Towards a Goal-oriented Approach to Ontology Specification

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Abstract. Competency Questions (CQs) elicitation has been a kind of black art at least for the last two decades. CQs elicitation is an important task in Ontology Specification activity, i.e., finding the scope, objective and whatever queries the ontology shall respond. Capturing high level strategic stakeholders' intentions has potential to contribute efficiently to eliciting a better CQs, some of them that traditional methods would pass, since these latter are concerned just with information content. Goal modeling, mostly after Yu's *i** framework, is a way to capture intentional elements very early in systems development; in this way capturing high level strategic goals and intentions of stakeholders. Our view is that this approach is beneficial to CQs elicitation, once it contributes to discover elements stratified in all levels of the enterprise activity. The manual transcriptions from texts or interviews to goal models seem to be easier and more intuitive. Moreover, CQs mapping to goals shrink the semantic gap as they actually derive from intentional elements. This work presents and discusses an idea developed to approaching this problem as a seed for future investigation. We also present an example extracted from the specification of a passengers' transportation regulatory agency domain, in order to illustrate the situation.

Keywords: Goal-orientation, Tropos, Ontology Specification, Ontology Engineering, Requirements Engineering

1. INTRODUCTION

Ontology Engineering is a relatively young discipline, having its traditions tight linked with Artificial Intelligence (AI) (Fox & Grüninger, 1994) (Fernández-López, Gómez-Pérez, & Juristo, 1997). Guarino concurs with the engineering approach, although from a very different perspective, proposing a conceptual model approach to ontology design (Guarino, 1998) (Nicola Guarino, 2009).

The approaches coming from AI tradition prescribe that ontology specification is its requirements specification. The product of ontology

specification activity is the scope, objectives (and in some its uses) and what questions the ontology shall respond. Although the approaches may differ in some aspects, we do not consider a mistake to warp them up in an assertion like the previous sentence. The elicitation of these Competency Questions (CQs) is an important task in the overall activity. Goal modeling, mostly after Yu's *i** framework (Yu, 2011) is a way to capture intentional elements very early in systems development; in this way, capturing high level strategic goals of stakeholders. Our view is that this approach, which has been applied with success in organizational modeling (Yu, 2011) and software engineering (Bresciani, Giorgini, Giunchiglia, Mylopoulos, & Perini, 2004), might be beneficial to CQs elicitation, once it contributes to discover elements that traditional methods would pass, as they are only concerned with information content. In this work, we present an idea developed for approaching this problem as a seed for future investigation. We also present an example extracted from the specification of a regulatory agency passengers' transportation domain, in order to illustrate the situation of partially applying the approach to this domain.

Baader and Nutt in (Baader & Nutt, 2003), p.48, and Brachman and Levesque in (Brachman & Levesque, 2004), p.170, state that classification is a natural way humans structure concepts and grasp some structure from the real world. The origins of classification systems lay in the philosophical principles of categorization. On the other hand George Polya (Polya, 1945), p.75-76, states that decomposing is natural to human beings. In addition, when we decompose a problem, i.e., thinking from high level of abstraction downwards, these levels of thought remain imprinted in our statements. When decomposing intentional elements in goal modeling reproduces the same phenomenon. In summary, is natural to human beings classifying and decomposing.

We observe this fact when "translating" from sentences in documents and interviews to goal models. Moreover, as doing so, we stratify these intentional elements in levels of abstraction. In organizational modeling, these levels are strategic, tactical and operational.

Goal modeling, besides providing means to classify and decompose stakeholders' intentions, conveys semantics, during means-end and contribution analysis. Goals are intended states of the world from the stakeholder viewpoint. With this mind set, we can think that they convey situations involving entities and their instances. This fact drives us to envision questions that contribute to goal satisfaction, whenever the answer holds. If we sum up goal derived queries with the semantics of the previous analysis, we shrink the semantic gap between the requirement and the question to answer it.

Our approach uses a number of considerations made in (Fernandes, Guizzardi, & Guizzardi, 2011). The paper presents an approach to represent CQs in Goal Models and derive the ontology as well-founded ontology conceptual model and use it in the development of an information system (N Guarino, 1998). The authors explore Tropos approach to RE in both phases, unlike ours, which uses only Early Requirements. Moreover,

our objective here is not information systems development, but contribute to the Ontology Requirements Specification Document (ORSD), as (Del Carmen Suárez-Figueroa et al., 2008) names the product of Ontology Specification activity.

The main objective of our investigation is to develop an approach (methods and techniques) to ontology specification that allow ontology engineers and domain experts do reach a set of better CQs than traditional methods would allow, and actually would pass in some cases. As secondary objectives we intend to show (a) how we can elicit CQs in enterprise modeling levels (strategic, tactical and operational); (b) that a knowledge level modeling approach is more eloquent to elicit CQs and (c) that the semantic gap between Ontology Conceptual Models' (OCMs) concepts and CQs can be mitigated using knowledge level modeling to guide ontology modeling.

We use models built in a real project, although registered the modeling observations in a proof of concept fashion. As we have been adapting the design of the concept proofing along with the work in the project, consequently affecting the investigation, in some sense, we may consider that we have also used action research techniques.

This paper shows the context for this investigation, our motives, and some theoretical justification, as well as, our problem and solution, adopting goal modeling. All this is presented in section 1. Sections 2 and 3 present a brief literature review of ontology engineering, more specifically, the specification activity, and about modeling goals using Tropos in Requirements Engineering. Sections 4 and 5 present the investigation and a real example, respectively. The example compares the traditional and the proposed approaches. Section 6 wraps up the paper showing a concise review of contributions, future work, the limitations encountered in this stage of the research, as well as final remarks.

