Validating Value Network Business Models
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Abstract
Different meta-models allow to model the business of organizations from different perspectives. Business models, value network models and enterprise architecture models potentiate a shared understanding of information and together, they permit an alignment from business idealization to business implementation, considering that an organization is a part of a value network. However, model representation does not allow automated model analysis, which enables automated detection of inconsistencies between models and additional support for decision making. Our goal is to overcome this issue with model-based representations by integrating three meta-models, Business Model Canvas, e3value and Archimate with ontology engineering techniques, to potentiate automated analysis of models represented with description logics. A developed application uses ontology reasoning and querying to perform an automated detection of components that cancel conformity between models for a value network. The proposal is demonstrated through a scenario with Business Model Canvas, e3value and Archimate models for a value network, by executing the consistency validation application and further model analysis.

Keywords: Business Model Canvas, e3value, Archimate, Ontology, Ontology Integration, OWL

1. Introduction
When developing technology-based businesses, different models of different perspectives on the business execution are created: from idealizing the business itself to the technological infrastructure that supports it. It is mandatory to have a shared understanding of what the business model is.

The Business Model Canvas (BMC) [21] provides a way of representing the business model of a company. It is composed by nine building blocks that should be filled with information that answers specific questions about a business model.

When a company is concretizing its business, it is part of a network of companies exchanging value, a value network. E3value [9] provides a set of components that specifies modelling of value networks, by representing the actors, the activities, the value exchanges and the value chains involved in the network.

BMC allows representing the business model of an organization in a strategic perspective. An e3value model is connected to the operational level but it does not contain any business processes, which can be modeled with Archimate. Archimate [?] is an enterprise architecture modelling language composed by different layers: business, application and technology, allowing an alignment between business, business processes and information technology infrastructure.

All together, the three meta-models represent the alignment from business model idealization to technology infrastructure. When modelling the business of an organization, several models may be instantiated for a value network. If they coexist for a value network, they must be consistent. There is no way to automatically validate the consistency of those instantiated models for a value network.

We analyzed the possibility to perform automatic consistency validation between models of BMC, e3value and Archimate by using ontologies. This can only be done if the meta-models are integrated. With ontology engineering, not only the models can be represented computationally, but we will also be able to ask queries to the models, validate the integration and demonstrate the proposal.

Demonstration will happen in an example of business model innovation, ePharmacare. The various models for the ePharmacare value network will be instantiated and represented in OWL. Queries will be executed for validation of the integration and for consistency analysis between models.

In previous research, this work has been introduced, where an integration of the meta-models was done [?]. Design science research methodology (DSRM) framework is used, thus every step of DSRM can be clearly mapped to this work.
2. Related Work

BMC and Archimate are used in this work because they are leading in their own domains [15], and e3value provides a network perspective. Ontology engineering has been a topic with growing interest in the past years. In the domain of computer science, an ontology can be defined as formal, explicit specification of a shared conceptualization [14].

2.1. Meta-models

The term business model can be defined as: A business model describes the rationale of how an organization creates, delivers, and captures value [21]. A value network articulates how producers, consumers and customers articulate the execution of a certain business model. A company may be interested in its value network for the opportunity to improve the way it behaves in the network or to establish a network of partnerships that overcome a business problem, otherwise impossible to solve.

The Business Model Canvas (BMC) [21] is a visual tool that aims to represent a business model and translate it into explicit knowledge. Its focus is close to a strategic perspective. A single canvas shows the business model of a single company and it is composed by nine building blocks that must be filled with relevant information.

The BMC is based in the Business Model Ontology [19]. BMC building blocks aggregate various BMO concepts, presented in [18]. The reduction of concepts comes from combining elements with sub-elements, making BMC of quick access through its simplicity at the cost of formality.

The BMC focuses in describing the business model of an individual company, so it is no so appropriate to understand networked business models. The authors did not include competition and business model implementation because their consider these issues are not an internal part of a business model, despite having connections with it.

The e3value ontology enables value network modeling, aiming to provide a common understanding of a business idea executed by a network of actors that jointly create, distribute, and consume value in inter-organizational business models.

E3value models allow reasoning under two purposes: to understand the position of a single company in the context of the value network, or to analyze how the network of actors can create and deliver value in cooperation.

