# Visual and Ontological Modeling Support for Extended Enterprise Models

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**Abstract.** Modern enterprises have to face changes brought on by multiple change drivers like evolving market conditions, technology obsolescence and advance, and regulatory compliance among others. Enterprises need to create and use both descriptive and prescriptive models such that prescriptive models leverage the descriptive models to operationalize optimum strategies in response to change. This paper presents a visual model editor and ontological support for aforementioned kinds of models of enterprise. The editor enables modeling a) motivations behind and goals in response to change, b) the AS-IS state of enterprise, c) possible TO-BE states, and d) operationalization model that captures paths from AS-IS to desired TO-BE states. The analyses required are carried out using ontological representation.

**Keywords:** Enterprise Architecture Modeling, Intentional Modeling, Motivational Modeling

## 1 Introduction

For enterprises to respond to changes in an efficient and effective manner requires complete understanding of AS-IS architecture, possible TO-BE architectures, a way to evaluate TO-BE architectures based on some criteria, and an operationalization path from AS-IS architecture to the desired TO-BE architecture.

In this regard, earlier we investigated an approach in which intentional modeling was treated as a enterprise problem solving technique [1]. We represented AS-IS enterprise architecture (EA) models using Archi [2] and intentional models for TO-BE EA using OpenOME [3]. We carried out the evaluation of alternatives in OpenOME. Only a single alternative from amongst the optimum alternatives was then materialized over the AS-IS enterprise model. The AS-IS architecture model coupled with modification and addition of elements and relations would indicate a specific TO-BE architecture. This TO-BE architecture captured the intentional alternative found to be optimum.

As we applied this procedure to several real world case studies, we found that it had shortcomings that we enlist below, which became evident when we started modeling large real world enterprise models-

1. For really large enterprise models, keeping the EA and intentional modeling concerns in sync in two different modeling tools became nearly impossible as models grew in size.
2. In our original approach, the traceability between intentional models and elements of TO-BE architecture was not preserved. We had to adopt an ad-hoc process in enacting desired TO-BE architecture model presuming that concerns expressed in intentional models are represented adequately in TO-BE architecture model.

In accordance with the pointers mentioned above, we extend Archi to enable integrated visual modeling of EA models as descriptive models and intentional and motivational models as prescriptive models. We also extend the EA ontology we presented in [4] to carry out various analyses required in terms of computing prescriptive courses of action from AS-IS to TO-BE EAs. The main component of extended visual and ontological modeling is an extended enterprise metamodel that integrates descriptive and prescriptive concepts. Our ongoing model building effort with a large real world case study suggests that visual modeling editor simplifies and streamlines modeling process and ontological models enable expressing requisite analyses with ease.

The paper is arranged as follows. In section 2, we describe the extended visual and ontological modeling support. Section 3 explains how visual and ontological models are used together in charting a course of action from AS-IS architecture to desired TO-BE architecture. Section 4 recounts related work and concludes the paper.

## 2 Visual and Ontology Modeling for Extended Enterprise Models

Figure 1 shows the steps from modeling intentions and motivations of an enterprise (henceforth called *IM modeling*) in its response to a change till the operationalization of chosen strategic alternative. Figure 1 also shows specific visual models and analyses in each step.

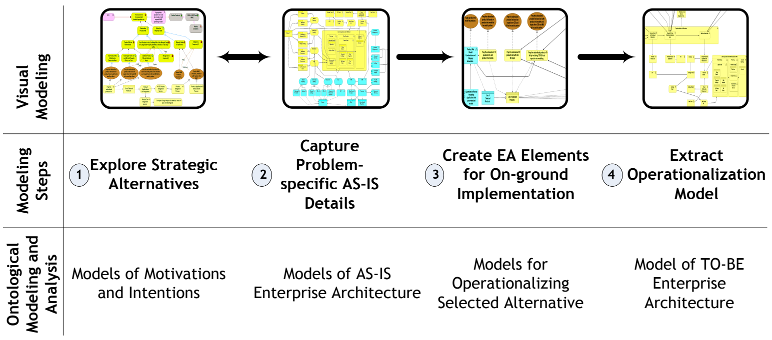


Fig. 1: Steps in Enterprise's Response to Change

In the following, we first describe the extended enterprise metamodel and how it is used as the basis of visual and ontological modeling. We then describe the steps in Figure 1 briefly.