2. ONTOLOGY SPECIFICATION

In order to build ontologies, we must understand what their required fundamental properties are. Those properties are related to the domain of the ontology, its scope and objective. Some authors call this phase "specification" (Fernández-López et al., 1997). The specification of an ontology is relevant to its quality and it is expected to follow the same logic than in software engineering (Fernandes et al., 2011). In software engineering the inadequate definition of requirements is responsible for a significant portion of errors that are only detected during the process of systems development (Lutz, 1993). Eliminating the engineering errors becomes increasingly difficult and expensive as the system progresses to later stages of its lifecycle (Davis, 1990). The goal of the ontology specification is to state why the ontology is being built, what its intended

uses are, who the end-users are, and what are the requirements the ontology should fulfill (Pérez, Carmen, Figueroa, & Villazón, 2008).

2.1. Traditional Methods

Del Carmen Suárez-Figueroa and other authors, show a summarized survey of ontology building methods in (Del Carmen Suárez-Figueroa et al., 2008). A thorough study, although older, from 2003, shows a broad scenario relating consolidated methods, as well as emergent ones (Corcho, Fernández-López, & Gómez-Pérez, 2003).

We focus ourselves in noncommercial offerings and take aside DILIGENT (Pinto, Staab, & Tempich, 2004), although an important contribution, explores collaborative issues, that is not the case here. We are concerned here with a technique for eliciting ontology requirements, mostly using modeling aids. We investigated how the original works of Uschold and King (M Uschold & King, 1995) and Grüninger and Fox (Fox & Grüninger, 1994), that are consolidated in (Mike Uschold & Gruninger, 1996), and Fernández-Lopez and others (Fernández-López et al., 1997) drove ontology requirements to its state-of the-art, shown in (Del Carmen Suárez-Figueroa et al., 2008). It is important to note that these approaches are oriented to knowledge bases development.

2.2. Competency Question

In the work of (Grüninger & Fox, 1995), the authors claim that defining competency questions is a way to determine the scope of the ontology and outline a list of questions that the ontology will be able to respond. CQs are a set of questions, agreed by the stakeholders that are important to the ontology to answer. According to (Fernandes et al., 2011), the ontology development should "begin with the definition of a set of questions, named competency questions, defining its objective, scope and expressiveness requirements". The same authors also draws a parallel between CQs for ontologies and system requirements for software development: "both a competency question and a requirement identify a future characteristic of the ontology (the former) and the system to be (the latter). In software, this is then translated into functionality, while in ontology construction this is materialized by the right set of concepts and relations".

Competency questions are being widely used in ontology specification. According to (Fernandes et al., 2011), in an extract of some of the most well-known approaches to ontology specification, seven of eight approaches have used some kind of competency questions in the ontology specification phase to achieve its goal. For example, the NeOn Methodology (Del Carmen Suárez-Figueroa et al., 2008) and the TOVE ontology methodology (Gruninger & Fox, 1994) use CQs to identify ontology requirements.

3. GOAL MODELING AND TROPOS

The goal-oriented approaches emerged in the late 80's and led to projects such as KAOS, described in (Dardenne, Van Lamsweerde, & Fickas, 1993) and (Darimont, Delor, Massonet, & Van Lamsweerde, 1997). Yu and Mylopoulos (Yu & Mylopoulos, 1994) present another framework called *i** that gives rise to a large multinational and inter-university project called Tropos. Unlike KAOS, Tropos develop an approach for analysis, design and construction of systems, not just requirements engineering (RE). Another evolution line of *i** framework is GRL (Goal Requirements Language) that is part of URN (Unified Requirements Notation). URN combines GRL with UCM (Use Case Maps) of (Buhr & Casselman, 1994). UCM is used for scenario and interactions modeling, while GRL for modeling (in this approach mostly for non-functional goal modeling). URN turned out as an international standard approved in November 2008, as a recommendation of the ITU-T (International Telecommunication Union) of Switzerland.

Although *i** has as its central element the agent concept and its strategic relationships, it is a framework for representing goal-oriented requirements models. Since strategic relationships between agents entail the satisfaction of the goals, it is thus consistent with the goal idea, which is central to the goal-oriented paradigm.

Tropos prescribes a software development life-cycle in four ordered distinct phases: (1) Early Requirements, (2) Late Requirements, (3) Architectural Design and (4) Detailed Design. Early Requirements concerns are about the definition of the organization's current goals in order to create a context for the system development. Late Requirements, allows the modeling how the system-to-be can solve the problems of the organization, defining the functional and non-functional requirements and considering the system as an actor in the organizational context. This allows the modeler to explore alternatives that turn out in software requirements, guided by organizational goals, while addressing all the organization's needs (Bresciani et al., 2004). Architectural Design and Detailed Design phases focus on the system specification, based on the requirements resulting from the above phases. These phases are out of the scope of this paper.

3.1. Syntax

Tropos adopts *i** modeling framework for requirements modeling, defining two diagrams: Actor Diagram (Strategic Dependency in *i**) and Goal Diagram (Strategic Rationale in *i**). The Actor Diagram allows the modeling of overall organization context, including its external aspects, providing an overview of the actors and theirs interdependencies. A dependency relationship represents a commitment made between two actors, indicating that one actor depends on the other in order, for a reason,

to satisfy some goal, execute some plan, or deliver a resource (Bresciani et al., 2004).

