

# Applying and Extending a Semantic Foundation for Role-Related Concepts in Enterprise Modelling

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In this paper, we provide a semantic foundation for role-related concepts in Enterprise Modelling. We use a conceptual modelling framework to provide a well-founded underpinning for these concepts. We review a number of Enterprise Modelling approaches in light of the concepts described (namely, ARIS, Archimate, DoDAF, RM-ODP and BPMN). This allows us to understand the various approaches, to contrast them and to identify problems in their definition and/or usage. We start with a core set of concepts and then extend this set to address the social aspects of actors and roles in an organization. In particular, this enables us to investigate the actor-role relations in further detail.

Keywords: roles, actors, enterprise modelling, conceptual modelling, object modelling

## 1 Introduction

The concept of “role” is present in several Enterprise Modelling approaches [21, 26, 28, 33]. In most of these approaches, enterprise activities are performed by entities which are called “actors”, “agents” or “objects” and that can be said to play “roles” in these activities. Typically, the concept of role is used to define the responsibilities and properties that apply to “actors” while playing “roles” and what actions (or kinds of actions) are performed by which “actors”.

“Roles” are also highly relevant when discussing the actions that are performed by users in interaction with a service or system and the service behaviour with respect to user interaction. In this case, it becomes necessary to define the (kinds of) actions that may be performed by particular (kinds of) users as well as the representation of users’ identities and their properties in the scope of the service or system.

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As discussed in [22] the role concept is based on a theatrical metaphor: “The text of a play is expressed in terms of lines and actions associated with various roles, which are declared initially in a cast-list. Putting the play on involves assigning actors to the various roles, although one actor may play several minor roles, and the actor playing a role may change during the run of the production. Identifying the roles rather than the actors obviously makes the script more reusable.” Similarly, defining an enterprise or service model in terms of “roles”, allows the model to remain stable in the presence of dynamic changes in role playing.

Although the term “role” is significantly present in Enterprise Modelling approaches, under close inspection, we can conclude that it often denotes different underlying concepts with different basic properties. Given the importance of roles in Enterprise Modelling, a clear semantic account for roles and role-related concepts is necessary and would serve as a basis for communication, consensus and alignment of the various approaches.

In this paper, we provide a semantic foundation for the role-related concepts in Enterprise Architecture and Enterprise Modelling languages. Our claim is that some theories of conceptual modelling (as consolidated in [13]) provide a well-founded underpinning for these concepts, and allow us to harmonize competing proposals for them.

We review a number of Enterprise Modelling approaches in light of the proposed semantic foundation: Archimate, DoDAF, ARIS, BPMN and the RM-ODP (Enterprise Viewpoint). This allows us to contrast the approaches and to identify the problems in the definition, interpretation and/or usage of role-related concepts which could lead to ambiguous and vague Enterprise Models. This is relevant from the perspective of modellers who must select and manipulate modelling elements to

describe an Enterprise Architecture and from the perspective of stakeholders who will be exposed to models for validation and decision making. In other words, a clear semantic account of the concepts underlying Enterprise Modelling languages is required for Enterprise Models to be used as a basis for the management, design and evolution of an Enterprise Architecture. We start with a core set of concepts we have introduced in previous work [2] and then in section 5, we extend this set to address the social aspects of actors and roles in an organization. In particular, this enables us to investigate the actor-role relations in further detail.

## **2 Features of the role concept**

Steimann [31, 32] has identified a number of features for roles that appear throughout the object-oriented and conceptual modelling literature (e.g., [9, 10, 11, 12, 13, 23, 24, 36]). We list each of those and introduce some examples to provide an intuitive notion of the role concept, prior to its rigorous definition:

- 1) *“A role comes with its own properties and behaviour.”* For example, when John is enrolled as a student at the University of Twente, he has a grade point average (GPA), he can register to courses, receive grades, produce assignments, take exams, etc. This feature seems to suggest that roles can be regarded as a “type” characterizing a number of instances.
- 2) *“Roles depend on relationships.”* For example, the roles of husband and wife as well as customer and supplier depend on the existence of a marriage or a business relationship. This is confirmed by the usage of the concept of role in the conceptual modelling literature as discussed in [13, 32] and as quoted in [10]: “as suggested by the work of Sowa and Guarino, a role is meaningful

only in the context of a relationship.” This feature makes the concept of role distinct from that of a phase or a state [32].

- 3) “*An object may play different roles simultaneously.*” For example, John can be a student and a husband at the same time.
- 4) “*An object may play the same role several times, simultaneously.*” John can be a student at the University of Twente and at the Tai Chi Institute simultaneously.
- 5) “*An object may acquire and abandon roles dynamically.*” John is still a Person after he graduates from the University of Twente.
- 6) “*The sequence in which roles may be acquired and relinquished can be subject to restrictions.*” For example, John can only register in a graduate school after he has completed an undergraduate course.
- 7) “*Objects of unrelated types can play the same role.*” For example, both a person (John) and an organization (the University of Twente) can play the role of customer in different business relationships.
- 8) “*Roles can play roles.*” For example, John can play the role of teaching assistant for a particular course only if he is a student at the University of Twente.
- 9) “*A role can be transferred from one object to another.*” For example, the commitments and responsibilities of the role of president are transferred from the incumbent president to his/her successor.
- 10) “*The state of an object can be role-specific.*” If John is a student at the University of Twente and at the Tai Chi Institute simultaneously, John has a GPA for each of those relations.

11) “*Features of an object can be role-specific.*” John attends all classes at this undergraduate course at the University of Twente but at the same time misses several classes in a row at the Tai Chi Institute.

12) “*Roles restrict access.*” We consider this an implementation-oriented feature, considered by Steimann since he has surveyed object-oriented approaches in general. Since we are concerned with conceptual models for enterprise architectures, we do not include this feature further in our discussions.

13) “*Different roles may share structure and behaviour.*” For example, both graduate students and undergraduate students have a student number, may register to courses, etc.

Features 14 and 15 contradict each other, showing that there is lack of agreement with respect to these features in the literature surveyed by Steimann:

14) “An object and its roles share identity.”

15) “An object and its roles have different identities.”

These features lead to the question of whether “John”, “John as a student of the University of Twente”, “John as a student of the Tai Chi Institute” and “John as a husband” are the same, or whether there should be different identities for each of the roles John plays.

### **3 Role-related concepts in conceptual modelling**

We proceed to identify a rigorous definition of the role concept, which requires some preliminary definitions. We use an extract from a philosophically and cognitively well-founded reference ontology (foundational ontology) that has been developed in [13, 14].

First, we distinguish between conceptual entities called *universals* and *individuals* [13]. The notion of universal underlies the most basic and widespread constructs in conceptual modelling. Universals are predicative terms that can possibly be applied to a multitude of individuals, capturing the general aspects of such individuals. Individuals are entities that exist possessing a unique identity.

Figure 1 shows an extract of the foundational ontology adopted here (all generalization relations depicted in this figure are disjoint, forming a simple “tree-like” taxonomic structure for the entities considered in this model.)

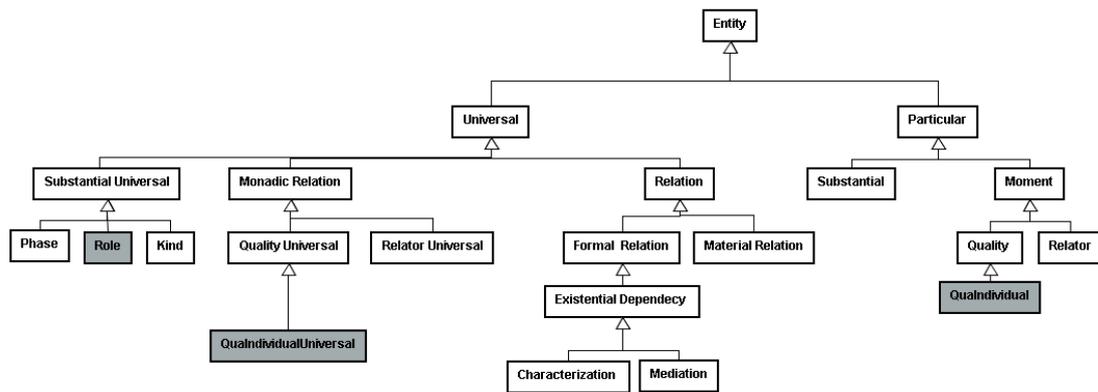


Figure 1. Extract of the foundational ontology adopted here from [15]

This taxonomic structure reveals that an individual can be categorized as substantial or moment [10]. A *moment* is an individual that existentially depends on another individual, named its *bearer*. In the conceptual modelling literature, a moment is said to *inhere* in its bearer. For example, the symptoms of a patient are said to inhere in the patient, who bears the symptoms. In contrast, a *substantial* is an individual that does not inhere in other individuals, i.e., which is not a moment. Inherence is much stronger than a one-to-one relationship, since it implies existential dependence between individuals. We have that an individual  $x$  is *existentially dependent* on another individual  $y$  if, and only if, as a matter of necessity,  $y$  must exist

whenever  $x$  exists. (A moment may also inhere in another moment, the moments forming a finite chain that ends with a substantial.)

