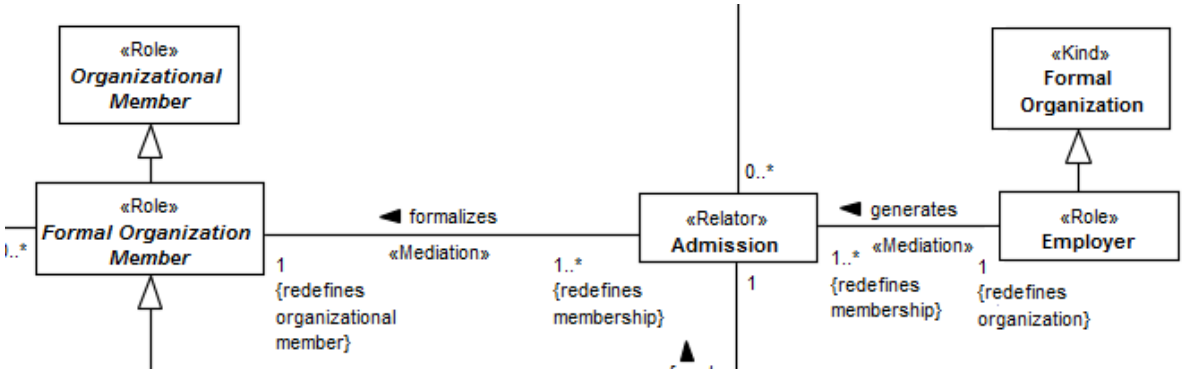

Figure 68. Fragment of O3 related with CQ06.

CQ07. To which organizational group is a particular employee assigned?

An employee may establish relationships with many organizational groups, including structural units (line unit, staff unit) and missionary units. These relationships are formalized by assignments between the members of the organization and its organizational units. The organizational groups to which a particular employee belongs are the ones to which he/she is assigned to.

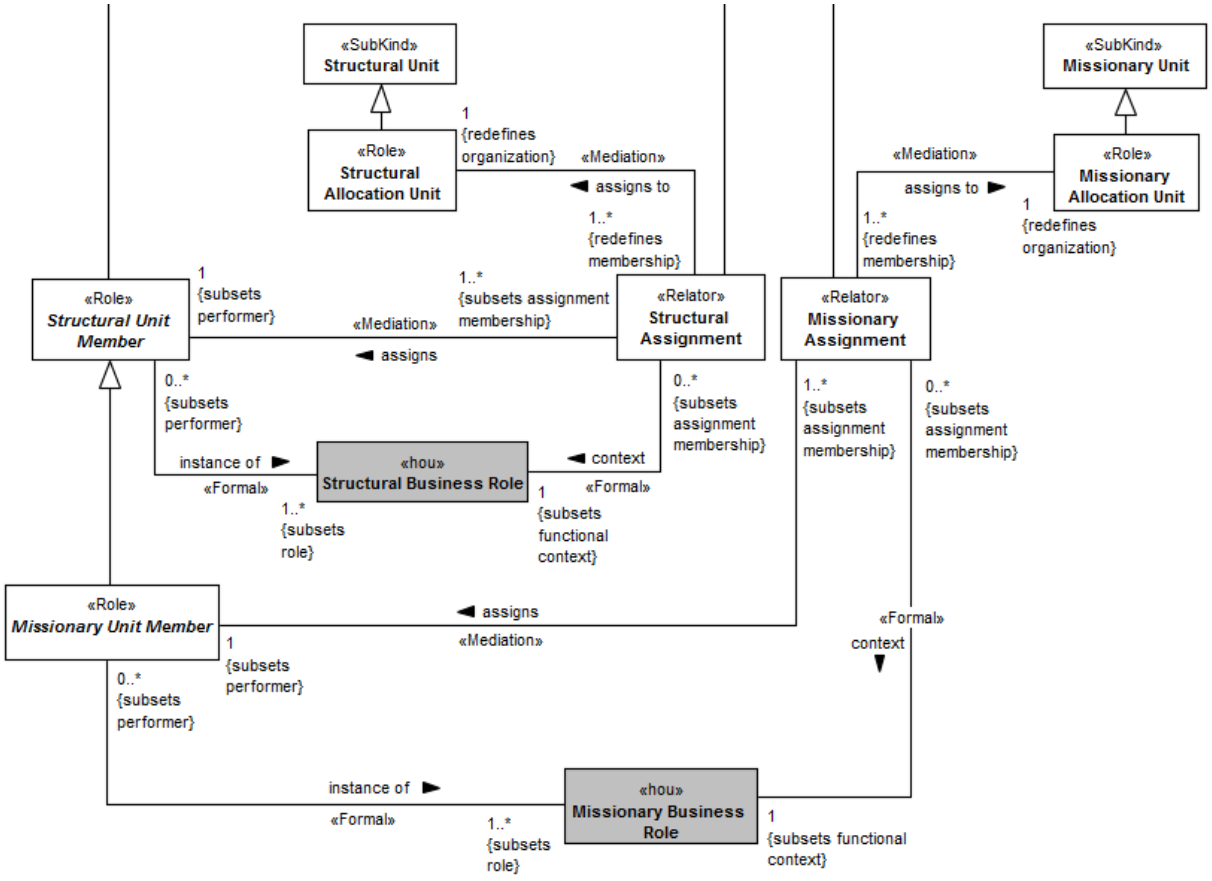

Figure 69. Fragment of O3 related with CQ07.

CQ08. What is the location of an organization?

An organization (formal organization) is located in the location with which it is associated.

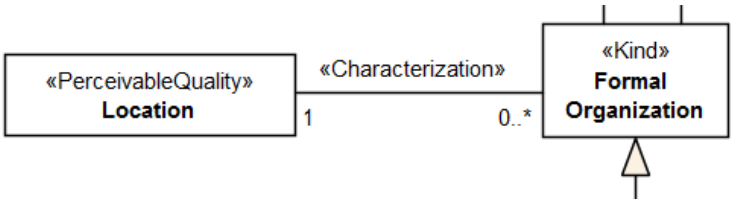

Figure 70. Fragment of O3 related with CQ08.

CQ09. What is the location of a particular employee?

In O3, we consider that location is a characteristic of a natural person. As an employee, the location of the person it is extended as the location of the employee (formal organization member).

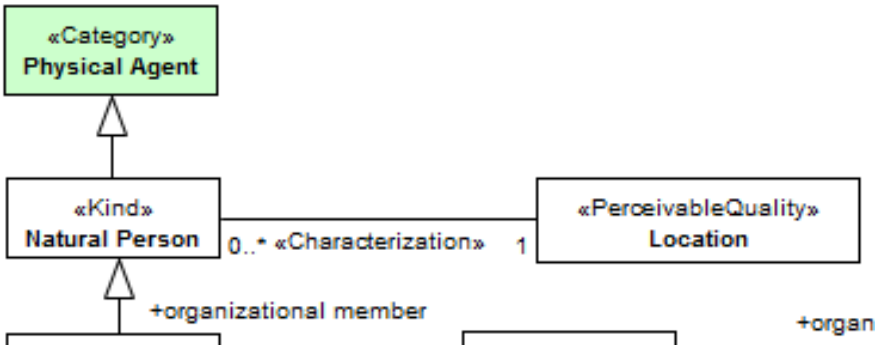

Figure 71. Fragment of O3 related with CQ09.

CQ10. Over which employees does a particular employee have authority?

The authority of an employee is associated with the roles that he/she plays. A particular employee (structural unit member and missionary unit member) has authority over all employees that are assigned to business roles subordinated to his/her business roles.