The Goal Diagram provides an overview of intentional elements that a particular actor is responsible for. It allows the representation of refined elements that details how to satisfy goals and execute plan, as well as resources may contribute to these events to hold. In addition, allows representations for contribution (positive and negative) and means-end analysis. From the point of view of an actor, we analyze goals as means-end relationships, as contributions and as decompositions. Means-end analysis is a ternary relationship defined among an Actor, whose point of view is represented in the analysis, a Goal (the end), and a Plan, Resource or Goal (the means). Contribution Analysis is a ternary relationship between an actor, whose point of view is represented, and two goals (Susi, Perini, Mylopoulos, & Giorgini, 2005). The Figure 1 presents the main syntactic elements of the Tropos approach.

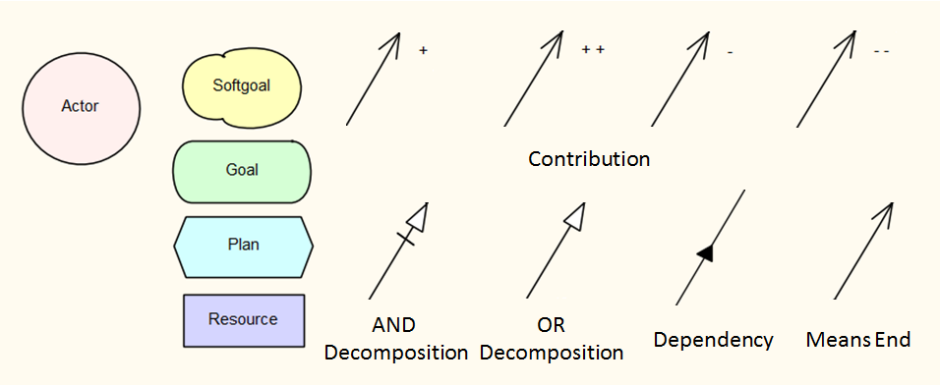

Figure 1. Modeling elements provided by the concrete syntax of Tropos' visual representation language.

In order to illustrate the use of this representation framework, we present an example of a fragment of the diagrams of Scientific Conference Management System. Figure 2 shows an Early Requirement Phase Actor Diagram. The problem domain deals with actors that somehow related to the conference. In this example we show the conference's Steering Committee (SC) as an actor, as well as the PC Chair (Program Committee Chair) and the Conference Chair. The Conference Chair (CC) is the executive who takes care of making things happen, while the Steering Committee is just a normative and strategic participant. The PC Chair is the Conference Chair arm to manage the receiving, distribution and review of papers.

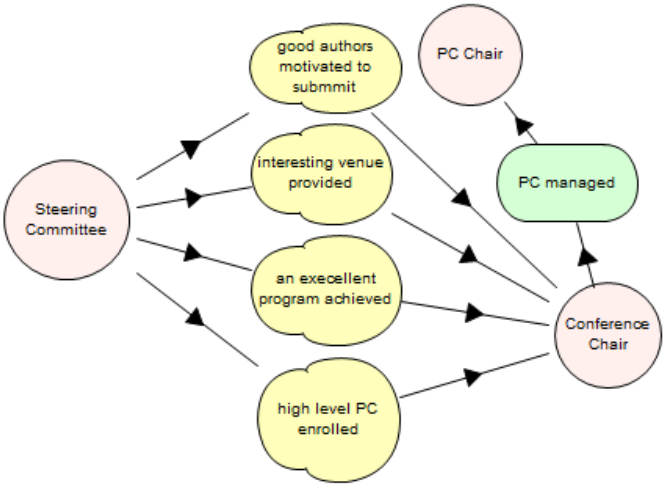

Figure 2. Fragment of an Early Requirement Phase Actor Diagram for the Conference Management System.

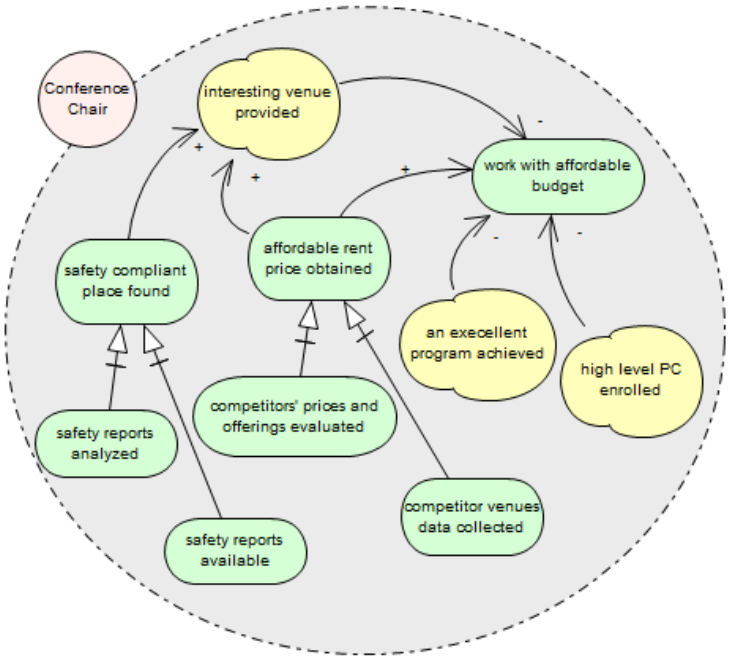

Figure 3. Partial Tropos' Goal Diagram for Conference Chair Actor.