In this paper, we characterize “actors”, “agents” or “objects” as *substantials* and we explain the role-related notions in terms of *moments*. We use meta-properties of universals (namely, existential dependence, external dependence and rigidity) to clarify certain aspects of role-related concepts.

### 3.1 *Qua individuals and relators*

The taxonomic structure presented in Figure 1 reveals a kind of individual which is of particular importance to the definition of role (in gray on the right side of the figure): a “QuaIndividual”.

An example discussed in [15] clarifies this concept. Suppose that John is married to Mary. John has a number of properties by virtue of being married to Mary. For example, imagine all the legal responsibilities that John has in the context of this relation. These newly acquired properties are moments of John that inheres in him (and are hence existentially dependent on John). However, these moments also depends on the existence of Mary. This type of moment is called *externally dependent moment*. An externally dependent moment is an intrinsic moment (or quality) that inheres in a single individual but that is existentially dependent on (possibly a multitude of) other individuals external to its bearer (i.e., which is not the bearer’s parts or intrinsic moments). In the example, this other individual is Mary.

In the case of an externally dependent moment  $x$  there is always an event which is the foundation of  $x$ . Again, in the given example, we can think of a certain action  $a_1$  (the signing of a social contract) in which both John and Mary participate and which founds the existence of the externally dependent moments inhering in John. Now, we can define an individual that bears all externally dependent moments

of John that share the same external dependencies and the same foundation. This individual is called a *qua individual* [23]. Qua individuals are, thus, a special type of complex externally dependent qualities. In this case, the complex quality inhering in John that bears all responsibilities that John acquires by virtue of the signing of a social contract can be named John-qua-husband.

To continue with the same example, we can think about another qua individual Mary-qua-wife which is a complex moment bearing all responsibilities that Mary acquires by virtue of the same foundation and that albeit inhering in Mary are also existentially dependent on John. The qua individuals John-qua-husband and Mary-qua-wife are existentially dependent on each other. Now, we can define an aggregate composed of these two qua individuals that share the same foundation. This aggregate is called a *relator*.

### **3.2 Role universals**

The taxonomic structure in Figure 1 also reveals a “Role” universal. A “Role” universal applies contingently to an individual that bears (at least one) qua individual of a certain type. In the example presented in the previous sub-section, we can say that John is not only an instance of a “Person” universal but also an instance of a “Husband” universal, while Mary is both an instance of a “Wife” universal. All instances of a “Husband” universal exhibit the behaviour required of a husband in a social contract (marriage).

At the same time John may play the role of student with respect to an “Educational Institution” for example, the University of Twente. In this case, John bears a qua individual John-qua-student, and is an instance of the “Student” universal (John can register to courses, receive grades, produce assignments, take exams, etc.).

Further, John may also play the role of student with respect to other “Educational Institutions”, for example, the Tai Chi Institute – bearing then qua individuals: John-qua-student of the University of Twente and John-qua-student’ of the Tai Chi Institute.

We can say that roles universals can be restricted by certain allowed or admissible types, i.e., certain universals to which a role universal can apply. For example, in this case, we can say that the “Student” role can only be played by an instance of the kind “Person”. A kind is the substantial universal which supplies a principle of identity for its instances and that is instantiated necessarily by its instances. Figure 2 shows a class diagram for this example, using the profile defined in [13]. The characterization association represents that instances of “PersonQuaStudent” inhere in an instance of “Student” (thus characterizing its behaviour).



Figure 2. A role universal, its allowed type and a qua individual universal (from [13])

Figure 3 reveals the Enrolment relator universal (an instance of this universal includes an instance of “PersonQuaStudent”). The relator universal reveals that both an instance of “Student” and an instance of the “Education Institution” exhibit particular properties (shared behaviour) in the relation. Please note that properties are merely a dual way to represent behaviour.

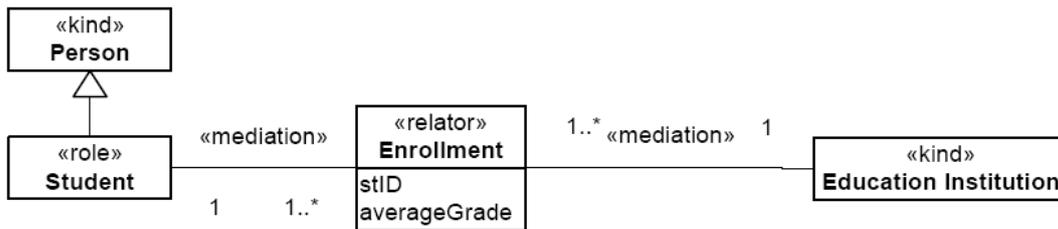


Figure 3. A role universal, its allowed type and a relator universal (from [13])

### 3.3 Role mixin universals

The conceptualization in [13] also allows for a notion of *role mixin universal* which captures commonalities in various role universals. This universal is used in a conceptual modelling design pattern for “roles with multiple disjoint allowed types” (see Figure 4). (We omit the description of role mixins from this paper, please see [13] for a comprehensive discussion and characterization of a role mixin as an anti-rigid non-sortal universal.) Intuitively, a role mixin universal allows us to add flexibility to a role universal, without tying its definition to a specific kind. In the example, it is possible to define a Customer independently of whether Persons or Organizations play that role.

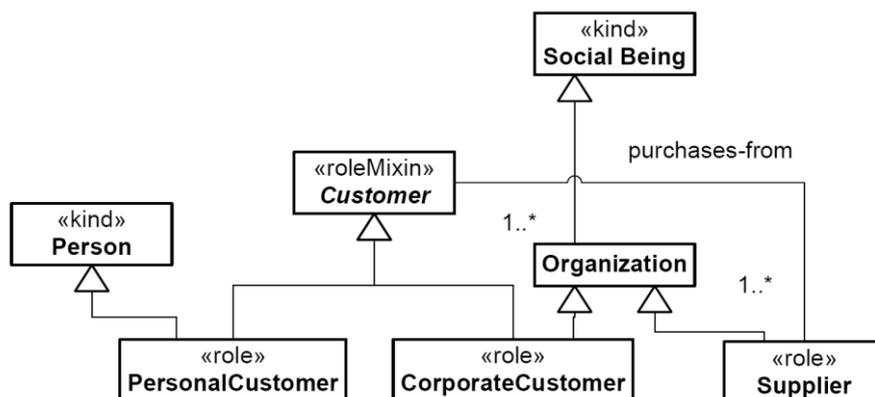


Figure 4. Modelling roles with multiple disjoint allowed types (an example from [13])

### 3.4 Examples

Table 1 summarizes the various examples presented throughout this paper and the concepts they illustrate.

<b>UFO-A</b>	<b>Example</b>
role universal (a role universal applies(contingently) to instances of the role's allowed type.)	Husband; Wife; Student; PersonalCustomer; CorporateCustomer.
role mixin universal (These universals apply (contingently) to instances of disjoint admissible types.)	Customer
instance of the role universal (individual that bears a qua individual) (instance of an admissible type for the roles involved)	John; Mary;
universals of the admissible types for particular roles	Person (admissible type for roles Husband, Wife, Student, Personal Customer); Organization (for CorporateCustomer); Customer (for CorporateCustomer and PersonalCustomer);
qua individual (A qua individual is the instance that characterizes the individual with certain behaviour in the context of a relation to another individual.)	John-qua-husband; Mary-qua-wife; John-qua-student (of the University of Twente); John-qua-student' (of the Tai Chi Chuan Institute).
qua individual universal	Person-qua-Student; Person-qua-Husband; Person-qua-Wife.
the foundation of the qua individuals (and hence the foundation of the relator, i.e. a founding action or behaviour.)	the signing of the social contract; the act of enrolling at the university; the act of enrolling at the Tai Chi Chuan Institute.
relator (an aggregate of the qua individuals in the relation.)	John and Mary's marriage; John's enrolment at the University of Twente; John's enrolment at the Tai Chi Chuan Institute.
relator universal	Marriage (this kind of social contract); Enrolment (this kind of social contract).
individuals that are mediated by a relator	John and Mary; John and the University of Twente; John and the Tai Chi Chuan Institute.