### 2.1 Extended Enterprise Metamodel

The mapping between core metamodels of ArchiMate and i* enabled treating intentional modeling as a problem solving technique for enterprises as described in [1]. As we modeled a number of in-home enterprise scenarios, we found that a distinction was needed between the concepts of motivation or driver and goal. Motivation is something that would lead an enterprise to consider certain goals. In practical enterprise modeling, concepts of drivers, stakeholders, and assessment make more sense to domain experts than notions of goals and soft goals. Figure 2 shows the extended enterprise metamodel which integrates ArchiMate's core metamodel with IM modeling concepts.

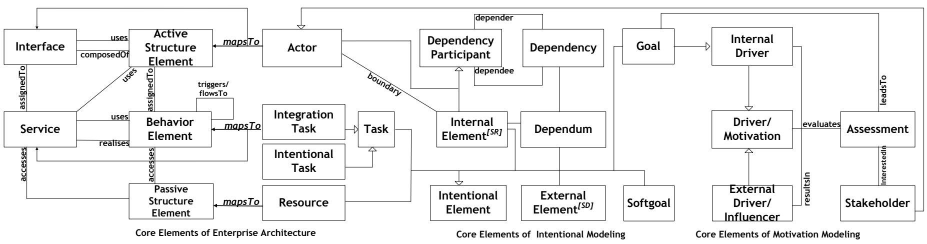


Fig. 2: Extended Enterprise Metamodel with EA and Intentional [1] and Motivational Concepts

While Figure 2 shows this mapping at conceptual level, various cardinalities are made explicit in the underlying ontology as described later in Section 2.3. This mapping enabled us to specify that *enterprise active structure entities are motivated by internal and/or external drivers to use or create passive structure entities while performing behavior (entities) as means to ends that are goal(s) or soft goal(s).* This kind of articulation of enterprise's problem context is streamlined using visual modeling support as we explain next.

### 2.2 Visual Modeling Support for EA and IM Models

As described earlier, we used open source tools Archi and OpenOME for enterprise and intentional modeling respectively. We chose Archi for extended enterprise modeling as it already supports modeling the business, application, and infrastructure layers of ArchiMate [2] and we would have to add only the IM concepts to it. With the core metamodel of Archi extended to metamodel in Figure 2, it becomes possible to visually model both EA and IM concepts together.

In Figure 3, 1 shows models of products and services rationalization problem in a case study of merger and acquisition (M&A) of two large wealth management banks which we introduced in [5]. We are modeling this case study in terms of models specific to problems described in [5] consisting of over a 1500 entities and more than 2500 relations so far.

The extended Archi elements based on the extended enterprise metamodel in Figure 2 are shown by 2 in Figure 3. Archi is itself based on Eclipse Modeling Framework (EMF) and makes addition of elements and relations easier on top of business, application, and infrastructure metamodels of EA that it already provides [2].

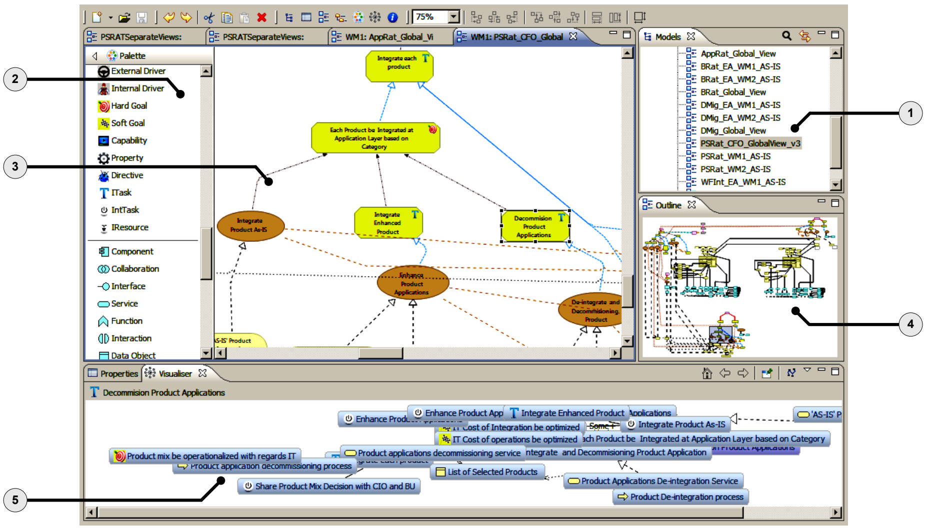


Fig. 3: Extended Archi for EA and IM Modeling

The process of adding elements to base metamodels is straightforward in which EMF-based classes have to be added followed by code generation etc. A relation is added in Archi, by internally assigning a specific character that recognizes a relation and then the source types mention the character to enable using this relation with the allowed target element. By defining all the elements required by EA and IM models and sets of allowed relations between various elements, EA and IM models can be drawn as shown by 3 in Figure 3. The models panel in Figure 3 enlists AS-IS EA models as well as IM models of these problems we refer to as global views. 4 shows such a global view of products and services rationalization problem. Current version of Archi supports visualization of a selected model element in terms of all other elements that it is related to as shown by 5 in Figure 3. An example of EA and IM models drawn in the context of aforementioned case study is shown in Figure 4.