The Conference Chair has to make the goals delegated by the Steering Committee happen. Figure 3 illustrates the goals that this actor is responsible for. It is relevant to note that the Chair is taking strategic and policy goals as her responsibility, having to complement them with hard goals that contribute to these intentional elements satisfaction. This

diagram shows the actor neighborhood, contribution (positive and negative) and "AND" refinement relationships. The picture shows just a fragment in order to contribute with the understanding what meaning, these diagrams convey.

The difference between hard and soft goals is that the former has a clear satisfiability criterion, but the latter does not. As illustrated, the clouds are of this latter type, as the SC has just strategic interests and high level orientation, delegating her goals to the CC. On the other hand, the CC is responsible to make that happen; taking her own goals and delegated ones. Figure 3 illustrates this situation, as well as shows other elements of the language visual syntax within the Goal diagram for the actor CC. One of the soft goals of Figure 2 has been taken off Figure 3, since it is out of cope in this latter fragment.

4. COMPETENCY QUESTIONS AND GOAL MODELING

We consider CQs as a main product of ontology specification. Based on this understanding, we devise hypotheses that using goal modeling, as a RE design technique, is an assumption that is in-line with the objectives of ontology specification activity. Moreover, authors report the use of some other RE techniques in ontology engineering, reinforcing these hypotheses (Del Carmen Suárez-Figueroa et al., 2008).

In order to evaluate these hypotheses we set up a prototype Ontology Requirements Engineering (ORE) process. We applied this process in a large project for a Brazilian transportation services regulatory agency. At first, we put up a beta process for tests, which we have been improving ever since. During the development of our modeling tasks, complying with the prototype process prescriptions, we feel the need for some language extensions. We analyze and refine the design of each one, incorporating them to our tool set. This section presents a discussion about the prototype process and the language extensions.

4.1. Prototype Process

We do not describe each process activity; instead we discuss the main ideas related to the process itself. Figure 4 shows the process's activity diagram using UML (OMG, 2006) modeling language. The prototype aligns with the deep normative commitment of the regulatory businesses. The literature, mostly legal, is paramount in this activity, serving as a foundation to modeling. Actor modeling, or stakeholders strategic dependencies, is the first modeling step in the process, followed by Goal modeling. It is important to remember that we address only early requirements.

We build the Normative Traceability (NT) diagram after determining all intentional elements, that is, doing refinements and contribution and means-end analyzes. This task refers to associating the intentional

elements to their counterparts in the legal and normative documentation. Following this task, we deal with discovering the CQs, browsing leaf elements at first, and trying to create question whose answers contribute to the satisfaction of that determined goal. We might also expect discovering CQs for non-leaf goals. They are probably the ones which address more aggregate concepts or derived properties values. They are the CQs addressing tactical and strategic matters. Based on this analysis, we can build the Competency Questions Traceability (CQT) diagram.

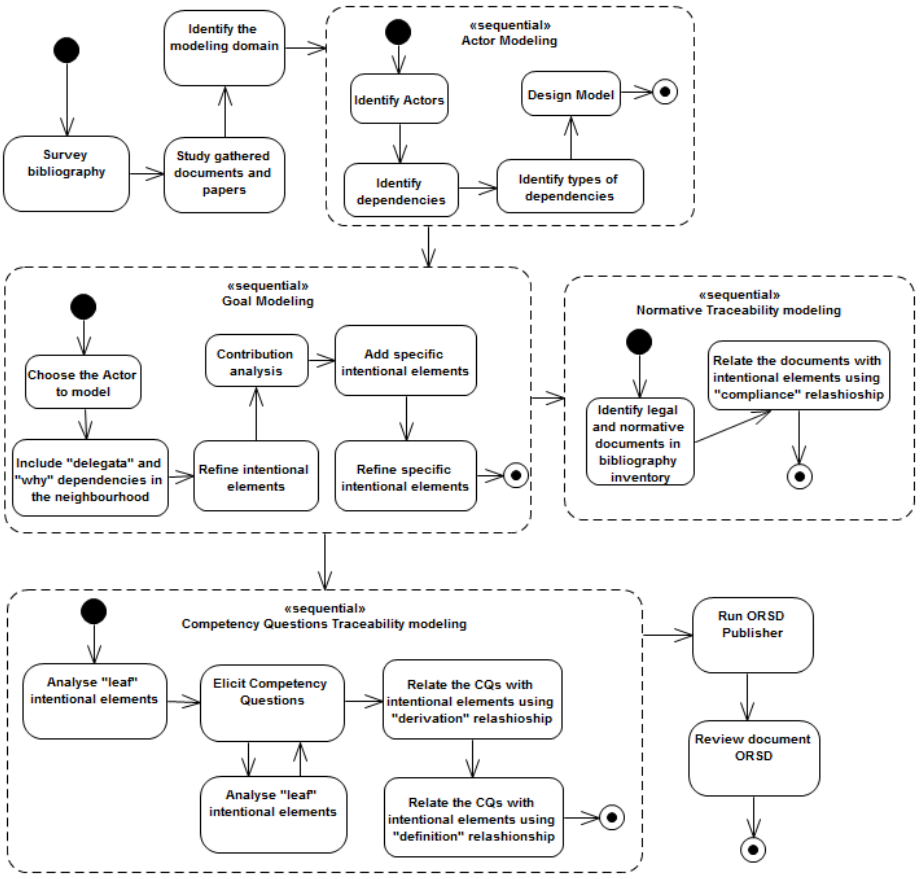

Figure 4. Ontology Requirements Specification Document (ORSD) production prototype process.