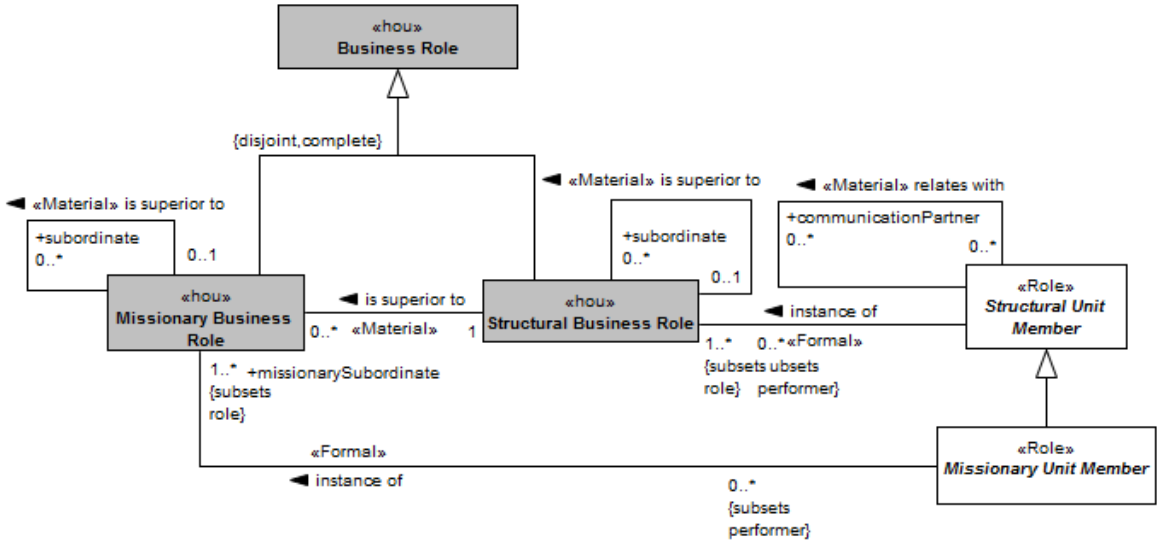

Figure 72. Fragment of O3 related with CQ10.

CQ11. With which employees does a particular employee have communication interface?

Here, we can understand the “interacts” relationship as a communication relationship, i.e., a formally defined relationship between two employees without the specification of authority. Two organizational members may interact to perform a function in a collaborative way. An example of interaction is the execution of a business process. In

O3, communication relationships are represented by “relates with” relationship between structural unit members.

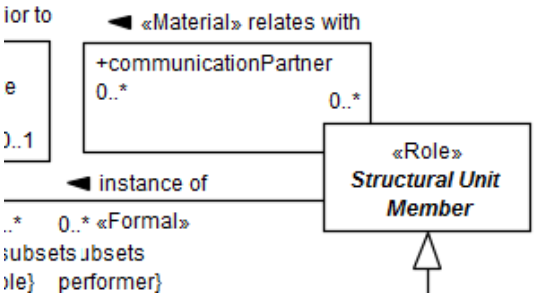

Figure 73. Fragment of O3 related with CQ11.

CQ12. What are the organizations with which an organization interacts?

A formal organization interacts with other organizations by means of its formal organization members and organizational units. The formal organizations with which a specific formal organization interacts are every organization that maintains business collaboration with its formal organization members or organizational units.

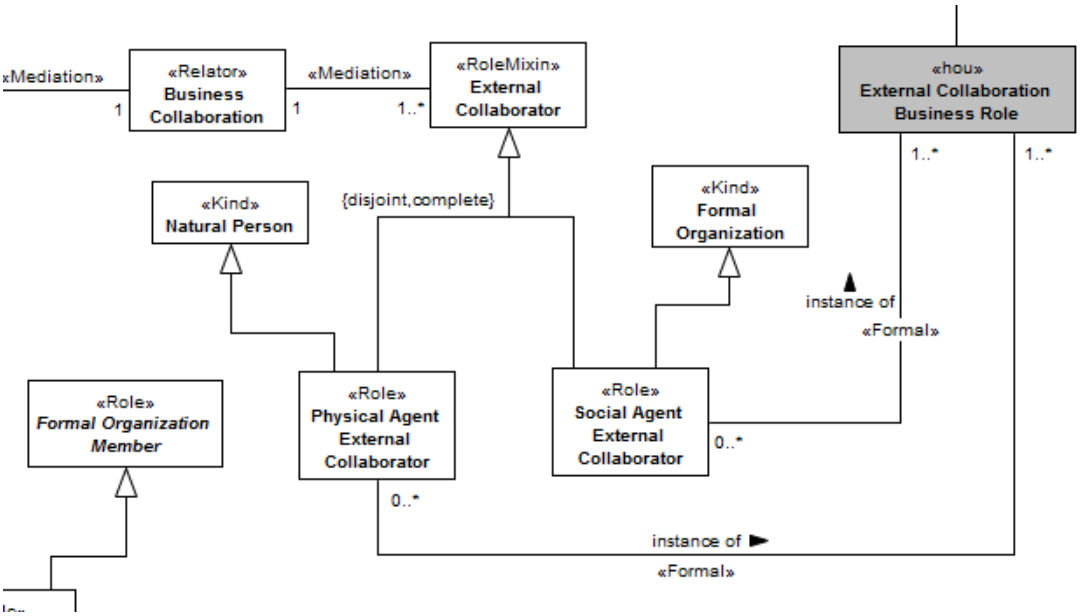

Figure 74. Fragment of O3 related with CQ12.

CQ13. Which people interact with the organization?

Here, we consider “people” as being external agents with relation with the organization. External agents (natural persons) may interact with the organization and establish a business collaboration. The people that interact with the organization are the ones that participate in business collaborations (with the organization) as “physical agent external collaborator”.

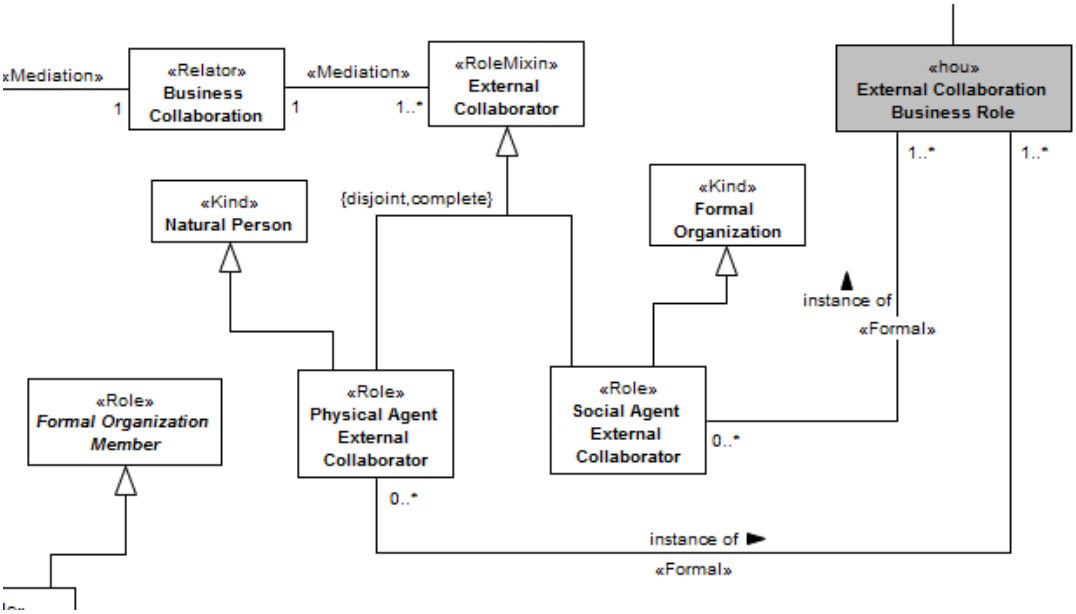

Figure 75. Fragment of O3 related with CQ13.