We need to keep the details of the case study outside the scope of the paper due to space restriction. Suffice it to say that the extended visual modeling elements proved to be considerably useful when modeling problem-specific aspects of the case study with domain experts. Both the implicit reasoning that the domain experts used and the existing EA elements could be modeled in the same view. This enabled clear flow of domain experts' understanding that is translated to models conforming to the extended metamodel.

### 2.3 Ontology Modeling Support for EA and IM Models

We presented an ontological representation that captures ArchiMate's core metamodel as well as layer specific metamodels in [4]. This representation was versatile enough for conducting change impact and landscape mapping analyses. We extended the EA ontology presented in [4], with IM concepts as shown in Figure 5. For EA ontology modeling and analyses, reader is requested to refer to [4]. We only explain ontological modeling of IM concepts here. Archi enables export to CSV files which retain EA element type and name of both source and target nodes along with relation and documentation if any. While custom exporters can be easily written, the default export option was quite sufficient for our purposes. The exported model is easily read into ontology model by first constructing the dictionary leveraging the type information of instances and then constructing the data in terms of relations.

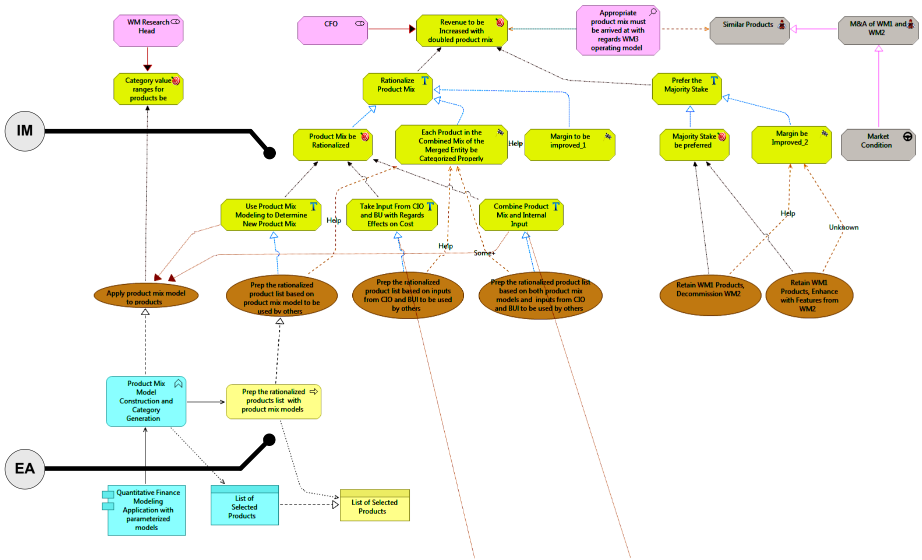


Fig. 4: *IM* and *EA* Model of Chief Financial Officer *Actor* in Products and Services Rationalization Problem

**Ontological Representation of IM Concepts** Intentional modeling concepts are captured under IntentionalEntity class as shown in Figure 5. The metamodel in Figure 2 distinguishes between elements internal to an actor (comprising strategic rationale model) and external to actors (strategic dependency model) [6]. We found that all of the relations in intentional model namely, means-end (MELink), task decomposition (TDLink), contribution (CTLink), and strategic dependency (SDLink) relations, benefit from being represented as *reified* relations [7]. For instance, a contribution link indicates not only which element contributes to a soft goal but also what that contribution is.

We have chosen those motivational concepts and relations from [8, 9], which we think have practical relevance as shown in Figure 2. These are captured under MotivationalEntity ontology class. Drivers, both within an enterprise and from the enterprise's environment, influence rest of the IM elements. Generally, a stakeholder becomes interested in assessment of a driver and it is this assessment that leads to formulation of a goal. From thereon, intentional modeling begins in terms of actor who is responsible for achieving the goal and actions that need to be taken by that actor, in some cases depending on other actors.