4.2. Proposed Intentional Elements, Relationships and Diagrams

In the course of our modeling tasks, we feel the need for some language extensions, in order to represent very important mentalist notions within the regulation domain. These notions refer to CQ, Normative Document (ND), and Generic Document (GD) and their relationships. The elements are used in two new types of diagrams, namely, CQT and NT, cited in the

previous subsection. NT diagrams depict the "compliance" relationship between a goal and the ND that it complies to, or from where we capture the goal itself. CQT diagrams traces CQs to goals, or other intentional element, through "derivation" relationships, to Normative Documents (ND) and Generic Documents (GD), using "definition" type of relationship.

Figure 5 shows these elements illustrating their visual concrete syntax for each diagram: (a) for CQT and (b) for NT.

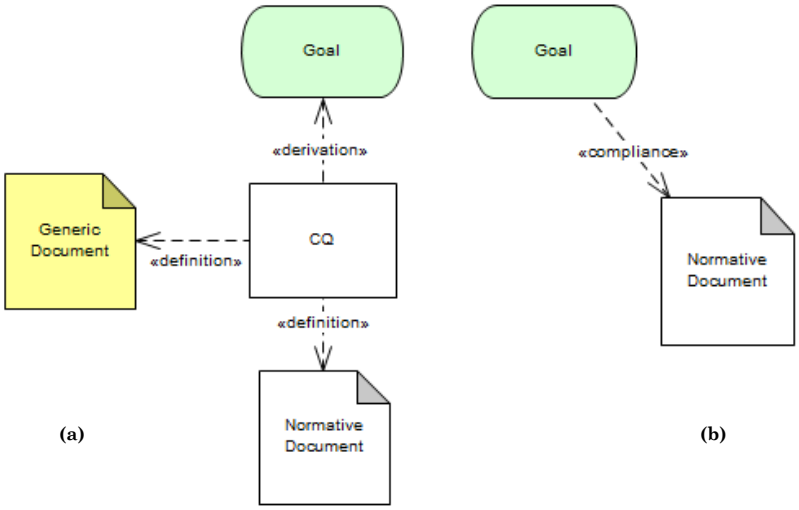

Figure 5. Proposed modeling elements and diagrams - (a) Competency Question Traceability Diagram: (i) Generic Document, (ii) CQ - Competency Question, (iii) Normative Document, (iv) derivation relationship, (v) definition relationship; (b) Normative Traceability Diagram : (i) Normative Document, (ii) compliance relationship.

Still using the Conference System domain, we present a small fragment of each proposed diagram in Figure 6. GD's interpretation is that it is any non-legal and non-normative document, such as an interview transcript, which is the case, but could be an e-mail, a journal paper and so forth. The method and the proposed extension are concerned in making an explicit difference with enforcement capabilities described by documents.

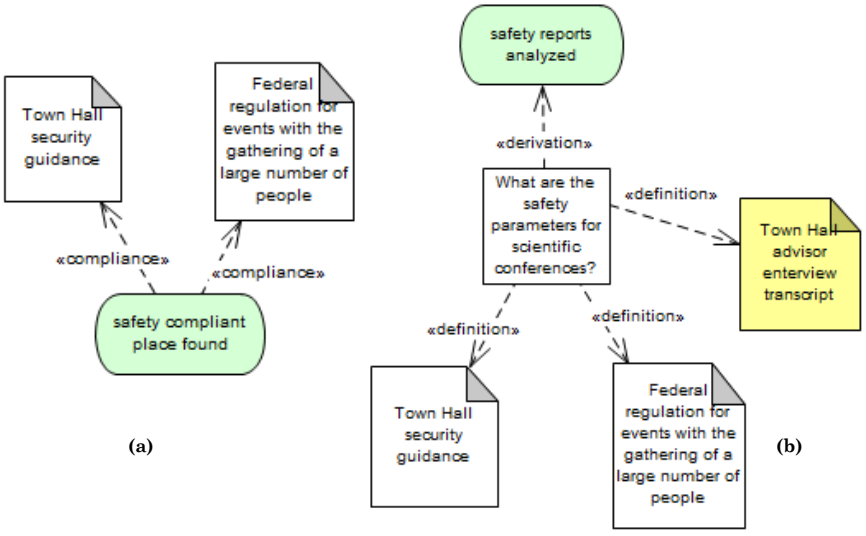

Figure 6. Examples of the proposed additional diagrams: (a) Normative Traceability (NT); (b) Competency Questions Traceability (CQT).

5. RUNNING EXAMPLE

5.1. Domain Used

In order to compare the approaches used in the construction of competency questions, we used a specific domain of the passengers' transportation regulatory unit of a Brazilian government trasportation services regulatory agency. This domain is the regulation of international and interstate passengers' road transportation.

There are two kinds of passengers' road transportation: regular and non-regular. The first one is about bus transportation between two end-points, with predefined fare and operational rules, like itinerary and schedules, among others rules, approved by the regulatory agency. The non-regular transportation represents charter bus operation between a source and a destination, with price, itinerary and schedule agreed between the hiring party and the carrier (contractor).