Table 1. Correspondence between role-related concepts in UFO-A and examples

### **3.5 Role-related concepts in the foundations and the features presented by Steimann**

We can consider the foundations with respect to each of the features of role-related concepts as presented by Steimann:

- 1) "*A role comes with its own properties and behaviour.*" Yes, a qua individual characterizes (with properties and behaviour) the substantials that play a particular role.
- 2) "*Roles depend on relationships.*" Yes, a qua individual is externally dependent.
- 3) "*An object may play different roles simultaneously.*" Yes, several qua individuals may characterize the same substantial.
- 4) "*An object may play the same role several times, simultaneously.*" Yes, several qua individuals that characterize a substantial may be instances of the same universal.
- 5) "*An object may acquire and abandon roles dynamically.*" Yes, a role universal applies contingently to substantials. In other words, a qua individual describes a complex of contingent properties of individuals.
- 6) "The sequence in which roles may be acquired and relinquished can be subject to restrictions." Yes, one can define conditions for the foundation of relators.
- 7) "*Objects of unrelated types can play the same role.*" Yes, the mixin universal can be used in the design pattern for "roles with multiple disjoint allowed types".
- 8) "*Roles can play roles.*" Yes, it is possible to restrict the admissible type of a role to another role.
- 9) "*A role can be transferred from one object to another.*" Yes, this only requires one to define rules for the foundations of relators.
- 10) "The state of an object can be role-specific." Yes, see 1.
- 11) "Features of an object can be role-specific." Yes, see 1.

13) “*Different roles may share structure and behaviour.*” Yes, a role universal may specialize another role universal or role mixin universal.

With respect to contradicting 14 and 15 we can conclude:

14) “*An object and its roles share identity.*” Yes, if one considers that roles are ultimately played by a substantial that carries a principle of identity.

15) “*An object and its roles have different identities.*” Yes, the qua individuals have identities of their own.

## **4 Role-related concepts in Enterprise Modelling**

In this section, we review role-related concepts in a number of enterprise modelling approaches (Archimate, DoDAF, ARIS, BPMN and RM-ODP). We contrast the definitions and usage of concepts in these approaches with the UFO-A conceptualization described in section 3.

### **4.1 Archimate**

In the Archimate Enterprise Architecture language [19, 21], the concepts of “business actor” and “business role” are introduced. A business actor is defined as an active entity that performs behaviour [21]. Examples of business actors include an individual person, a department and a business unit. A business role is identified with the purpose of making “the link between actors and behaviour more flexible.” A business role is defined as that which “states which business behaviour is performed by a business actor that fulfils this role.”

Intuitively, the definitions seem to imply that the business actor concept is a *substantial* and that the business role concept is a *role universal* that may be applied to actors (although the criteria of external dependency is not explicitly mentioned).

The language allows “actors” and “roles” to be related by what is called “assignment”. Figure 5 shows an example of Archimate model with actors depicting “actors” and “roles”. In this example, an “actor” named “Client” is assigned to the “role” named “Insurance buyer”, which executes the behaviour “Buy insurance”. Further, the actor “ArchiSurance” is assigned to the “role” named “Insurer”, which executes the “Take out insurance” behaviour.

Although the definition for “actor” seems to imply that an “actor” is an *individual*, the language makes no distinction between the “actor” as an *individual* and a *universal* for “actors”. This can be observed in the example show in Figure 5. The figure shows the “ArchiSurance” “actor” which denotes a particular insurance company, i.e., it represents a particular *substantial individual*. Nevertheless, it also shows a “Client” “actor” which is certainly not tied to a particular client (such as “John”) (otherwise the business process itself would be client-specific.) We can conclude that a “Client” in this case represents a *universal* for actual clients which may participate in the business process. Based on this example, we can state that the language lacks expressiveness with respect to the distinction between *universals* and *individuals* when considering the “actor” concept. Thus, this lack of expressiveness leads to a construct overload, which reduces the clarity of the language.

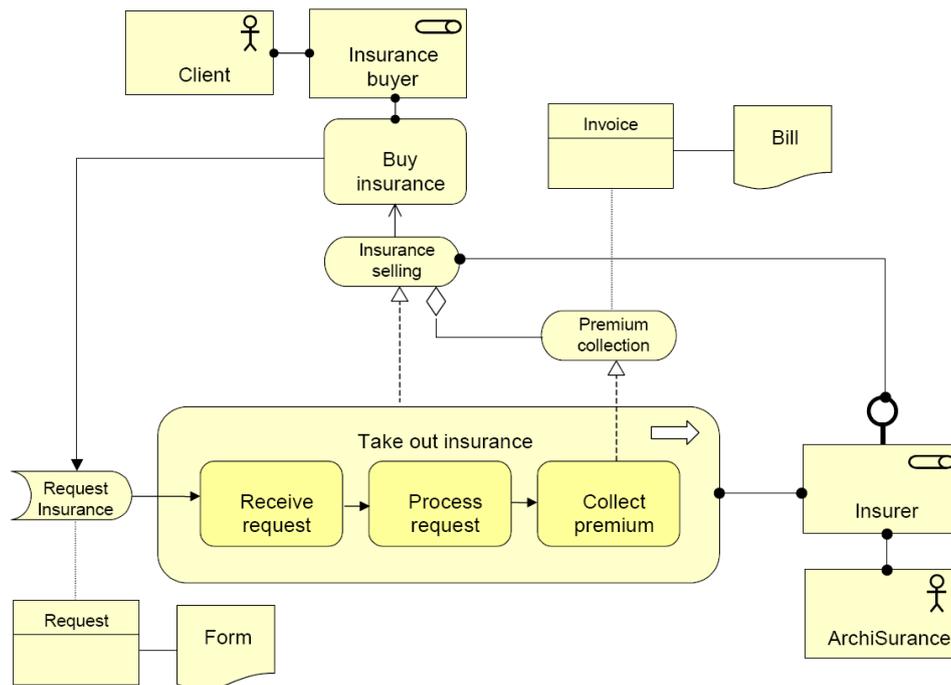


Figure 5. Archimate model (from [20])

#### 4.1.1 Concept analysis: Interpretation A (Actors denote universals)

A feasible interpretation to enable our analysis is to consider all “actors” in Archimate to denote *universals*, with certain “actors” representing *universals* that have only one instance (and, hence, are singletons, such as “ArchiSurance” in the example presented in Figure 5). Nevertheless, even with this interpretation, the language would not allow one to identify which universals are singletons and which are not.

Under this interpretation, we consider that the “assignment” relation represents a specialization/generalization relation between a *role universal* and its *admissible type*. In this particular example, instances of “Client” are the individuals that can play the role of “Insurance buyer”, i.e., that can instantiate the “Insurance buyer” universal.

#### 4.1.2 Concept analysis: Interpretation B (Actors denote individuals)

An alternative interpretation would be to consider that the actor modelling element indeed represents *individuals* and that Figure 5 represents an abuse in notation and that in this case “Client” should be omitted from the model. This would be consistent

with the usage of the “actor” modelling element in several examples in the Archimate documentation. See Figure 6 for an example of an Archimate model with a nesting of actors, all of which are *individuals* (nesting of actors in Archimate implies either aggregation or composition with no notational distinction possible).

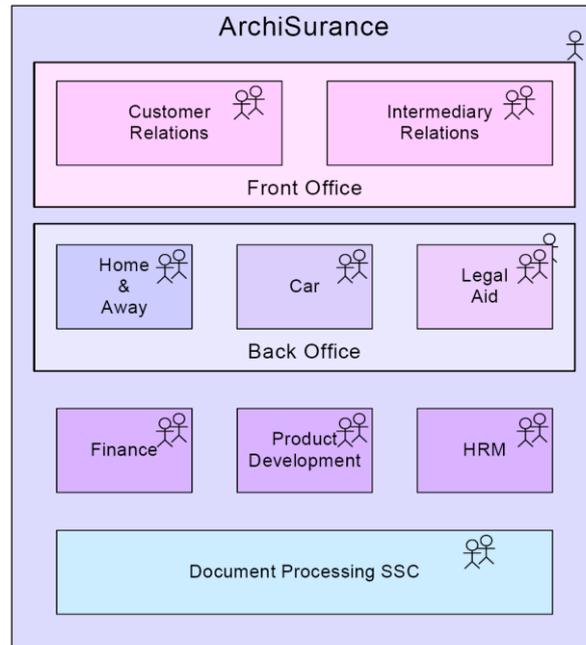


Figure 6. Organization model (from [19])

Another example that corroborates this interpretation is presented in Figure 7. The figure shows specific persons (“A. Smith”, “D. Jones”, and “M. Baker”) as “actors” which are part of the departments of the insurance company.