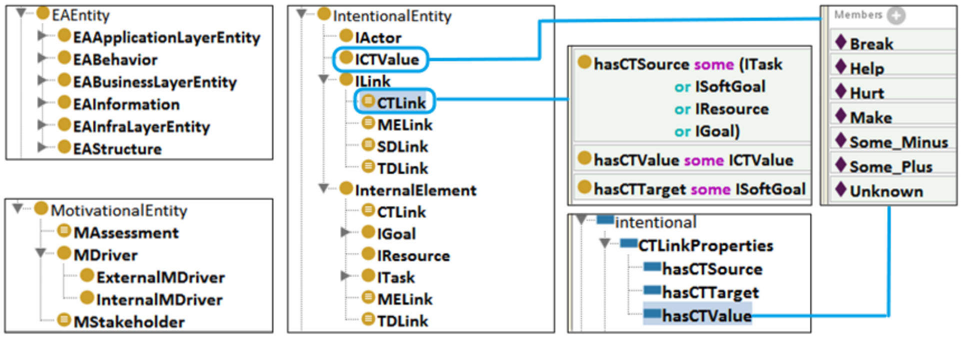


Fig. 5: Ontological Representation of Extended Metamodel in Figure2

## 3 Using Visual and Ontology Modeling

In the following, we describe in brief how visual and ontology modeling is used in a step by step manner as previously indicated in Figure 1.

**Step 1- Exploring Strategic Alternatives** In our approach, IM modeling is carried out first to gain clarity of the problem context. The AS-IS architecture of the enterprise with elements pertaining only to the problem situation at hand could be then easily modeled.

Upon completion of the IM modeling activity for a given problem, leaf tasks can be assigned satisfaction levels. We have implemented the bottom-up label propagation algorithm in [10] to compute satisfaction level of the root goal. The ontological representation easily enables implementing the label propagation as well as computation of specific routines. A SPARQL[1] query to get all the immediate tasks that are means to a specific IHardGoal instance is shown in Listing 1.1.

**Listing 1.1: Traversing Reified Means-Ends Links**

```
"SELECT ?task " + "{ " +
"?s rdf:type :IHardGoal . " + "?s :name \"" +
<IHardGoal> + "\" . " +
"?meLink :hasMEGoal ?s ." +
"?meLink :hasMETask ?task ." +
" }";
```

**Step 2- Capturing Problem-specific AS-IS Details** We showed how EA ontology for given enterprise model can be leveraged to query the model in [4]. Using what-if analyses of IM models and queries on enterprise models and going back and forth between these models, both models can be refined such that they capture the reality to the satisfaction of domain experts.

**Step 3- Creating EA Elements for On-ground Operationalization** In the next step, leaf tasks in IM models are related to EA elements that will operationalize them from TO-BE EA perspective. IM alternatives can be combined in various ways based on whether they satisfy the root goal. In order to preserve which elements were added

[1] http://www.w3.org/TR/rdf-sparql-query/

for specific leaf tasks, we tag them in the ontological representation using an object property called isOperationalizationElementOf. This achieves two purposes- first, the EA elements that are added anew in contrast to AS-IS elements are identified; and second, which new elements constitute the operationalization of a specific leaf task is made explicit.

**Step 4- Extracting Desired TO-BE Operationalization Model** The specific set of elements that would comprise an operationalization model of a specific strategy is computed by creating an extended Archi viewpoint only of the operationalization models of all alternatives and exporting it as the sole model to import into ontological representation. Using this as the base model, the set of operationalization elements of a specific strategy can be easily separated out using a SPARQL query over the tagging introduced in Step 3.

## 4 Related Work and Conclusion

Various approaches have suggested combined treatment of enterprise and IM concepts [8, 11, 12], but with either the visual modeling support or the programmatic means of analyzing models missing, they remain without use in practice for large scale enterprise what-if analyses. Similarly, visual modeling support remains one sided- either IM modeling support is at an early stage as in [13] or EA based modeling is lacking as in [14].

Our ongoing experience in modeling the M&A case study suggests that visual modeling support for extended enterprise models streamlines the case modeling activity while ontology modeling support enables implementing requisite analyses. Visual models are imported into ontology and therefore models and analysis results remain in sync. While visual modeling support explained in the paper is working as desired, we suspect that when many modelers are simultaneously modeling various problem-specific IM and enterprise models in multiple interactions with domain experts, a more robust distributed enterprise and IM modeling environment will be necessary. We are actively pursuing the possibility of implementing such an environment using our proprietary reflexive metamodeling framework which we have used successfully in several business engagements [15].

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