ArchiMate [2] is an open enterprise architecture modeling language, allowing to establish an alignment between business models and information and communication technology. The ArchiMate framework organizes its meta-model in a 3-by-3 matrix, three layers: business layer, application layer, infrastructure layer; and three aspects, one within each layer: structural, behavioral, and informational.

2.2. Ontologies

Regarding ontologies, the term formal means it is computable, while the term shared conceptualization refers to a consensual abstract model of phenomena in the world by having identified the relevant concepts of those phenomena. The used concepts and constraints are explicitly defined.

Ontologies are shared representations of knowledge and they potentiate communication between people with different needs and viewpoints; interoperability between systems, as it facilitates the exchange of data between them; and re-usability, reliability, and specification of systems [26]. An ontology is composed by certain concepts and the relationships between them. Concepts and relationships must have precise and unambiguous definitions.

The word integration has been used with different meanings in the ontology field. In simple terms, ontology integration is the process of identifying common concepts and relationships shared between two or more ontologies [23]. Three main techniques of ontology integration can be described as follows.

- *Ontology alignment.* is the process of building a new ontology by identifying correspondences between all the concepts of two ontologies, which are said to be equivalent.

- *Ontology mapping.* is the process of building a new ontology by finding common concepts between two (or more) concepts belonging to two (or more) different ontologies.

- *Ontology merging.* is the process of building a new ontology by merging several ontologies into a single one that will unify all of them, and create a more general ontology about a subject.

One of the key features of ontologies is that they can be validated and analyzed by reasoning methods. The term reasoning is used, in the context of ontologies, to denote any mechanism for making explicit a set of facts that are previously implicit in an ontology. The two main purposes of reasoning are validation and analysis.

Validating an ontology means ensuring that the ontology is a good representation of the domain of discourse that you aim at modelling. Reasoning is extremely important for validation. For example, consistency checking is a kind of reasoning, which can be performed to capture possible inconsistencies in the definition of the classes and properties of the ontology. Also, a reasoner can then be used to obtain inferred information about the model, such as inferred super-classes, inferred equivalent classes, and inferred types for individuals.

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3. Proposal

We need to use a set of ontology techniques to support the solution. The consistency validation method (figure 1) in models of Business Model Canvas, e3value and Archimate is based on a set of mapping rules between the three meta-models and automatic validation of those rules using ontology techniques.

![Figure 1: Solution diagram.](image)

With Web Ontology Language (OWL) representations of the three meta-models, we have formal representations of the models. Further on, those models can be queried with other ontology techniques like OWL-DL and SPARQL.

It is needed to define mapping rules between the meta-models. Those mapping rules will assess the consistency between models of the three meta-models. The goal is to have a set of mapping rules that establish an alignment between the concepts of the meta-models.

We still need to be able to validate those rules on instantiations of the meta-models. Those instantiations (or models) are transformed to OWL, so that ontology techniques can be applied and validate the models, basing on the mapping rules previously defined.

Protege is a free ontology editor and knowledge-based framework in which OWL ontologies can be managed. To query ontologies, OWL-DL and SPARQL will be used to guarantee consistency and query the models. The Apache Jena framework is used to execute SPARQL queries. Apache Jena is a semantic web applications framework that provides SPARQL support for RDF.

The mapping rules are conceptually defined in the domain of the three meta-models and the models. The meta-models and the models are transformed into OWL. Meta-models become classes and models become individuals of those classes. The mapping rules are implemented OWL, with Protg to apply such transformation and manage the ontologies. OWL is transformed into RDF so we can query ontologies with SPARQL through Jena framework.

3.1. Mapping Rules

To define the mapping rules, the meta-model mapping technique defined in [27] was partially applied. It distinguishes different types of mappings and this work uses class-to-class mappings, which define relations between concepts of two distinct meta-models and also equivalence and aggregation mappings between concepts. The referenced technique is only used to define the mappings since the goal is not to merge ontologies.

We consider mapping rules from a value network perspective, which means we should identify the core concepts from e3value that help to model a value network. Then, we mapped those concepts with BMC and Archimate, understanding how we can represent value network exchanges in each of the two meta-models.

The core concepts of e3value to model a value network are: Value Interface and Value Transmission which are related to links between actors; Actor and Value Activity which are related to the nodes of the network; Value Object is also a core concept and it is important either for the linkage between nodes and for the nodes themselves.

3.1.1 BMC to e3value Mapping Rules

The authors of the BMC and e3value made a comparison of both [10] where they discuss similarities and differences between them and analyze integration possibilities in order to improve representation, design and analysis of business models.