CQ14. To which resources does a particular employee have access?

The access to a resource is granted by the specification of permission between a resource, a permission holder and a permission provider. The permission provider grants permission to a permission holder over a particular resource. A particular employee has access to resources to which he/she holds permission.

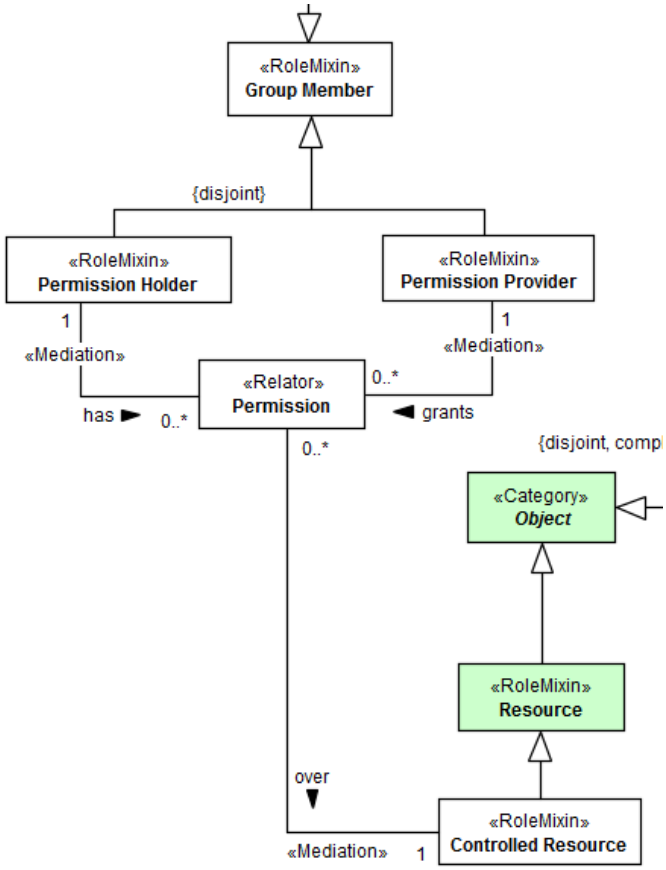

Figure 76. Fragment of O3 related with CQ14.

CQ15. Does an organization own a particular resource?

An organization owns the resources, which it is associated through an organizational ownership. In this case, the organization plays the role of organizational owner and the resource plays the role of owned resource.

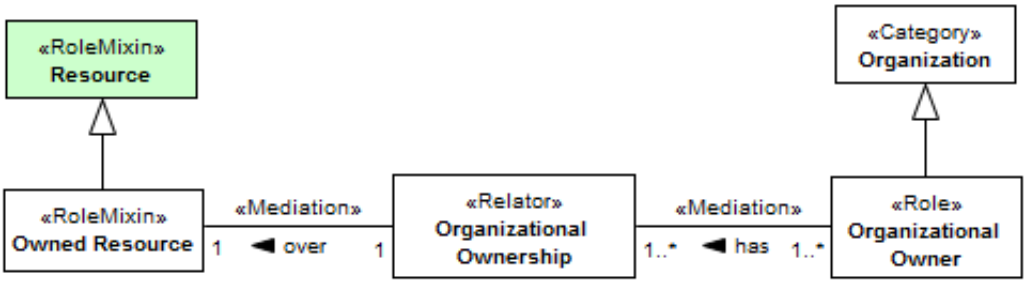

Figure 77. Fragment of O3 related with CQ15.

CQ16. Who does manage the organization?

The manager of the organization is the formal organizational member that plays the role of organization head. In terms of headquarters, we have that functional organizations are managed by the standalone functional organizations that play the role of functional headquarter. Similarly, missionary organizations are managed by the standalone missionary organizations that play the role of missionary headquarter.

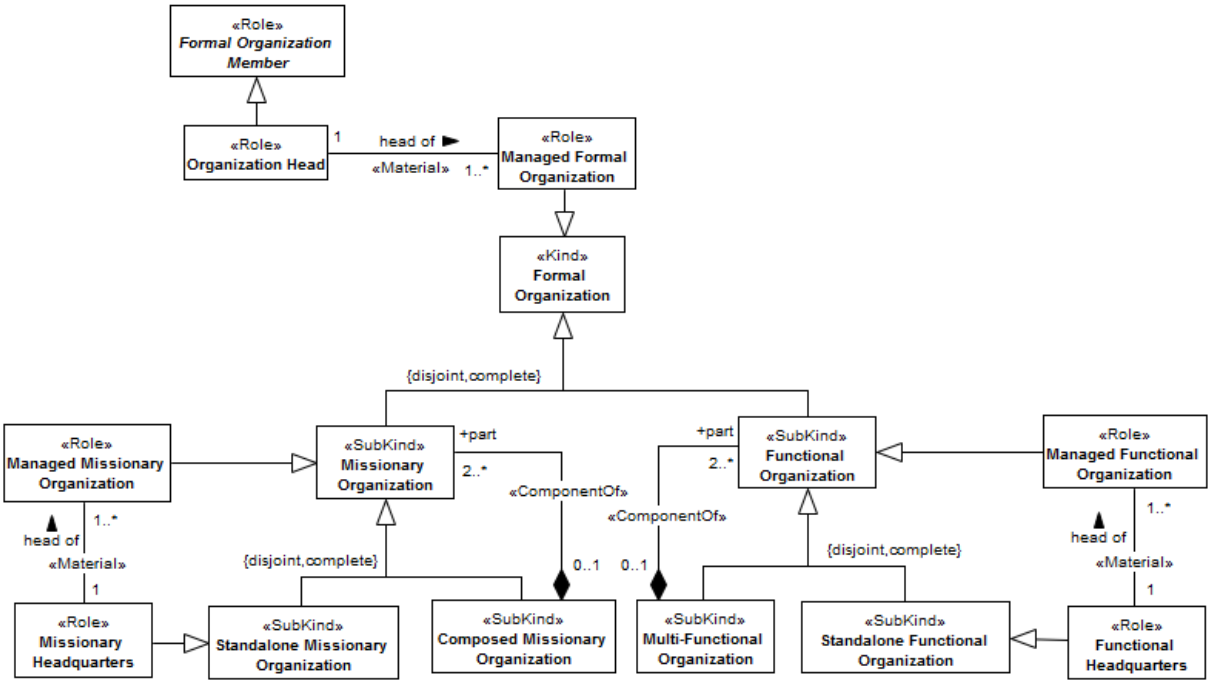

Figure 78. Fragment of O3 related with CQ16.

CQ17. Who does manage a particular organizational unit?

Organizational units are extended in structural units and missionary units. The manager of a structural unit is the structural unit member that plays the role of structural unit head. Similarly, the manager of a missionary unit is the missionary unit member that plays the role of missionary unit head.

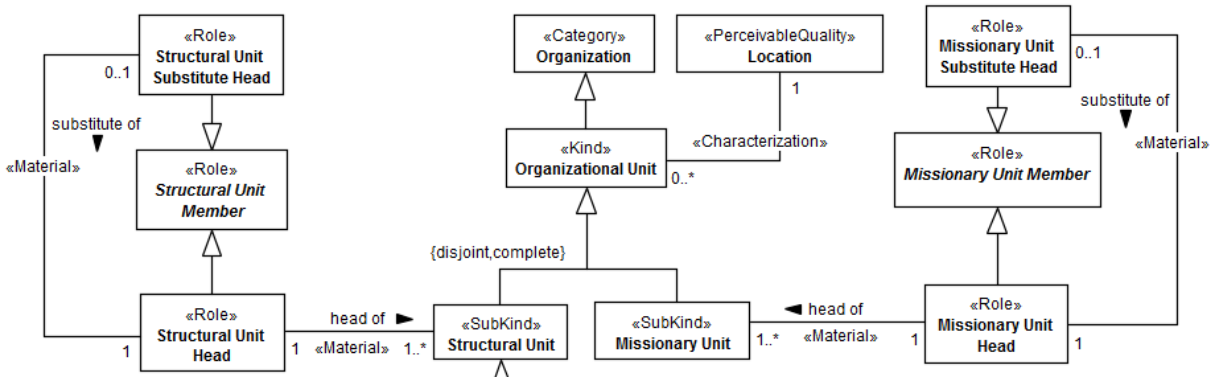

Figure 79. Fragment of O3 related with CQ17.