The non-regular transportation can still be divided in Continuous, Eventual or Touristic. Continuous means frequent transportation of passengers from an origin to a pre-defined destination e.g. students' charter transportation. Eventual or Touristic are sporadic endeavors, without periodicity, as charters for shows, excursion groups and sporting events. Among the goals of the operating unit that deal with this domain, we choose as running example a specific part, that is, the preparation and

monitoring of contracts for the passengers' transportation under charter regime.

5.2. Traditional Approach

The traditional approach consists in producing mind maps about the domain. A mind map is often created around a single word or text, placed in the center of the map, to which associated ideas, words and concepts are added. Figure 7 shows an example of partial mind map that identifies two operational goals from a strategic goal.

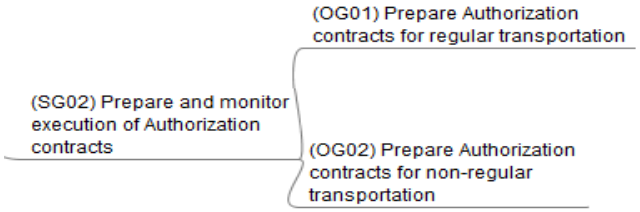

Figure 7. Operational Goals identified and transcribed to the Mind Map.

In strategic goal "(SG02) Prepare and monitor execution of Authorization contracts", we identified two operational goals: "(OG01) Prepare Authorization contracts for regular transportation" and "(OG02) Prepare Authorization contracts for non-regular transportation". Figure 8 illustrates the competency questions derived from the latter.

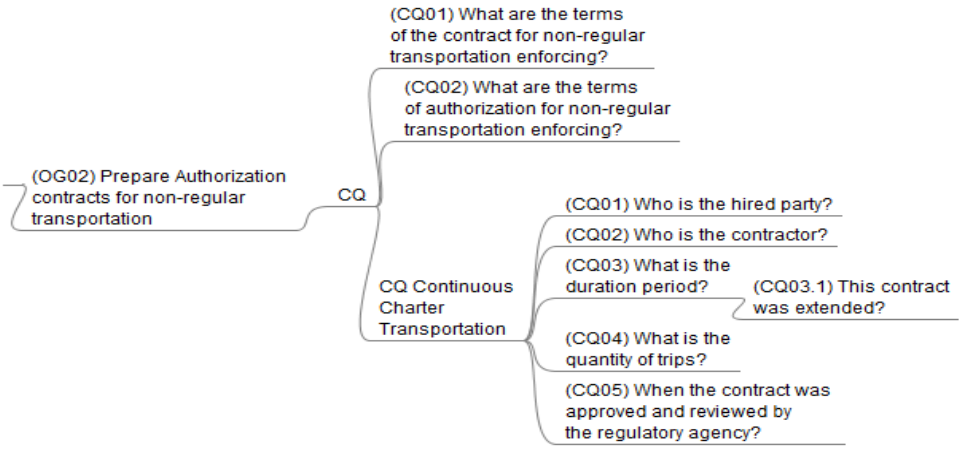

Figure 8. CQs elicited using the method for determined Operational Goal.

Based on the second operational goal, "(OG02) Prepare Authorization contracts for non-regular transportation", we have created two general competency questions: "(CQ01) What are the terms of the contract for non-regular transportation enforcing?" and "(CQ02) What are the terms of authorization for non-regular transportation enforcing?". After, we created a subdivision of competency question to continuous charter transportation and we generated six competency questions: "(CQ01) Who is the hired party?", "(CQ02) Who is the contractor?", "(CQ03) What is the duration period?", "(CQ03.1) This contract was extended?", "(CQ04) What is the quantity of trips?" and (CQ05) When the contract was approved and review by the regulatory agency?".

5.3. Proposed Approach

This subsection presents how we applied the proposed approach to the same domain previously depicted using the traditional approach. We carried out the agency goal modeling activity in three steps, each one representing an organization level. On the first step we modeled goals for the agency as a whole, taking into account all legal dispositions associated to it. In the following steps, we modeled the goals at superintendence's level, and middle management's level, respectively, obeying the downward hierarchical structure. The modeling covers Early Requirements phase of the Tropos development method, representing current goals of the regulatory agency (as-is). This paper presents a fragment of the model that is significant to our intent: convey how the prototype process works and the results about comparing the approaches and evaluate the hypotheses.

Figure 9 presents a Goal diagram at middle management's operational unit (GEFAE Actor). This actor, generally speaking, takes care mostly of regulatory activities related to passenger's charter transportation. The diagram shows the goal "Monitoring passengers' interstate road transportation charter services done" as the main goal of the diagram[1]. This one is refined, by AND decomposition, in five goals, and so forth, as illustrated. During the contribution and means-end analyzes, we identified two database related goals that contribute to the monitoring evolution indices for charter services. The diagram fragment of Figure 9 is consistent with the fragments of the mind maps presented in Figure 7 and in Figure 8.

[1] The label "[fromSUPAS]" indicates that the goal was delegate by this higher operational unit (Superintendence level). We made this decision in order to circumvent the problem of modeling the organization in hierarchical levels instead of a flat organization. Describing organizational goals from a top-down approach is beneficial, as we can understand the agency from its higher levels intentions and dependencies, capturing why goals are delegated to each middle management level units. Using this approach, we can also describe "compliance" relationships from top level intentional elements, as well.