Under interpretation B, we consider the assignment relation (shown in Figure 7) to show that the actor is an *instance of the role universal* represented by the role modelling element. No statement is thus made about admissible types in general.

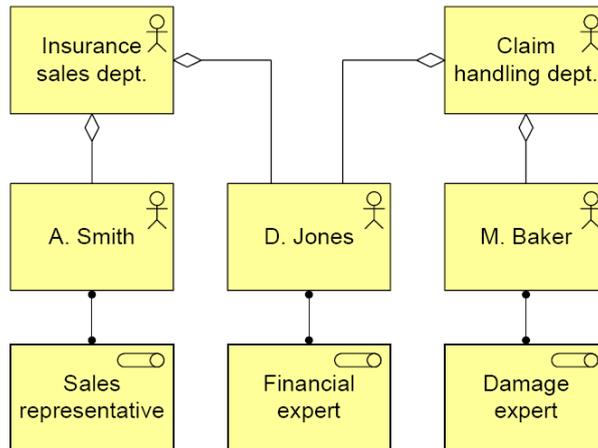


Figure 7. Organization model (from [19])

This interpretation would imply that Archimate cannot represent *universals* for actors (the resemblance of Figure 7 with the UML Class Diagram notation is unfortunate in this case, since the relations should be interpreted as links that relate the whole to the part).

#### 4.1.3 Generic relations

The Archimate language has a number of generic relations which can be applied between a number of modelling elements. Nevertheless, the detailed semantics of these relations when applied to particular kinds of concepts is not always clarified. A particular example is the “specialization” relation.

The Archimate language reference manual [19] defines that “the specialization relationship can relate any instance of a [modelling] concept with another instance of the same concept.” The case of specialization of roles is mentioned explicitly (e.g., ‘junior’ and ‘senior’ specializations of the same role [20]), thus corroborating our claim that roles are *role universals*. Nevertheless, the case of specialization of “actors” is not mentioned explicitly. Specialization of “actors” would be acceptable under interpretation A, but would be impossible under interpretation B (the specialization relation is a relation between *universals*).

Other relations are “aggregation” and “composition”. These can be applied between “actors” (as shown in Figure 6 and Figure 7), between “roles”, and also between “actors” and “roles” (as shown in Figure 8.) Please note that from this model it is impossible to derive the cardinality of the relation (i.e., should we interpret this model as stating that there can be multiple “Damage experts” in a “Claim handling department”?)

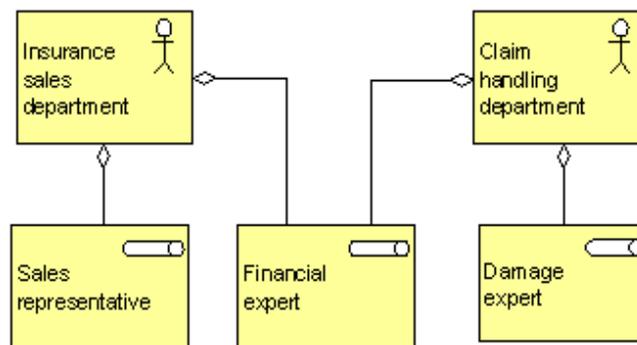


Figure 8. Relations between actors and roles [1]

Although examples of organigrams such as the one presented in Figure 9 appear in the Archimate Resource Tree [1] and in examples of tools such as BizDesign Architect [4], the semantics of the “relations” between “actors” is not discussed in the Archimate language reference manual. Ideally, these “relations” should be *instances of material relations* that are derived from *relator universals*. Relator universals would define the particular attributions of each of the *relata*, and their dynamics (creation and destruction) could be defined in the context of business processes.

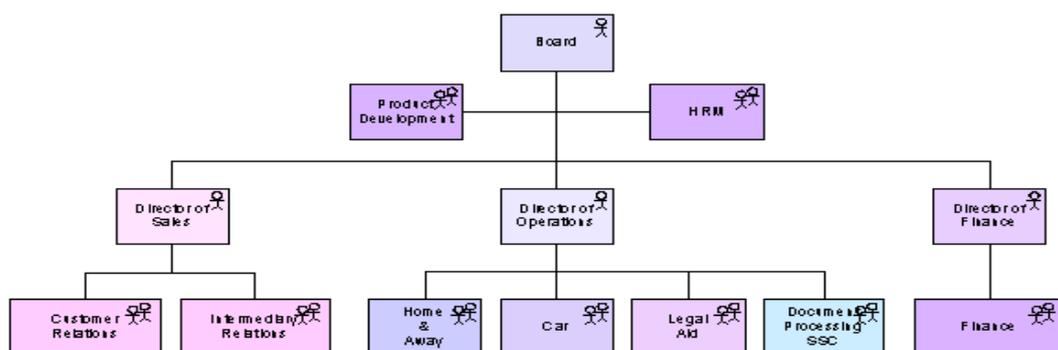


Figure 9. Example of Organigram [1]

## 4.2 DoDAF

The Department of Defense Architecture Framework (DoDAF) [33] defines two products in the Operational View (OV) that include role-related concepts. These are Operational Node Connectivity Description (OV-2) and Organizational Relationships Chart (OV-4).

In OV-2, “An operational node is an element of the operational architecture that produces, consumes, or processes information. What constitutes an operational node can vary among architectures, including, but not limited to, representing **an operational/human role (e.g., Air Operations Commander), an organization (e.g., Office of the Secretary of Defense (OSD)) or organization type, i.e., a logical or functional grouping (e.g., Logistics Node, Intelligence Node)**, and so on. The operational node will also vary depending on the level of detail addressed by the architecture effort.” [33]

In OV-4, “the Organizational Relationships Chart illustrates the command structure or relationships among human roles, organizations, or organization types that are the key players in an architecture.” [33]

The following definitions are provided for OV-4: “Human Role - Skills are needed to perform the operational activities or business processes described in the architecture”; “Organization - An administrative entity with a, identity, structure, and mission.”; “Organization Type - A Class of Organization”; “Organizational Relationship - relationships can include supervisory reporting, command and control relationships, and command-subordinate relationships.”

Based on the definitions, we can, intuitively, interpret the “Human Role” concept as a *role universal* with an *implicit admissible universal* to represent humans.

Further, we can interpret “Organization” as a substantial, and “Organization Type” as a *kind*. There is no concept for *kinds* or *substantials* when applied to model humans.

DoDAF proposes a number of UML styles for representing an architecture, including the aspects of the architecture that are related to *roles* and *substantials*. Figure 10 shows the proposed UML style for OV-2. Similarly to Archimate, “roles” are associated with the business processes in which they participate. Also, similarly to Archimate, the structuring of “roles” in “nodes” with the “aggregation” relationship suggests that nodes represent organizational units types in the context of which *substantials* that play the roles operate. (It is unclear from the documentation whether roles can be associated with multiple nodes directly.) We concluded that a “node” represents a *kind* and that a “role” represents a *role universal*. The representation in the lower part of Figure 10 confirms that by showing instances of “roles” and “nodes”.