The five identified core concepts of e3value are mapped to BMC. BMC defines a clear distinction between the client-side and partner/support-side of the business model. On the client-side we have the following building blocks: customer segments, customer relationships, channels, value proposition, and revenue streams. On the partner/support-side lays what supports the business idea: key partners, key activities, key resources and the cost structure. This distinction client and partner sides is important because some actors of the network relate to the clients-side and other actors relate to the partners-side.

3.1.2 BMC to Archimate Mapping Rules

Research work [18][15] explored the connection between BMC an ArchMate, where the concepts of BMC were successfully mapped to e3value. The authors only consider Archimate business layer since business models domain do not relate to application or infrastructure layers. Archimate motivation and valuation extensions are also considered. In [18] relations of BMO are also mapped to relations of Archimate.
[15] has more mappings from Archimate’s motivation extension and it uses the concept capability as an abstraction for behavior elements: the ability of an entity to perform activities.

The defined mapping rules are inspired on previous work. We do not consider any mapping between Customer Relationships (CR) and Business Collaboration because CR refers to the types of relationships an organization maintains with its customers. Key Partners is only a list of partners, so the mapping is simplified to Business Actor. Cost Structure is not mapped to Value because it is only the cost of performing internal activities and managing resources.

3.1.3 e3value to Archimate Mapping Rules

Comparisons between e3value and ArchiMate with the final goal of establishing an alignment of business and Information and Communication Technology show that direct transformation from e3value to ArchiMate is inhibited by different levels of abstraction between the economic transactions modeled in e3value and ArchiMate [6].

[7] aims to ensure consistency through model integration. Using the Archinsurance case study, the e3value model was converted to ArchiMate, and vice-versa. Afterwards, the authors discuss integration between the two meta-models.

The same authors use DEMO [8] as a bridge for the different levels of abstraction of e3value and ArchiMate [7], showing an unidirectional transformation starting from e3value value transactions model, to DEMO transactional model, and finally to ArchiMates business layer.

Another paper [24] proposes a map between e3value and DEMO, based on the coordination acts and facts of the transactional pattern and the corresponding competences by the value actors. This paper is used additionally to support the mapping between value transmission and business service.

The defined mapping rules are inspired on previous research work. We must have present the idea that providing an external service in archimate is equivalent to be willing to give-out or receive a value object in e3value. Thus, a value interface with one inbound value port and one outbound value port is equivalent to two business services, one providing the acceptance of a value object and the other providing providing the release of a value object (figure 2).

3.2. e3value Ontology

The computational representation for the e3value meta-model was performed by analyzing concepts, relations and constraints of the e3value meta-model. At first, the meta-model was transformed and then, axioms and cardinalities were added.

An analysis of e3value meta-model was performed concept-by-concept and every concept was transformed into an OWL Class and every relation into an OWL Object Property.

Figure 2: Side by side comparison between the usage of business services by external actors in ArchiMate and the value transmissions between actors in e3value.

![Diagram of business services and value transmissions](image)

Figure 3: Partial of e3value OWL ontology: e3value Value Interface definition

Object properties have defined OWL characteristics as, for instance, the property isPerformedBy is a functional property. Additional constraints are defined to enforce the definitions in the meta-model, namely the inclusion of cardinality restrictions in relations: has min 1 InboundValuePort, as depicted in figure 3.

3.3. Integrated Ontology

The research proposal sets an unified meta-model for the purpose of integration of the BMC, e3value and Archimate meta-models. After defining the mapping rules between the three meta-models, it is required to represent them computationally using the OWL ontology language. The BMC OWL representation was obtained from other authors [20][22][1]. Archimate OWL representation was obtained from [4][3][2]. E3value transformation process to the OWL representation was presented previously.

The integrated ontology is a new ontology that references the other three ontologies guaranteeing that each ontology remains unchanged and guaranteeing the existence of each ontology separately as different modules.

Computational representations are specified in OWL-DL, including the mapping relations, which
fulfill the integrated ontology. In order to define a
generic representation for the contextualization of
the integrated ontology, we define a general perspec-
tive on the relations of value networks with business
models and enterprise architectures. A meta-model
for the generic representation is depicted in figure
4.

Figure 4: An general perspective on the relations of
value networks with business models and enterprise
architectures.