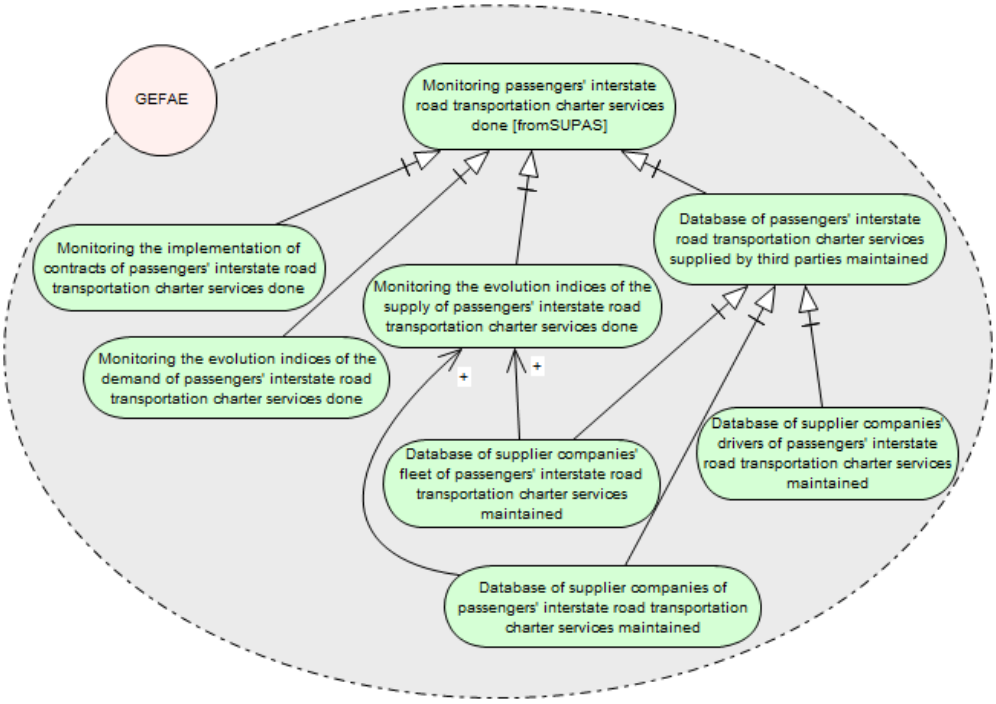

Figure 9. Fragment of a Goal Diagram for a middle management branch specialized in interstate passengers' road transportation using charter regime.

Guided by the diagram depicted in Figure 9, we executed the task of capturing CQs. We elicit and represent them by means of CQT diagrams, as discussed in the previous section. At this point we can clearly devise different levels of questioning we can make, in order to contribute to goal satisfaction through their answers. Figure 10 shows the CQT diagram fragment for monitoring implementation of transportation services contracts goal. This goal is in-line with the scope worked upon using traditional method. We can say that these CQs are at operational level; the majority of the questions are of the "look up" kind, i.e. querying for values of properties of an instance, or an instance in a set.

We also observe that, even using this small fragment of the project's real diagrams, we can map the CQs captured with both methods, but one that traditional method was not able to show; the CQ questioning about the renewal rate of service contracts is not captured in traditional method. This happens because using that method the ontology engineer could not identify that goals concerning monitoring evolution indices, that is, "rates" monitored, is a desired state of the world for the stakeholders. This is evidenced as it is part of an "AND" decomposition.

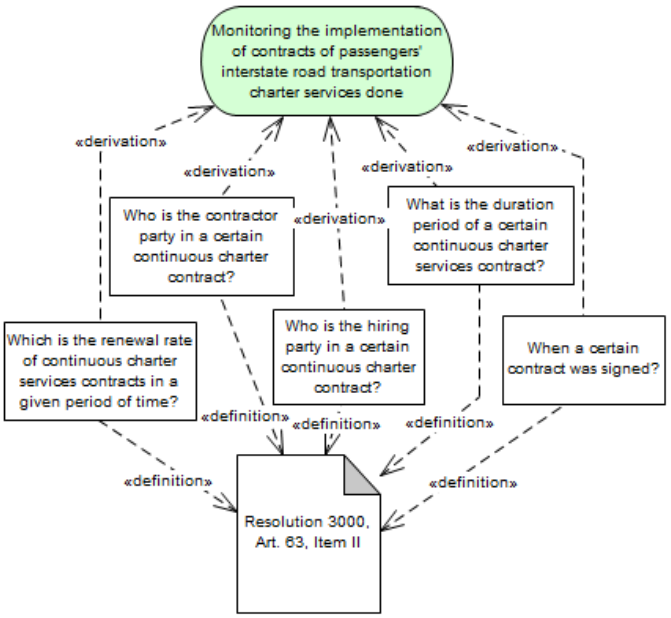

Figure 10.CQs concerning imlementation monitoring of transportation servives contracts (operational viewpoint).