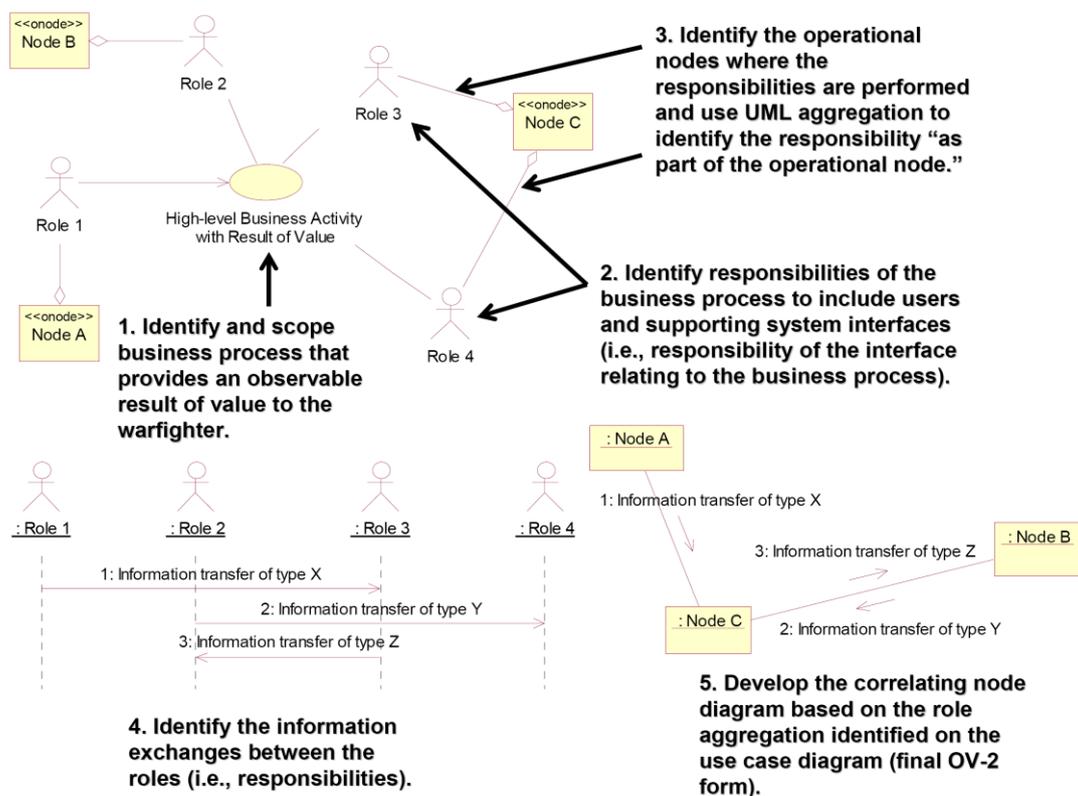


Figure 10. UML OV-2 template from [33]

Roles can be played by instances of other roles as can be seen in Figure 11. In this case, we interpret the relations depicted as representing that the “Mission Planner” “role” (*a role universal*) may apply to admissible type “Role 1”.

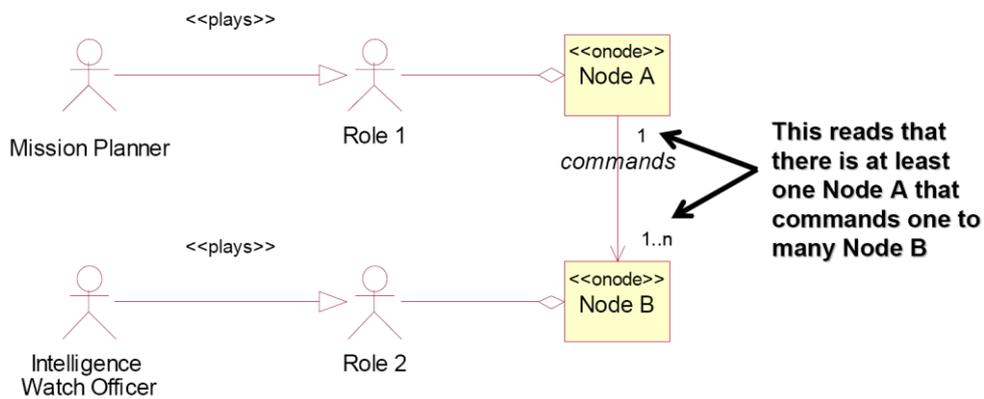


Figure 11. UML OV-4 Sample from [33]

The guidelines for UML usage in the DoDAF documentation are not prescriptive enough, and hence, a number of tools, represent DoDAF architecture in different styles. For example, MagicDraw provides a plug-in for DoDAF using its own modelling elements. Figure 12 shows a screen shot of a model produced with this plug-in.

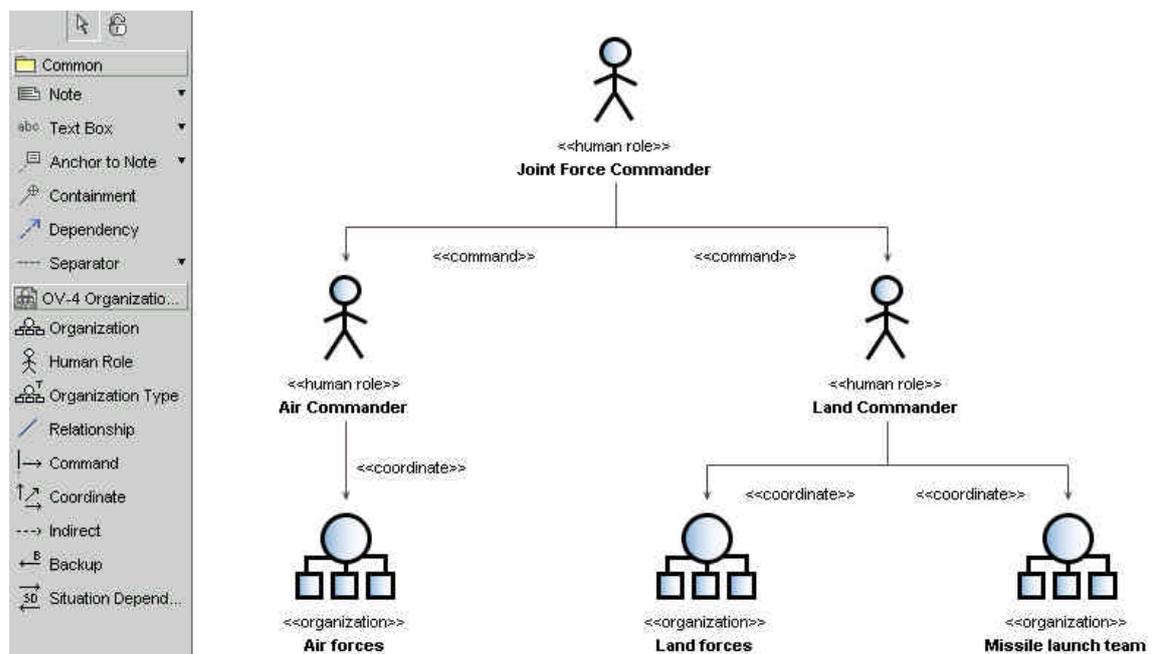


Figure 12. DoDAF OV-4 Organizational Relationships Chart in MagicDraw [25]

In the IBM Rational Approach to the DoDAF [35], there is no semantics associated with OV-4 diagrams. The document suggests the following with respect to an organizational structure chart: “Create a Freeform diagram and name it Organizational Structure. Add rectangles and label them for each organizational element to be represented. Use vertical relationships via solid lines to reflect command relationships, with higher authority at the top of the diagram. Show coordinating relationships using dashed lines.”

The UML Profile for DoDAF/MODAF (UPDM) [27] defines an industry standard UML representation for DoDAF and MODAF compliant enterprise architectures. However, with respect to OV-4, the profile states that “this diagram represents information generally developed and maintained using techniques and tools better suited to the task than UML”.

### **4.3 *RM-ODP***

In our previous work [3], we have discussed the relation of the foundations presented here and the RM-ODP foundations. We have concluded that the RM-ODP provides a rich conceptualization when referring to the acts which constitute the foundation for roles. In the Enterprise Viewpoint is possible to describe “enterprise objects” as “communities” and detail their composition by using the concepts of “roles” and constituent “objects”. We refer to [3] for further discussion on the topic.

### **4.4 *BPMN***

The Business Process Modelling Notation (BPMN) [26] focuses on business process modelling, and therefore does not provide constructs for organization modelling. Nevertheless, activities in a business process may be related by using the

“Participant” model element to either an “Entity” or a “Role”. Possible interpretations for these concepts are kind and role universal or role mixin universal.

#### 4.5 ARIS

The “Architecture of Integrated Information Systems” (ARIS) [28] framework is widely employed for the description of enterprise architectures.

ARIS includes the following role-related concepts: “Organizational Unit”, “Organizational Unit Type”, “Position”, “Employee” and “Role”.

The concept of “Organizational Unit” represents a substantial, instance of the “Organizational Unit Type”, which we interpret as a *kind*. A “Position” is defined as the smallest organizational unit possible (a particular job position). If we interpret this definition literally, a “Position” represents an *individual* similarly to an organizational unit. “Positions” can be related to “Organizational Units” to represent responsibility (e.g., the CEO of IBM is “responsible for” the entire company) or to represent a whole-part relation.

An “Employee” is a particular *individual* (an instance of a universal that is not explicitly modelled.) A “Role” represents a *role universal*, all instances of which are necessarily “Employees”, i.e., the only *admissible type* for “Roles” is the implicit *universal* that characterizes all “Employees”.

The relation between “Roles” and “Positions” is rather indirect: when an “Employee” is related to a “Position” (the foundation for this relation is the hiring process), he/she plays the particular “Roles” that are somehow associated with the “Position”.