CQ18. What are the roles associated with a particular working group?

Working groups are composed of people. In the active structure domain, the organizational units are composed by formal organization members, which perform the expected behavior of their business roles. The behavior of the group as a whole (organizational unit) must be defined by the sum of the heterogeneous collective behavior, formally specified by the corresponding business roles. Thus, it is necessary to relate the business roles that specify the behavior of an organizational unit (structural units and missionary units). In O3, this is performed by the relationship “inherent to”.

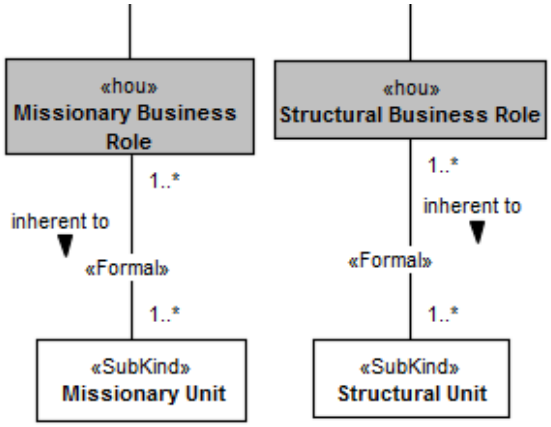

Figure 80. Fragment of O3 related with CQ18.

4.3 CONCLUSION

In this section, we presented the evaluation of O3 in light of precision, coverage and scope quality criteria. In the comparative analysis against the defined organizational aspects, O3 covered satisfactorily all listed items. Despite this result, O3 also has expressivity shortcomings, since it provides limited support for describing concepts such as authority, responsibility, external collaborations, internal collaborations and geographical location. Despite the existence of a relationship to represent internal collaborations (relates with), O3 does not cover all the inherent complexity of “communication” and should not be taken as a reference for such. The approaches that have shown less alignment with the active structure domain (following the criteria established in this work) were ARIS and RM-ODP. A hypothesis for this result is the greater alignment of these approaches to the development of systems. Among the group of ontological approaches, stood out the Enterprise Ontology. In addition, among the group of language approaches, UPDM did very well.

Finally, the competence analysis has shown that O3 can answer all the specified competency questions. This additional scope evaluation illustrates the user’s view and goes beyond the coverage analysis of organizational aspects. Its result demonstrate that O3 fits with its purpose and meets all the defined “information needs”.

5 ARCHIMATE ANALYSIS

In this chapter, we present a semantic analysis of the fragment of the ArchiMate metamodel related with the representation of active structures. In addition, we present a proposal to extend the metamodel based on O3. Our objective is to enrich the language with important capabilities to represent organizational structures using a principled ontology-based approach.

5.1 APPROACH

We address ArchiMate's active structure representation limitations with a principled approach. The O3 reference ontology enables us to analyze the capacity of ArchiMate to represent information about the active structure domain. We perform our analysis with the following steps:

- A study of the ArchiMate language focusing on the fragment of the language metamodel that addresses the active structure domain. This task provided us the basis for understanding the semantics of the language.
- An interpretation of ArchiMate's constructs in the relation to the concepts of our reference ontology.
- The identification of problems and their consequences for the generation of high-quality Enterprise Architecture models.
- A proposal to extend the language metamodel to address the identified issues and to contribute to increase the expressiveness and clarity of the language.

5.2 ARCHIMATE METAMODEL

Figure 81 shows a fragment of the metamodel of ArchiMate, whose purpose is to define the abstract syntax of ArchiMate models. The fragment in this figure focuses solely on the active structure constructs at the Business Layer. Since the diagram only reveals

some of the possible relations between constructs, we show all possible relations in a table on the right-hand side of Table 16.

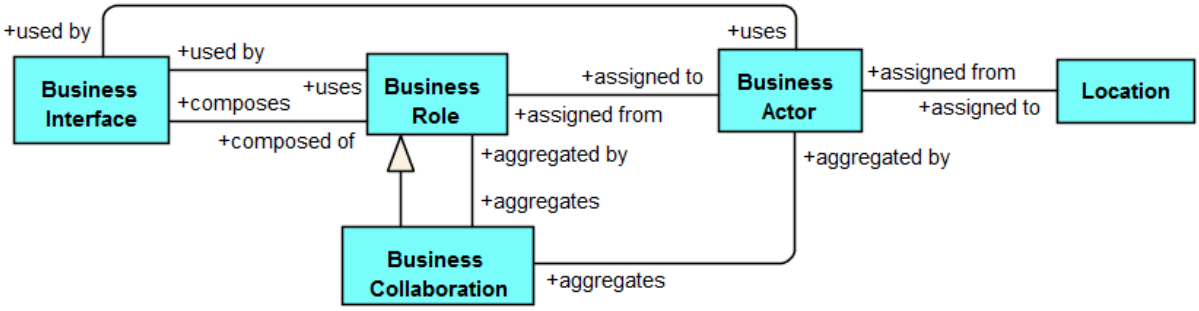

Figure 81. ArchiMate metamodel fragment and relations between active structure elements. Adapted from (THE OPEN GROUP, 2012)**.**

Table 16. Relations allowed between metaclasses of ArchiMate.

From ↓ / To →	Business Actor	Business Role	Business Collaboration	Location	Business Interface
Business Actor	cfgostu	fiotu	fiotu	o	cfiotu
Business Role	fotu	cfgostu	cfgostu	o	cfgiotu
Business Collaboration	fgotu	cfgostu	cfgostu	o	cfgotu
Location	fiotu	fiotu	fiotu	cfgostu	fiotu
Business Interface	fotu	fotu	fotu	o	cfgostu

(a)ccess ass(i)gnment (c)omposition (r)ealization
a(g)gregation ass(o)ciation (f)low (s)pecialization
(t)riggering (u)sed by

A Business Actor is defined in the ArchiMate specification as “an organizational entity that is capable of performing behavior” (THE OPEN GROUP, 2012). It can represent an individual entity or a group entity, as a department, for example. Examples of Business Actors are: “John”, “Customer” and “Marketing Department”. A Business Role is the “responsibility for performing specific behavior, to which an actor can be assigned” (THE OPEN GROUP, 2012). In other words, it represents the classification of the obligations and prerogatives in reusable roles that Business Actors, individuals and groups of individuals can play. Examples of Business Role include “Project Manager”, “Secretary” and “Sales Consultant”. In ArchiMate, a Business Role can be assigned to a Business Actor through a relation called “assignment”.

The Business Collaboration construct represents the interactions between two or more Business Roles. The Business Collaboration does not have an official status within the

organization and can be temporary (THE OPEN GROUP, 2012). An example of Business Collaboration is a “Supply Chain” collaboration performed between two organizations, which one plays the role of “Customer”, and the other plays the role of “Supplier”.

A Business Interface exposes the functionality of a business service to Business Roles and Business Actors, or expects functionality from other business services. The exposed interface is a channel that provides means to interaction, e.g., “Internet”, “Mail”, “Telephone” and “Care Unit”. Finally, Location, in the scope of Business Active Structure, allows the definition of the distribution of the Business Actors. A Location “is defined as a conceptual point or extent in space” (THE OPEN GROUP, 2012).