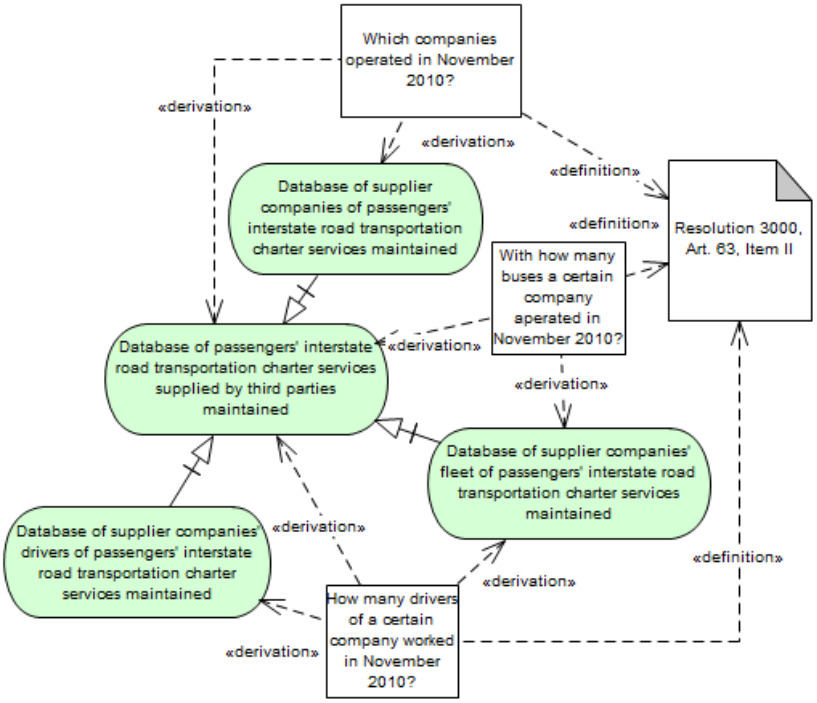

Figure 11.Database related CQs.

Although they are also at the operational level, we think that is relevant to show CQs derived from database desired states, as Figure 11 does. The interesting fact here is that CQs cross-reference the different databases searching for linked data questioning for derivatives, or quantities and lists of linked instances.

The goal modeling approach may favor the creation of more complex CQs, as we can see in Figure 12. These CQs, select, filter, and group data, from many concepts, and presuppose complex calculations. The questions captured in this fragment are eloquent to deliver the ability of goal modeling for representing very different level of intentions and derive these questions.

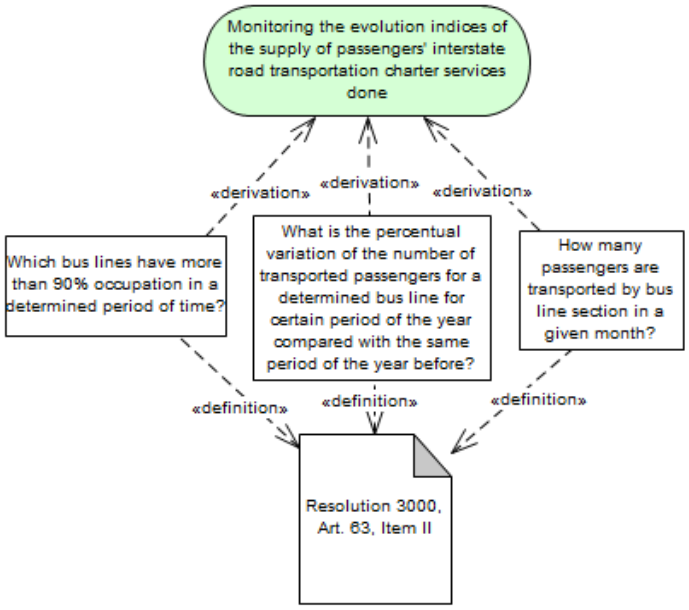

Figure 12. Tactical and strategic CQs.

5.4. Discussion

We can clearly see that competency questions elicited by means of mind mapping refers only to the operational goal identified. The problem is that mind maps have no semantics and are exactly what the expression means: maps of modeler's mind. Furthermore, in large domains is difficult keep any type of traceability in the model.

We proposed a new approach, discussed in the section 4, that consists in an ontology specification that allows ontology engineers and domain experts do reach a set of better CQs than traditional methods would allow. We can realize that competency questions derived by means of goals are less related with look-up actions, i.e., retrieving of information, and uses more aggregated information and cross-referenced concepts. In addition, the goal modeling approach decreases the semantic gap between the goals and CQs,

since the language constructors have a defined semantics. Although the goal modeling approach may provide a better base for eliciting CQs, it still lacks an accurate method to guide de modeler in the process of creation of these queries, maintaining this task as a "black art" and strongly dependent of the modeler experience.

6. CONCLUSIONS AND FINAL CONSIDERATIONS

We conclude this stage of the investigation with relevant results and big questions. However, we could evaluate and conclude that inherent decomposition and classification meta-model support drives to a natural goal translation from reference documents (normative or generic), at least makes it easier.

We were able to capture CQs at enterprise information stratification levels, as well, and even shrinking the semantic gap, we could not eliminate it. The prototype process worked fine.

Our hypothesis for the failure in eliminating the semantic gap between goals and CQs is that this fact occurs due to insufficient goal refinement. In another way, we could not reach actual leaf goals in our readings and interviews. We shall conduct this investigation in order to evaluate this hypothesis.

The approach does not capture ontological distinctions, once its covers epistemological concerns. We cannot capture domain constraints either, because questions are not able to convey these ideas, unless the question could be: Is it possible that I can marry myself? Usually we do not make this type of questions.

The hypothesis of getting more precise reference ontology models cannot be evaluated, since, in this part of the research, we actually have not a conceptualization activity.

This is an on-going investigation. We expect to go on based on these results, given that lots of research questions turned up from this part of the research. The prototype method can be improved using the experiences gathered.

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