Figure 13 shows an example of organigram in ARIS, illustrating the usage of the concepts of “Organizational Unit”, “Positions”, “Employee” and “Role”.

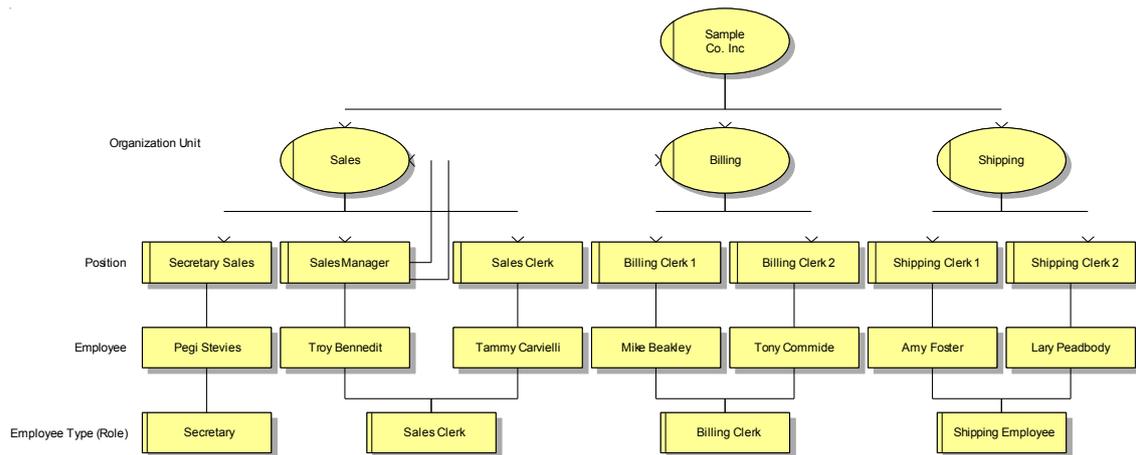


Figure 13. Example of organigram [28]

“Organizational units”, “organizational unit types”, “positions”, “employees” and “roles” can be related to a business process or its activities through an “executed by” relation, as depicted in Figure 14.

The semantics of these concepts and relations are not clearly documented in [28]. Thus, the analysis we have provided here must be considered as a first attempt to establish a consistent interpretation of the constructs based on usage examples.

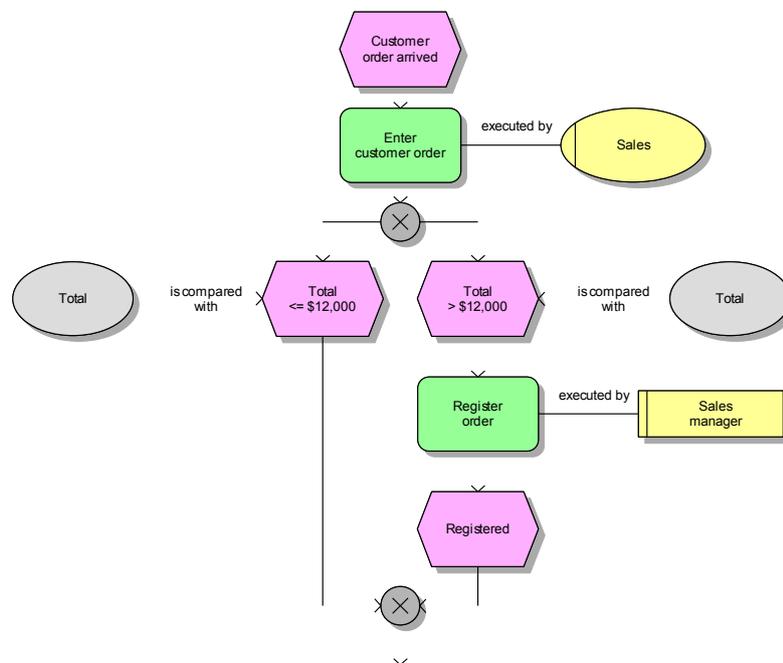


Figure 14 Example of process model with organization units and a position [28]

## 5 Role-related concepts in Enterprise Modelling using UFO-C

So far, we have employed a semantic foundation that applies to entities in general, consolidating concepts from the conceptual and object-oriented modelling literature that make no specific reference to the “social” aspects of these entities. In other words, the concepts in this semantic foundation are neutral with respect to the social aspects of entities and can be applied equally to refer to a building, a book, a person and an organization such as a university.

Since organizations can be characterized as social individuals [6], further specialization of this semantic foundation could help to clarify the social aspects of actors and roles in an organization. In particular, we should observe that roles in the scope of an organization are part of the social reality that is “constructed” because of the acceptance of norms or rules in the scope of the organization [30]. This observation helps us to clarify the relation between organizational units (actors) and the roles that are played in the scope of organizational units. In the remaining of this section, we briefly discuss a fragment of the extension of the UFO-A ontology called UFO-C [16, 17]. This fragment introduces a specialization of concepts of UFO-A, to include the concepts of *agents*, *institutional agents*, *social objects*, *normative descriptions*, *social roles* and *social relators*. These concepts are depicted in Figure 15.

First of all, UFO-C differentiates the category of substantial individuals in *Agents* and non-agents or *Objects* by employing the criterion that the former but not the latter have the capability to bearing intentional moments. Intentional moments have a type (e.g., *Belief*, *Desire* or *Intention*) and *Propositional Content*. For instance, as an agent, John can hold the belief that “Mary is in love with him” and the desire of being loved by Mary. In this case, we have that there are these two individual

moments which inhere in John (the individual belief and the individual desire) which share the aforementioned propositional content. The propositional content of an intention is named in UFO-C a *Goal*. For further details, please read [16, 17].

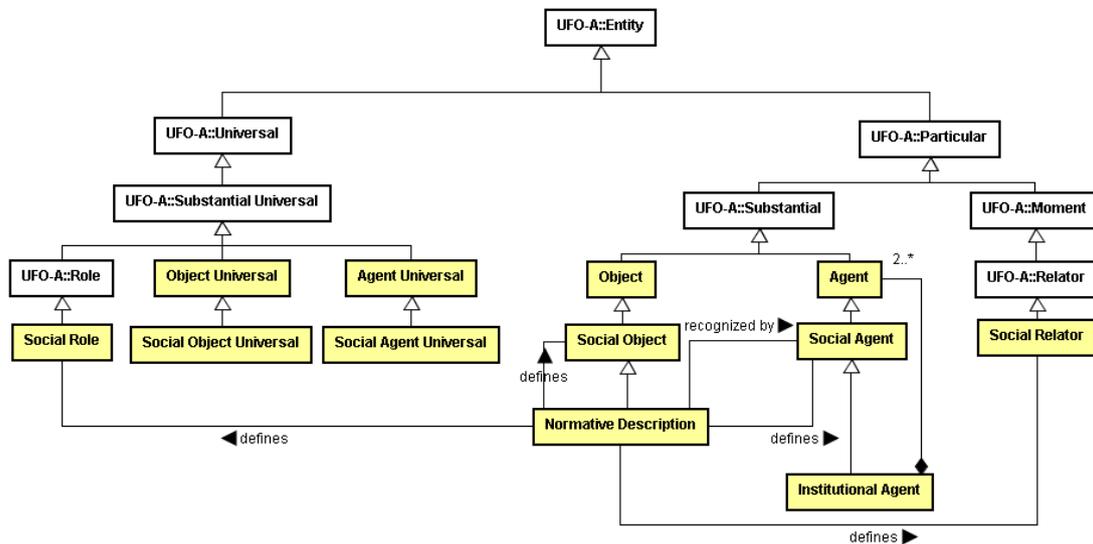


Figure 15 UFO-A fragment augmented with UFO-C extensions

The category of agents further specializes in *physical agents* (e.g., a person) and *social agents* (e.g., an organization, a society). In an analogous manner, objects can also be categorized as *physical objects* (e.g., cars, rocks and trees) or *social objects* (e.g., a currency, a language, the Brazilian constitution). Agents can also be further specialized into *human agent*, *artificial agent* and *institutional agent*, which can be represented, respectively, by human beings, computationally-based agents and organization or organizational unit (departments, areas and divisions). *Institutional agents* are composed by a number of other agents, which can themselves be *human agents*, *artificial agents* or other *institutional agents*.