Table 17 presents the interpretation of ArchiMate metamodel concepts to O3 concepts.

Table 17. Interpretation of ArchiMate metamodel concepts to O3 concepts.

Reviewed Metamodel Concept	O3 Concept
Business Actor	Natural Person Formal Organization Organizational Unit
Business Role	Employee Type Business Role Internal Collaboration Business Role External Collaboration Business Role
Business Interface	-
Business Collaboration	Business Collaboration
Location	Location

5.3 SHORTCOMINGS ANALYSIS

Using O3 as a semantic background, and based on the ArchiMate specification and official examples, a number of observations can be made with respect to the expressiveness of ArchiMate in the specification of organizational structures. First of all, we can note that the Business Actor construct is used indistinctly to model both social agents and natural persons. Absence of such distinction prevents the specification from elaborating on rules for the language syntax. For instance, aggregation (a whole-part relation) may be used inadvertently by language users to relate business actors representing natural persons (e.g., Mary as part of John).

Another point of attention identified is related to the inability to indicate that a business role is pertinent to an organizational unit. Despite the absence of such possibility in the current version of ArchiMate, this type of relationship was possible in earlier versions, as explained in (ALMEIDA, 2009). In addition, it is not possible to represent the relation between staff units and line units, a basic notion of organization charts.

There is further no explicit construct for representing missionary units. Although there is a business collaboration construct, it is unclear whether business collaboration results in the definition of a new social agent. Finally, observing the ArchiMate metamodel (Figure 81), business collaboration seems to hide several problems: we can see that business collaboration can aggregate business actors without the intermediary of roles. Moreover, because it is a business role, business collaboration inherits all relationships of the business role construct, thus, an actor can “play” a collaboration. These situations defy a clear interpretation of the business collaboration construct as is.

5.4 METAMODEL REVISION

Considering identified shortcomings, we propose a revision of the metamodel, as shown in Figure 82. Classes marked with darker colors represents constructs added.

The constructs natural person, organizational unit, formal organization, staff unit, line unit, missionary unit and employee type of the revised metamodel have a direct mapping to the corresponding O3 concepts. The business actor construct is partitioned in three sub-categories: formal organization, organizational unit and natural person. The specialization of business actor comes in response to the overload of constructors present in the original meta-model.

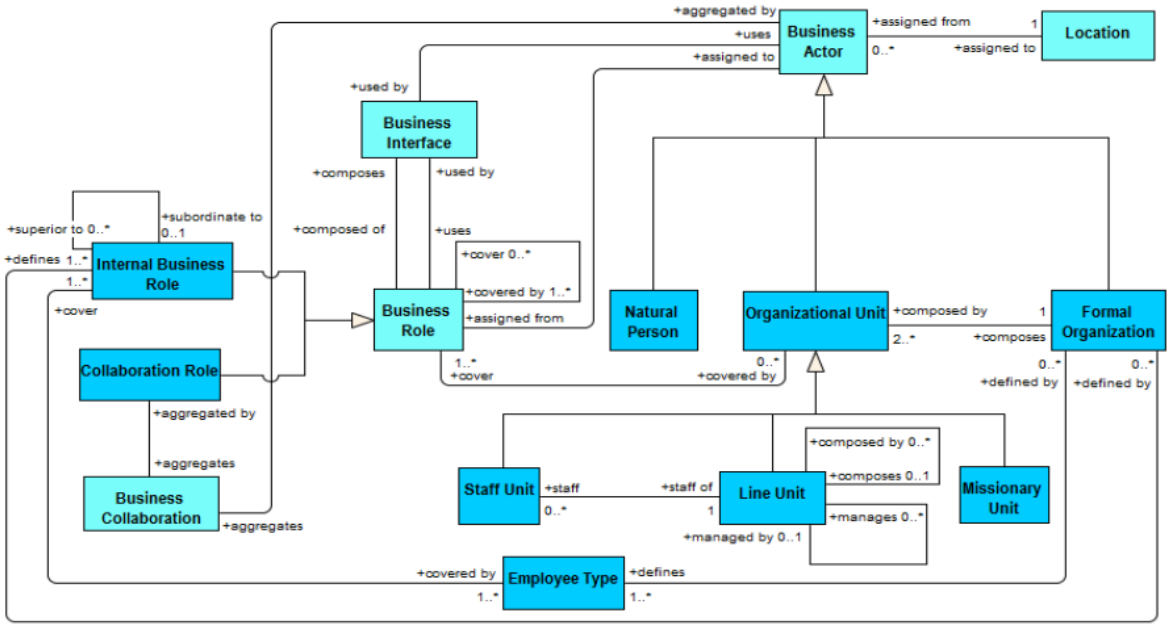

Figure 82. Revised ArchiMate metamodel.

Besides the constructs added to the metamodel, we have added or removed some of the relationships between the constructs of the original metamodel. We modify extensively the business role construct, including a different proposal of semantic interpretation, which eliminates the semantic overload existing between a role in an internal context (played by an employee) and a role in an interaction context, e.g., between a supplier and an organization. In the revised metamodel the business role construct is thus refined into: internal business role and collaboration role.

An internal business role defines more specifically than employee type the capabilities, duties and privileges of an employee who plays a certain role. Moreover, while it is a member of the organization, an agent can play different internal business roles (both at the same time, as well as switching between different roles). The internal business role construct also limits the range of business roles that a member of the organization that plays a certain Business Role can claim (through the "cover" relationship). This situation is common in matrix organizations, where an employee can play a business role in a department and a different business role in a project. A business role is defined in the context of a formal organization.

Collaboration roles represent roles played in recurrent interactions outside and inside the organization. They are defined in the context of the business collaboration

construct, being part of the definition of a collaboration. The collaboration role is more flexible than internal business role, admitting that an external actor (physical or social) may play the collaboration role, while only members of the organization can play internal business roles. In the revised metamodel, the business collaboration construct is no longer a specialization of business role. We made this change in response to the semantic problems that arise from relationships that were inherited from business role in the original metamodel, but that cannot be applied meaningfully to collaborations.

Table 18 presents the interpretation of revised metamodel concepts to O3 concepts.

Table 18. Interpretation of revised metamodel concepts to O3 concepts.

Reviewed Metamodel Concept	O3 Concept
Business Actor	-
Business Role	Business Social Role
Business Interface	-
Business Collaboration	Business Collaboration
Location	Location
Internal Business Role	Business Role
Collaboration Role	Internal Collaboration Business Role External Collaboration Business Role
Natural Person	Natural Person
Organizational Unit	Organizational Unit
Line Unit	Line Unit
Staff Unit	Staff Unit
Missionary Unit	Missionary Unit
Formal Organization	Formal Organization
Employee Type	Employee Type

5.5 CONCLUSION

This section demonstrates the application of O3 in the semantic analysis and improvement of Archimate. The use of the well-founded OntoUML profile for modeling O3 leverages the conceptual distinctions in UFO as well as the tool support already developed for OntoUML. The analysis using O3 has revealed some themes of the literature on organizational structure that have been left out of the range of expressions of ArchiMate. We have proposed a revised metamodel that address the identified

shortcomings, enabling a more sophisticated representation of organizational structures in the language. We have strived to maintain the alignment of the introduced revisions with the original metamodel in order to favor the acceptance by prospective users. Thus many of the additions are in fact specializations of the existing constructs of the language. Further investigation is required in order to propose graphical conventions to represent the abstract syntax elements identified here.