Relations between value networks, business mod-
els and enterprise architectures are defined but such
definition is not coupled to any specific meta-model
for each of the three perspectives on business. We
then define a relation of ownership, that is specific
to the scope of this research work, between business
model, value network and enterprise architecture to
BMC concept, e3value concept and Archimate con-
cept respectively.

The generic representation also allows to define
that a particular component of, for instance, a BMC
model belongs to that BMC model, via the owner-
ship relation. Otherwise, it could not be possible
because multiple business models and enterprise ar-
chitectures exist for a given value network.

Additionally, the integrated ontology has the
mapping properties between the classes of BMC,
e3value and Archimate ontologies. There is no need
to represent redundant mapping rules in the inte-
grated ontology, for instance, a mapping rule from
BMC-to-Archimate that can be represented by a
BMC-to-e3value plus a e3value-to-Archimate map-
ing rules. A meta-model for the mapping rela-
tions represented in the integrated ontology can
been seen in figure 5.

Key partners and customer segments have di-
rect correspondence to actors and to business ac-
tors (Archimate). Revenue stream corresponds to
value transmission and it transmits value because
because we use value to represent money exchanges
since money is a value object that is not represented
as business object. Value transmission directly cor-
dresponds to business service but it also relates to
two aggregation relations.. Value transmission gets
value from key partners using a certain key activity
or value transmission transmits a value proposition
through a channel, to a customer segment. Value
proposition directly corresponds to value interface
and to product. Key activity directly corresponds
to value activity and to high-level business process.
Key resources directly corresponds to value object,
which may correspond to value or business object, if
tangible. Channel directly corresponds to business
interface.

The mapping relations between concepts were im-
plemented in OWL-DL in the integrated ontology.
Figure 6 shows a partial of the integrated ontol-
ogy and in the right pane, the definition of Value
Transmission class, along with the mapping rela-
tions, relationships with other concepts and con-
strains: in the equivalent To section is defined
the correspondence of Value Transmission with
Business Service and also the aggregation rela-
tions of Value Transmission with BMC concepts.

3.4. Automatic Consistency Validation of Models
The research problem identifies potential inconsis-
tencies between the existing models in a value net-
work, which are realized by the non existence of
modeling components in certain models. These inconsistencies may happen between models belonging to the same perspective, for instance, in the business model perspective, that is, between BMC models or they may happen between inter-perspective models, that is, between models of the business model, value network and enterprise architecture perspectives. The define mapping rules help the detection of inconsistencies related to the latter type.

A set of competency questions suitable for consistency validation between models was defined:

1. Is there any customer segment or key partner that does not exist in e3value?
2. Is there any actor (e3value) that does not exist in any BMC?
3. Is there any actor (e3value) that is not represented in Archimate?
4. Is there any business actor in Archimate that is not represented in e3value?
5. Is there any revenue streams not represented in e3value?
6. Is there any key activity not represented in e3value and not represented in Archimate?
7. Is there any value activity not represented in any BMC and not in Archimate?
8. Is there any high-level business process not represented in any BMC and not in e3value?
9. Is there any value transmission without a business service related to it?
10. Is there any business service in archimate without any value transmission related to it?
11. Is there any Value transmission not related to the delivery of a value proposition or related to a key activity?
12. Is there any missing combination of key activity and key partner that may be mapped to a value transmission?
13. Is there any missing combination of value proposition, customer segment and distribution channel that may be mapped to a value transmission?
14. Is there any non correspondence between key resources and value objects?
15. Is there any value object not represented as a value or a business object?
16. Is there any Value or any business object not represented as a value object?
17. Is there a channel not represented in Archimate?
18. Is there any business interface not represented in any BMC?

Analogously to previously defined competency questions, these can also be formalized into OWL-DL or SPARQL queries. One of the objectives was to have automatic validation of models, therefore SPARQL queries are used in this case. The semantic web Jena framework allows the execution of SPARQL queries over ontologies represented in the RDF format. The SPARQL query for the first consistency validation competency question is presented below.

```sparql
SELECT ?customerSegment ?keyPartner
WHERE {
  {?
    MINUS {
      ?e3act rdf:type e3value:e3Actor .
      ?kp integrated:corresponds ?e3act .
    }
  }
  UNION
  {
    MINUS {
      ?e3a rdf:type e3value:e3Actor .
    }
  }
}
```

A Jena semantic web application was built and the consistency validation SPARQL queries are embedded in it. The application loads the ontologies, including the models of BMC, e3value and Archimate as individuals of the ontologies, and it runs every SPARQL query consecutively, resulting in a report composed by the answers to all competency questions.