We should now briefly elaborate on what is meant by stating that “*Institutional agents are composed of other agents*”. An institutional agent exemplifies what is named a functional complex in [13], i.e., a mereologically complex entity whose parts play different roles with respect to the whole. By instantiating each of these roles defined in the characterization of that functional

complex universal, each part contribute in a different way to the integral behaviour of the whole. In the case of a social functional complex such as an institutional agent, the characterization of the universal instantiated by that agent is made via what is termed in the literature a *normative description* [6].

Each institutional agent has a normative description associated to it. Moreover, this institutional agent defines a context in which a normative description is recognized (see relationship *recognized by* in Figure 15). We can state then that *normative descriptions* are social objects that create social entities recognized in that context. Examples include *social roles* (e.g., president, manager, sales representative), *social agent universals* (e.g., a political party, an education institution), *social agents* (e.g., the Brazilian Labour Party, the University of Twente), *social object universals* and other *social objects* (e.g., a piece of legislation, a currency) or other normative descriptions. A normative description that defines social individuals in the context of an institutional agent is termed a *constitutive normative description* [6].

The functional compositional structure of an institutional agent is hence defined in the following manner. Let X be an institutional agent (or institutional agent universal) and let N be a normative description associated to it. N defines for X a number of functions that must be instantiated in order for X to exist, persist and exemplify the essential properties (including behaviour) associated to (an instance of) X. These functions are ascribed to a number of *social roles* prescribed to exist for X. Finally, an agent z is said to be a functional part of X (or an instance of X) iff z instantiates one of the social roles defined in the normative description N associated to X.

Besides defining social roles, normative descriptions can also define social relator universals. As previously discussed, roles are relationally dependent

universals, i.e., roles are always defined in a context or in the scope of a relation. Thus, in order for an individual (e.g., Mary) to instantiate a role (e.g., wife), she must be mediated by a particular relator (e.g., the particular marriage between Mary and John). The relator universal Marriage, in this case, characterizes the properties that every instance of Wife (Husband) has in the context of that relation (or, equivalently, while playing that role). Likewise, for an individual  $z$  to play a social role in the structure of an institutional agent  $X$ , she must be mediated by an instance of a social relator universal defined in the normative description  $N$  associated to  $X$ .

An example of a normative description type that defines social roles and social relators is a *social contract* [7]. According to [7], social contracts describe tasks, rules and specific obligations that are assigned to social roles that agents can assume in an organization such as: interval in which an agent instantiates a social role; control conditions, that is, how the organization is capable of governing an agent associated to a role; consequences suffered by agents when norms are violated, among others. A social contract is, hence, constituted by both *deontic norms* and *technical norms* [6]. Deontic norms prescribe and constrain the social behaviour of entities by defining permission, obligations and rights associated to social roles. Technical norms regulate the behaviour of individuals playing social roles inside an institutional agent by prescribing the behaviour that should be exhibited by those individual when performing actions associated to those social roles [6]. Finally, a social contract provides a link between agents and social roles in the context of an organization, since the signing of a contract constitutes a *declarative speech act* that serves as a foundation for the creation of the social relator that binds the involved parts [29, 30].

## 5.1 *Implications of the semantic extensions to Enterprise Modelling languages*

In this section, we revisit the analysis of the role-related concepts of Archimate and ARIS under the light of the UFO-C extensions presented in the previous section. We focus on Archimate and ARIS for the sake of brevity.

### 5.1.1 *Archimate*

The first modelling element we revisit is Archimate's "Business Actor". A "Business Actor" represents an active entity that performs behaviour. In terms of the UFO-C extensions, a "Business Actor" must be characterized as an *agent* (as opposed to an *object*, which is *non-agentive*.) A distinction similar to that of agentive and non-agentive entities is also present in Archimate, and is referred to using the terms "active structure" and "passive structure". Nevertheless, this distinction is not formulated in terms of *intentionality* in action as in UFO-C.

When a "Business Actor" is used to represent an organization or organizational unit, it should be interpreted as a special kind of agent, namely an *institutional agent*. The relevance of this interpretation is that an Enterprise Modelling language must be able to represent the decomposition of organizations and organizational units into their various sub-organizational units and employees. If we re-examine the model illustrated in Figure 7 (reproduced in Figure 16 below), we may observe examples of institutional agents ("Insurance sales department" and "Claim handling department") and other agents that are not further decomposed (e.g., "A. Smith", "D. Jones" and "M. Baker"). Although Archimate does include notational elements with different adornments to represent these different kinds of agents, their usage is optional, and hence both organizational units and employees may be depicted with the same notation, as in the model in Figure 16. This is a case of semantic

overloading and prevents us from incorporating a useful rule with respect to agents such as “A. Smith”, “D. Jones” and “M. Baker”, namely that they cannot be involved as a whole in a part-whole relation in the scope of the enterprise model.

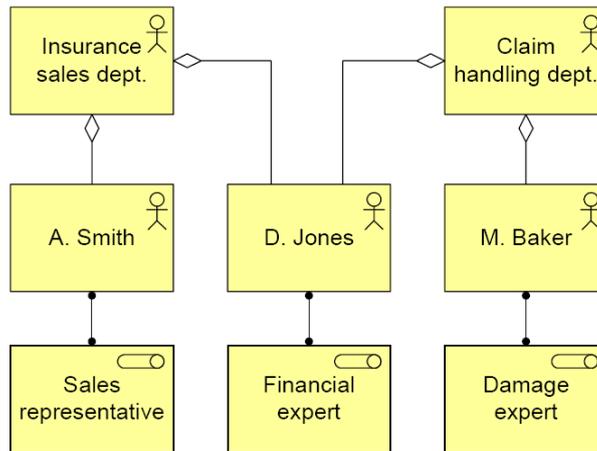


Figure 16. Organization model (from [19])

The model in Figure 16 reveals a particular decomposition for the “Insurance sales department” and the “Claim handling department” but omits the relations between these institutional agents and the roles that would typically be captured in a normative description that defines these departments. These relations are revealed in the model of Figure 17, as a result of the omission of the “Business Actors” “A. Smith”, “D. Jones” and “M. Baker”.

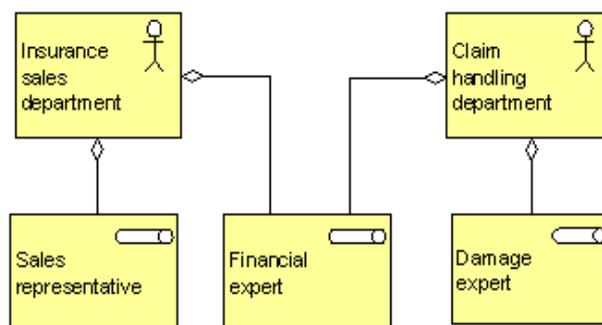


Figure 17. Relations between actors and roles [1]

Our first observation is that the diamond-adorned line is used in different ways in Figures 16 and 17 leading to a case of semantic overloading of that syntactical construct. In Figure 16, these lines represent a whole-part relation between agents (we

assume here all at the instance level). In contrast, in Figure 17, these lines represent a relation between “Business Actors” and “Business Roles”.

This latter relation deserves further attention, since it collapses several notions which are required to relate institutional agents, social roles and the agents that perform them. There are multiple possible interpretations to the model in Figure 17:

In the first alternative interpretation, which is suggested by the comparison of Figures 16 and 17, each role “Sales representative”, “Financial expert” and “Damage expert” represent in fact an anonymous instance of the role (an agent) and not the role universal. The number of agents is defined here to be three.

In the second alternative interpretation, the “Business Role” modelling element is a genuine universal and the institutional agents “Insurance sales department” and “Claim handling department” consist of a number of agents that perform the roles of “Sales representative”, “Financial expert” and “Damage expert”. (As noted earlier, the number of agents is undetermined in this model.)

It is important to highlight that, judging by most of the available examples using the Archimate notation, the second interpretation seems to be intended one. However, as a consequence of the aforementioned semantic overloading as well as the lack of precision in the definition of the real-world semantics of the semantic primitives of this notation, both interpretations can be elicited when construing Archimate models. We can conclude a revision of these modelling elements is necessary in order to establish a precise and useful semantics for the actor-role relation in Archimate.

Further, since the concept of normative description remains implicit in the models, we can either assume that (i) the roles “Sales representative”, “Financial expert” and “Damage expert” are defined in the scope of the organization as a whole

(perhaps in a normative description that defines the organization as a whole) or that (ii) these roles are created in the normative description that defines the institutional agents “Insurance sales department” and “Claim handling department”. In the latter case, these roles may be specific to the organizational units in question, and may be useful to determine specific attributions in the scope of that organizational unit (e.g., there could be “Car insurance sales representative” and “Home insurance sales representative” roles in the “Insurance sales department”). There are no modelling elements currently in Archimate to provide this distinction. This distinction seems particularly important when modelling large bodies of organization with several levels of hierarchies and rules, such as a government body or a community in federation.