6 PROOF-OF-CONCEPT: GOVERNMENT ONTOLOGY

In order to demonstrate the applicability of O3, in this section we present a domain ontology created by extending it. Our discussion here is based on an ontology of the Brazilian government structure domain, outlined in (MPOG, 2011) by the Ministério do Planejamento, Orçamento e Gestão (MPOG). Our main purpose in this section is to present the applicability of O3 as a core ontology to support the development of domain ontologies. In addition, we aim to demonstrate O3's extensibility. With these purposes in mind, we present a revised version of the ontology outlined in (MPOG, 2011), adapting it to extend the elements defined in O3.

In this chapter, we firstly perform a brief discussion about the original version of the government structure ontology specify in (MPOG, 2011) (Section 6.1). On the sequel, we define a revised version, which extends the elements of O3 (Section 6.2). Finally (Section 6.3), we discuss the application of O3 on the revision of the government ontology.

6.1 THE ORIGINAL ONTOLOGY

The government structure ontology presented in (MPOG, 2011) is represented in OntoUML and extends external ontologies, such as foaf, goodRelations, org and umbel. Some concepts extend many external concepts at same time, but for the purpose of simplification we consider only one extension when presenting the diagrams. Extending an ontology consists in the reuse of semantic definitions for concepts and relationships to create more specific concepts and relationships for a given domain. The extension specializes concepts through the creation of new subtypes and relationships as well as through the redefinition of existing relationships.

The ontology requirements are described in (MPOG, 2011) in the form of competency questions, which are listed below.

- What is the name of a hierarchical government unit?
- What is the acronym of a hierarchical government unit?

- What are the legal responsibilities of a hierarchical government unit?
- What legal diploma established the hierarchical government unity?
- How a hierarchical government unit relates hierarchically with other currently on the federal government?
- Which public organizations are represented in a collegiate body?
- Which public organization a collegiate body is bound?
- To which government agency a public entity is bound?

Figure 83 presents the core of the government structure ontology, which describes the hierarchy of public organizational units and how they are related. The concepts highlighted in yellow represent external elements extended by the government structure ontology. Table 19 presents the external concepts (extended concepts of external ontologies) used by the original government ontology. The left column present the concept described on the original ontology (in yellow). The right column describe the external concepts with the indication of its scope (scope::concept).

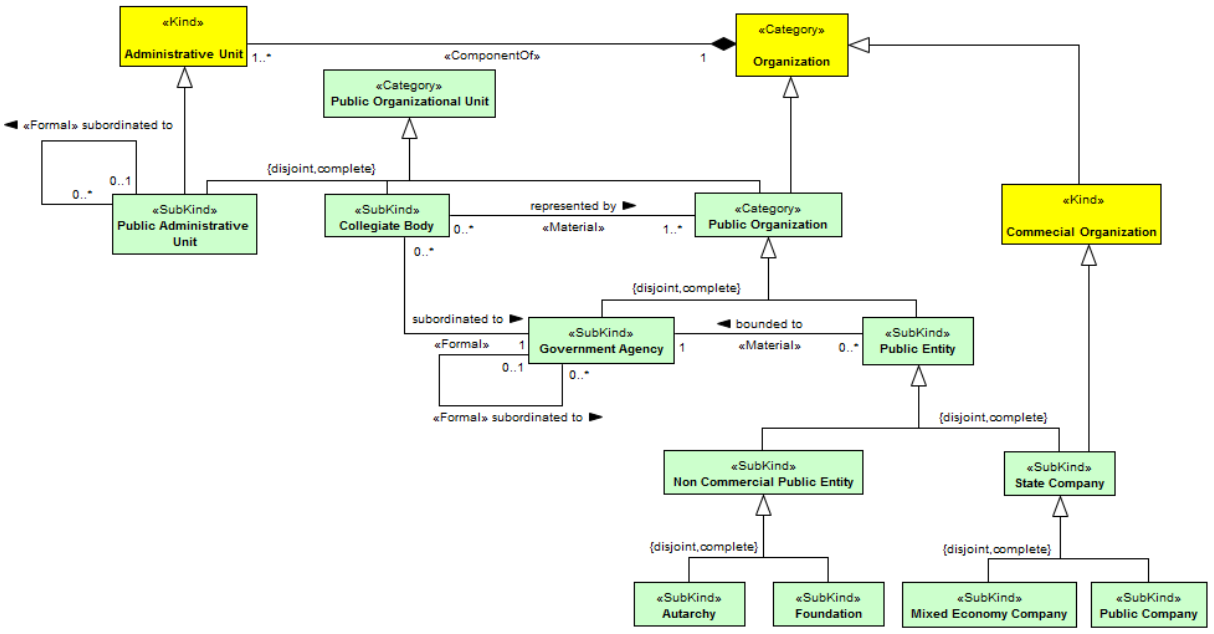

Figure 83. Original government ontology.

Table 19. External concepts used by the original ontology.

External Ontology Concept (Yellow)	External Concepts Referred

Organization	umbel::Organization foaf::Organization org::FormalOrganization
Administrative Unit	umbel::AdministrativeUnit org::OrganizationalUnit
Commercial Organization	umbel::CommercialOrganization goodRelations::BusinessEntity

On the government structure domain, “public organizational units” (*unidade organizacionais públicas*) are “public organizations” (*organizações públicas*), “collegiate bodies” (*órgãos colegiados*) and “public administrative units” (*unidades administrativas públicas*). Public organizations are organizations in its broader sense, i.e., the organizational body as a whole. They are composed by public administrative units, which are formal units created by specific legal instrument (normative). The public administrative unit only has wide recognition within the context of this organization (MPOG, 2011). There is no precise classification of the organizational nature of collegiate body. Here, we will limit ourselves to point out that they are “represented by” public organizations, and are “subordinated to” a government agency. In (MPOG, 2011), an alternative interpretation is presented in natural language, which specifies a collegiate body having pluripersonal composition comprising representatives of government agencies or entities and, if applicable, also of private entities.

Public organizations are refined in “government agencies” (*órgãos*) and “public entities” (*entidades públicas*). A government agency is part of the direct public administration and configures the government administrative hierarchy (through the “subordinated to” relationship). In their turn, public entities are refined as “noncommercial public entities” (*entidades públicas não empresariais*) and “state companies” (*estatais*). Public entities are bound to government agencies, but have their own legal personality, administrative and financial autonomy (MPOG, 2011). Despite having own legal personality of non-commercial public entities, these entities cannot be considered companies, such as the “autarchies” (*autarquias*) and the “foundations” (*fundações*). In turn, state companies are commercial organizations with company characteristics, such as public companies (e.g. Dataprev) and the mixed economy companies (e.g. Petrobras).

Finally, the autarchies and the foundations are non-commercial public entities and differ on the nature of their functions. As defined in (MPOG, 2011), the autarchies perform typical activities of public administration, which require, for their better functioning, decentralized administrative and financial management while the foundations develop activities that do not require implementation by government agencies or public right entities. On the other hand, public companies are constituted exclusively by capital of the Union. They are established by law for the operation of economic activities that the government is led to perform by contingency or administrative convenience (MPOG, 2011). Similarly, mixed economy companies are joint-stock companies constituted by public and private capital, with the Union as the majority actionist.

6.2 THE REVISED ONTOLOGY

Figure 84 shows the main concepts of the revised ontology. The revised ontology extends elements of O3 and specifies new elements relevant to the domain. The description of additional elements (highlighted in green) is performed with the purpose of illustrating the potential of O3 in the development of domain ontologies. We avoid repeating unaltered definitions, and focus only on the differences between the original government structure ontology and its revised version.

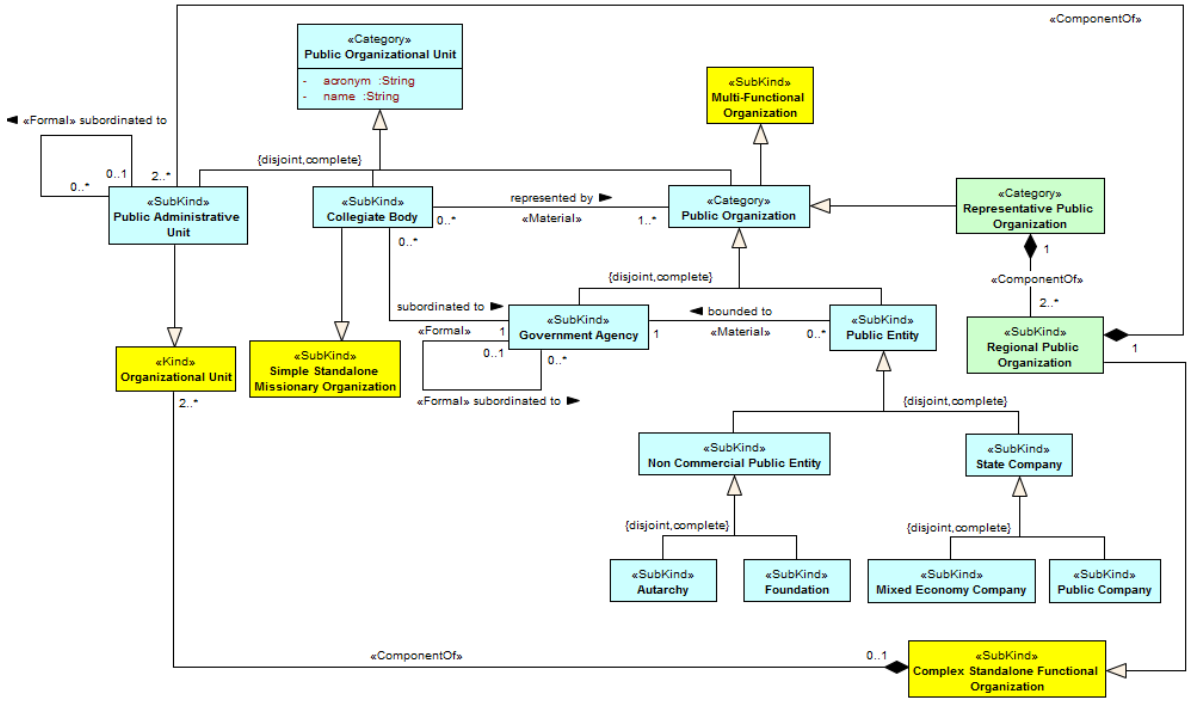

Figure 84. Revised government ontology – Organizational structure aspect.

First, we replaced the external elements extended by the original government structure ontology by O3 concepts. We understand that public organizations are multi-functional organizations, since their main purpose is to deliver a service to the population and they are externally formally recognized. Further, they can be decomposed in other functional organizations.

The concept collegiate body is classified as a simple standalone missionary organization due to its “council” characteristic and structure. According to the definition of the Oxford English Dictionary, a council is a formally constituted advisory, deliberative, or legislative body of people. The nature of the term collegiate concerns the form of management in which the direction is shared by a group of people with equal authority, making joint decisions. Its members come from administrative units as representatives. In addition, a collegiate body “has no formal structure, and its executive office services are mandatorily provided by administrative units already part of the structure of any of its representatives” (MPOG, 2011).

Originally related with public organizations, on the revised ontology the concept public administrative unit describes an administrative unit internal to a regional public organization. It is classified as organizational unit due its limited recognition scope. An

organizational unit only has full recognition within an organization. The choice of relating public administrative unit with regional public organization is associated with the reclassification of the concept public organization.

As a common arrangement, we also define a new concept for regional arms of a certain public organization, namely regional public organization. A regional public organization is a complex standalone functional organization and describe the many subsidiary related with a public organization to attend regional demands. We have to point out the abstract nature of multi-functional organizations. A multi-functional organization gives identity and general recognition for the union of its formal parts, namely here regional public organizations.

With the purpose of demonstrating the full potential of O3, we specify some complementary concepts to address the human resource aspect of the entities that compose the government administration. In this view, we are concerned with how people are related with public organizational agents. Figure 85 illustrates this perspective.

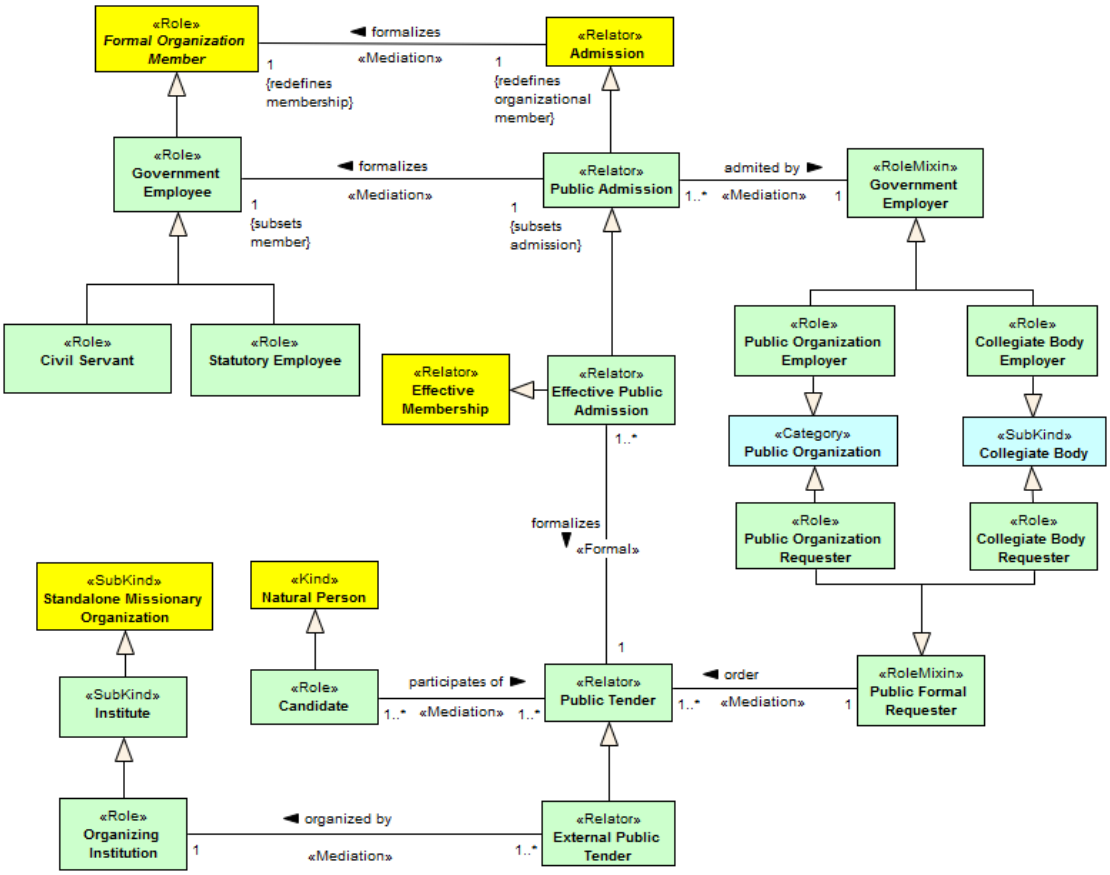

Figure 85. Revised government ontology – Human resource aspect.

Unlike what happens in the private sector, employees associated with the public sector have their own legal characteristics. Of course, we do not try to go into details about the legal regulations and administrative law in this work, but rather indicate the essence of the characteristics necessary for the classification of an employee of the public sector.

The main concept of this view is the government employee. A government employee basically is a person working for the government. Note that an important constraint here is related to the guarantee that a government employee only will be associated with a public organization or collegiate body. The nature of the admission of a government employee is a public admission, which has the peculiarity of requiring a public tender for the case of admission to effective positions (effective public admission). A public tender may have many candidates and is organized by an institute selected by a public formal requester. Public Organizations and collegiate bodies can act as public formal requesters.