### 5.1.2 ARIS

The concepts introduced in the UFO-C extension also enable us to revisit the interpretation for the “Organizational Unit” and “Position” modelling elements in ARIS.

First, we are able to refine the interpretation of the “Organizational Unit” modelling element, concluding that it represents a particular kind of substantial, namely, an institutional agent. This is not particularly surprising given that organizational units can be decomposed recursively into smaller organizational units and eventually into “Positions”.

If we follow the ARIS definition literally, i.e., if we accept that “a position is the smallest organizational unit” as we have done in section 4.5, we may be tempted to suggest that a “Position” should be interpreted as an institutional agent. However, a “Position” cannot be further decomposed, and it would thus be interpreted as an institutional agent with a single constituting agent. This would violate the *weak supplementation principle* [13]. In other words, why should one distinguish the

institutional agent that corresponds to the “Position” from the actual agent in that “Position”? Secondly, and perhaps more importantly, this allegedly characteristics of “Positions” would make it of an intrinsically different nature than other organizational units. Moreover, even if “Positions” are to be accepted as an uncanny type of organizational unit, one still could not dispense with position universals. Take for example, the model reproduced in Figure 18. There we have that the Billing department “has” a “Billing Clerk 1” and a “Billing Clerk 2”. Still in this example, there is implicitly the universal “Billing Clerk” which defines properties which are common to these two “Positions”. Now, what is the difference between a social role “Billing Clerk” and the position universal “Billing Clerk”?

Intuitively, one could assume this is necessary to decouple organizational units and employees, however, the same effect can be obtained with the roles employees perform in an organizational unit. This suggests that the existence of both “Positions” and “Roles” is a violation of parsimony in ARIS and that “Positions” can be safely be replaced by roles to be performed in the scope of a particular organizational unit.

The implications for the example discussed earlier (and reproduced in Figure 18) are that the “Positions” identified here would be specializations of the “Roles” which are allowed types for the agents filling these “Positions” (these specialization relations are not modelled here). The relations between “Employees” and “Positions” and between “Employees” and “Roles” are in this case, instantiation relations. Further, the existence of multiple “Positions” with similar designations such as “Shipping Clerk 1” and “Shipping Clerk 2” may suggest that these are in fact just cardinality restrictions for the instantiation of an implicit role “Shipping Clerk”. However, depending on the intention of the modeller, this could actually mean that there are different attributions to “Shipping Clerk 1” and “Shipping Clerk 2”, in which

case these would just be two different roles (universals) that do not share all properties. Still in this case, we could have that the social roles “Billing Clerk 1” and “Billing Clerk 2” could be specializations of the social role “Billing Clerk”. The relation between “Organizational Units” and “Positions” is similar to that discussed for the relation between “Business Actors” and “Business Roles” in the Archimate insurance example.

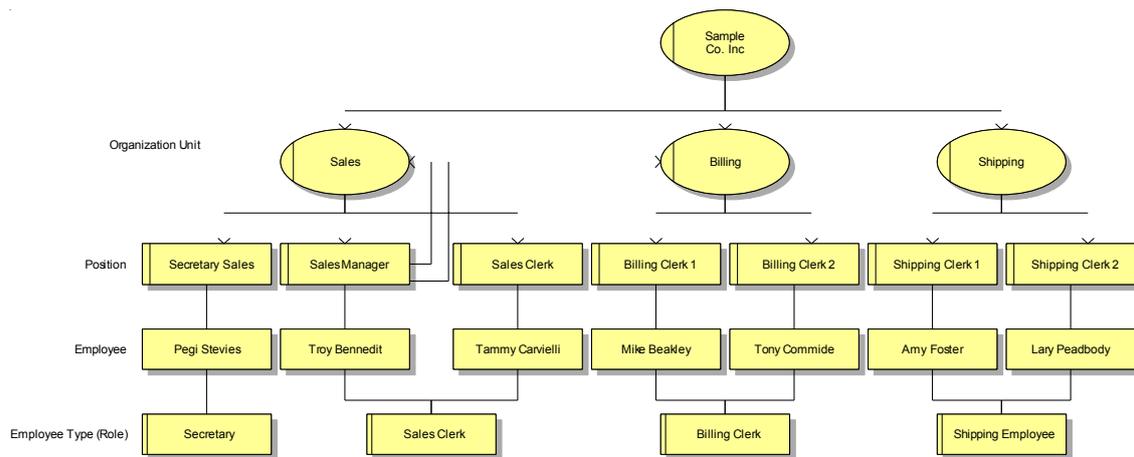


Figure 18. Example of organigram [28]

At first investigation it seems that the relation between the “Organizational Unit” and “Position” modelling elements would indicate that the role specified by a “Position” is defined in a normative description that is recognized only in the scope of the containing “Organizational Unit”. However, the relation between “Sales Manager” and “Billing” suggests otherwise. Therefore, we conclude that, similarly to Archimate, the relation between the “Organizational Unit” and the “Position” modelling elements does not indicate the context in which the roles are defined.

## 6 Conclusions

We have contributed a semantic foundation for role-related concepts in Enterprise Modelling. Our contribution is well-positioned with respect to the literature in conceptual and object-oriented modelling<sup>†</sup>, thus possibly leading to a common foundation for these modelling domains. The semantic foundation also incorporates social concepts in line with approaches in enterprise modelling and enterprise ontology, such as [5, 6, 8].

We have found a number of difficulties in evaluating the selected enterprise modelling approaches, which reveals certain problems in the definition and potentially in the usage of some modelling elements in these approaches:

In the case of Archimate, the main difficulties refer to the interpretation of the concept of “actor”. It was unclear from the documentation and from examples, whether the concept should be interpreted as a universal or an individual. We believe both universals and individuals for actors are relevant in enterprise modelling efforts (see section 5). Further, we have identified a number of issues in expressing the relations between actors and roles in the approach. Future work should focus on language revision and specific modelling guidelines to ensure the language can be given a precise semantics for this relation.

In the case of DoDAF, most issues relate to a lack of consensus on the language representation for the concepts, which restricts our analysis to the concepts as defined in the framework. We have concluded based on our analysis that there is no concept for kind or substantials when applied to model humans in DoDAF. This would make it impossible to model the interest in particular individuals (such as the

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<sup>†</sup> For an extensive discussion on roles in the conceptual modelling literature that justify the UFO-A conceptualization see [13, 15]. In [13, 15] the conceptualization provided here is defined formally, in order to allow for unambiguous interpretation of the intended semantics for concepts.

allocation or deployment of persons to particular organizational units, as shown in Archimate and ARIS).

In the case of ARIS, both universals and individuals are provided for modelling organizational units. Individual human actors are also represented. The ARIS documentation has been hard to interpret (especially the role-related concepts as presented in [28]). Therefore, the semantics of the various modelling elements has been derived based on its usage in examples. We have proposed a revision of the ARIS "Position" concept unifying it with the notion of role. This leads to a more parsimonious set of role-related concepts in ARIS and, ultimately, more parsimonious models.

In none of the approaches, we could identify the distinction between the concepts of role universals and role mixin universals. In order to be able to model the design pattern for "roles with multiple disjoint allowed types" (which is one of the challenges presented in [32]), the approaches would have to collapse both concepts of role universals and role mixin universals in a single concept.

In all approaches, roles are used to represent the participation of actors in particular behaviours or processes, decoupling the definition of these behaviour or processes from particular instances of actors. None of the approaches, however, discuss the dynamics of role playing or provide modelling elements to describe how actors are assigned to roles dynamically (except the RM-ODP). The concept of qua-individual is very important in this respect and necessary to enable features 1, 9, 10 and 11 of the list proposed by Steimann, i.e., those related to the properties and behaviour that individuals carry when playing a certain role. Qua individuals are also necessary to clarify the issue of identity and to solve the so-called "counting problem" [15].

Further, in all approaches, the concept of normative description remains implicit in the models, thus, the scope of social roles is left unspecified. We believe that modelling the scope of social roles could be particularly beneficial for modelling large bodies of organization with several levels of hierarchy and federation.

Further work is needed to discuss the the metaproperties of whole part relations for role-related concepts in details. Some discussions on this topic can be found in [13]. Further, some work is needed to relate the concepts discussed here to social concepts which are also available in enterprise modelling approaches such as commitments, delegation, contracts, goals, etc. [5, 6, 8,16].

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