A government employee is refined in civil servant and statutory employee. Civil servants are those working under a regular private sector employment contract (CLT rules) having peculiarities about stable employment and retirement. In contrast, statutory employees are those related directly to the exclusive functions of the state and are governed by the federal constitution. Because of the complexity inherent to the distinctions between these two types of employees, it is not the scope of this ontology to describe these characteristics in detail. These descriptions can be specified on an extension of this ontology.

6.3 CONCLUSION

In this chapter we presented a revision and extension of an existing government ontology for incorporating some of the O3 distinctions. Regarding the organizational structure aspect (first revised ontology fragment), the revised ontology allows semantic distinctions about the internal structure of an organization. This can be visualized on the specialization of the concepts Multi-Functional Organization, Simple Standalone Missionary Organization and Organizational Unit by, respectively, Public Organization, Collegiate Body and Public Organizational Unit. The benefit of use of O3 for the development of a domain ontology resides on reusing its basic organizational distinctions, which help to avoid semantic problems.

In addition, we provided an example of a possible application of O3 for extending the scope of the original government ontology. Here, we described also the human resource aspect, which includes the notion of Public Tender and Government Employee. Our goal is to demonstrate how the basic semantic distinctions can be used to define more specific organizational concepts, according to a given domain.

7 FINAL CONSIDERATIONS

This work presented a well-founded ontology for the active structure domain. The active structure domain ontology presented covers the basic aspects discussed in the organizational representation literature, such as division of labor, social relations and classification of structuring units.

In this chapter we present and discuss similar works in Section 7.1. In the sequel, we perform a general analysis of the contributions in this master's thesis. Finally, we provide a discussion about the limitations of this work and a vision about its possible evolutions.

7.1 RELATED WORKS

Given the recognized importance of active structure in the description of enterprise architectures, many approaches have been proposed to meet this need. Among these approaches are included modeling languages and ontologies, which were discussed in detail in Section 2.3.

Going beyond the analysis of approaches to the description of the organizational active structure, we can mention works with purposes similar to ours. In (NARDI et al., 2013), Nardi et al. propose a commitment-based account for the notion of service captured in a core reference ontology called UFO-S. In their work, Nardi et al. "address the commitments established between service providers and customers, and show how such commitments affect the service lifecycle". Their ontology, like O3, is grounded in UFO (in their case UFO-A, UFO-B and UFO-C). As result, UFO-S can serve to harmonize different notions of service in the literature.

Another similar work is presented in (BRINGUENTE, 2011). In her work, Bringuente proposes a well-grounded software process ontology (SPO) in order to provide support for system integration at semantic level. "In this context, a domain ontology can be used to define an explicit representation of this shared conceptualization and as reference during the integration process. In order to suitably serving as a reference

model, SPO has gone through a process reengineering based on UFO" (BRINGUENTE, 2011).

7.2 CONTRIBUTIONS

The main contributions of this master's thesis are presented below.

- **Organizational structure reference model (O3).** O3 is a reference model for organizational structure description and communication. The ontology is partitioned in seven viewpoints, namely: organizational structure, allocation, organizational role, social relationships, capability, resource and business collaboration. Its viewpoints address many organizational aspects common to the organizational representation literature and existing approaches. O3 provides a well-founded core ontology for the active structure domain, which has practical applications in the context of domain ontology engineering, semantic analysis of modeling languages and semantic harmonization between models and systems.
- **Comparative analysis of existing organizational approaches.** As part of the evaluation process of O3, we have performed an analysis of the existing approaches against the organizational aspects specified (Section 3.1.1). This analysis provides input for future researches, as it provides an overview of the expressivity of the analyzed ontologies and modeling languages. Here, the shortcomings and qualities of each approach are pointed out by a classification of its concepts according to basic organizational aspects (defined in 3.1.1).
- **Well-founded government domain ontology.** Built with the purpose of presenting a proof-of-concept, the revised government ontology, presented in Chapter 6, is a well-founded ontology for the government domain. Among the benefits of this revision we can include the increase of semantic ground of the ontology. Further, this ontology can be implemented in OWL and integrated with existing ontologies to provide semantic support to linked open data publishing.
- **Semantic analysis and revision of ArchiMate.** Chapter 5 performs a semantic analysis of the well-known modeling language ArchiMate. A revised metamodel for the active structure aspects has been presented in order to suggest a means

to solve the identified shortcomings. The result of this work may increase the expressivity and semantic precision of ArchiMate (subset of concepts related with active structure). This effort was published in FOMI 2014 (PEREIRA; ALMEIDA, 2014).

7.3 DISCUSSION

Regarding of O3 scope, we have intentionally left out behavior aspects like business services and business functions. Although O3 does not cover these aspects, the ontology provides a means for future work to extend it, in order to cover other relevant aspects to Enterprise Architecture.

The use of reference ontologies for evaluating and revising enterprise modeling languages have been shown to be promising, as observed in (AZEVEDO et al., 2011)(ALMEIDA, 2009)(SANTOS; ALMEIDA; GUIZZARDI, 2013)(ALMEIDA; GUIZZARDI, 2013). The analysis in Chapter 2 showed an overview of the expressiveness of the analyzed approaches. As a result, the shortcomings and qualities of the approaches were explained (chapters 4 and 7) in order to guide further analysis in search of the solution of these deficiencies.

The use of the well-founded OntoUML profile for modeling O3 leverages the conceptual distinctions in UFO, as well as the tool support already developed for OntoUML.

Future works in the development of O3 include the systematic implementation of O3 in computational level languages such as OWL. This effort can support the semantic alignment of relational databases for future publications in Linked Open Data. In addition, the publication of O3 and its integration with existing published ontologies may to provide a semantic reference for other ontologies.

The analysis using O3 has revealed predominant themes of the literature on organizational structure – those that have influenced the design of the O3 – have been left out of the range of the analyzed modeling languages. We have proposed a reference ontology that provides a good coverage, enabling a more sophisticated

description of organizational structures. Although we endeavor to accurately describe organizational aspects, we do not provide means for ensuring its effective application as conceptual language, once O3 does not describe a metamodel (abstract syntax) either presents a notation (concrete syntax). Future work on specifying a modeling language based on O3 to support modeling activities seems promising.

7.4 SHORTCOMINGS

The result of this work contributes to a better understanding and conceptualization of the organizational domain. Despite the effort to represent the various organizational aspects, the ontology has shortcomings which are the result of the choices made during the course of this work. For example, O3 does not support temporal aspects, such as the natural changes that affect the organizations. The ontology only provides a conceptualization of a “snapshot” of the organization and does not describe its multiple structures in the time. Differently, the W3C Org ontology provides means for a (simplistic) representation of organization changes through “change events” which generates a new organization.

O3 provides support for all identified organizational aspects, demonstrating significant expressivity. While this broad coverage is necessary considering the intended scope of use of O3, this choice may prove to be counter-productive for some simple applications. One example is its use to provide an implementation of OWL files, in order to publish linked open data. Its details may overload the generated file with irrelevant aspects. In addition, some second order concepts can be difficult (or impossible) to be represented in OWL.

Despite our effort to provide sufficient expressivity, O3 has limitations to describe the organizational external environment. The ontology addresses only business collaborations, but does not differentiate the many kinds of collaborations that may exists between organizations and external agents; for example, it does not differentiate between providers and consumers in collaborations (e.g. it is not possible to determine in a supply chain if an organization is a supplier or a consumer). However, the

distinctions of UFO-S (NARDI et al., 2013) can be incorporated into O3. This task is facilitated by the fact that both share common foundations (UFO).

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