4. Demonstration

Demonstration shows the utility of this research proposal and it is based on the application of the solution to example models of ePharmacare [13][12][16], which is an eHealth business model innovation research problem that intends to provide new services to chronic patients, through an advanced pharmaceutical service platform. New pharmaceutical services have been considered extremely valuable for health professionals, patients, and health systems. They represent economic savings but they also increase efficiency and improve health systems quality and patient health related outcomes.
Consistency validation queries are executed on ePharmacare models, in order to find inconsistencies on the components of the multiple models, basing on defined mapping rules.

EPharmacare models have been designed with the knowledge obtained from researching the ePharmacare project and semi-structured interviews. They include instances of multiple BMC models, one e3value model and multiple Archimate models. The tools: Canvanizer\(^1\), e3editor\(^2\) and Archi\(^3\) were used to build the BMC, e3 value and Archimate models respectively.

Figure 7: ePharmacare project business model canvas.

Figure 8: Community pharmacy business model canvas.

The ePharmacare platform aims to be a channel for the provision of information, disease management, warnings, home-delivery of medicines, pharmacovigilance, and therapy compliance. Multiple BMC and Archimate models coexist with one e3value model for a value network. The ePharmacare web platform stores information about chronic patients’ treatment, which is generally inserted in the platform by doctors.

Pharmacies manage clients’ treatments. When a medicine, in a chronic patient possession is finishing, the platform generates a warning that is delivered to the patient and to his pharmacy.

Figure 9: ePharmacare e3value model.

Figure 10: ePharmacare Archimate model.

Figure 11: Community pharmacy Archimate model.

1http://canvanizer.com
2http://e3value.few.vu.nl/tools/index.php
3http://archi.cetis.ac.uk
have the required medicine in stock, reducing possible waiting days if there is stockout when the patient tries to buy the medicine.

The patient and the pharmacy may additionally interact through the platform, using a web chat. Doctors can access and visualize the treatments evolution. The platform is paid by a pharmaceutical company. It acquires aggregated information of treatments (insights) but the platform also potentiates compliance between medicines, doctors and chronic patients, which is very important for the success of the pharmaceutical company.

5. Evaluation
Validation of ontologies demonstrate the ability to analyze and query the models for retrieving answers for stakeholders, including: validation of the e3value ontology, validation of the integrated ontology (mapping rules) and the consistency validation between models. With this, research questions are verified by defining a set of mapping rules, representing the three meta-models and those mapping rules computationally using ontologies, along with models of those three meta-models, and by building an application that executes consistency validation queries between the instantiated models automatically.

Demonstration in the ePharmacare case study allows to perform an analysis on the created report, regarding the mapping rules.

- A completely direct correspondence cannot be defined between key resources and value object because some key resource are an internal part of a value network and are not acquired or delivered to other nodes (justified by the results to the competency question 14).

- SPARQL queries that ask for value transmissions need to be improved because they consider value transmissions that are internal to actors, which is not supposed (queries 9 and 11).

- Two questions need always additional human interpretation because they suggest potential combinations for aggregation mapping relations (queries 12 and 13).

- The mapping between value transmission and business services could be better mapped. Despite value transmission is a core concept for a value network and connecting two business services, business services would be better mapped to value port, even because value ports also represent, in e3Value, an abstraction to the business processes.

- There is no guarantee that the BMC and ArchiMate models are complete, only that they are consistent with the value network scenario. For instance, deficiencies in a BMC model can not be detected, only if it is consistent with the rest of models.

We have shown how, for existing model representations of BMC, e3Value and ArchiMate, we can process and analyze the models regarding the consistency between them, for a value network. However, this proposal can also be used for model transformation. For instance, we could use this proposal to transform a set of existing business models (BMC) into a value network e3Value model. If the consistency validation queries are executed on the BMC models individually, the result of such consistency validation between models will provide all the inconsistencies, which will be pointers for building the desired e3Value model.

We have shown also, by presenting possibilities of questions for model analysis in sections ?? and ??, how different types of stakeholders, business model idealization, value network idealization, and enterprise architects, can ask interesting questions to the models.

6. Conclusions
An integrated ontology was created with the three meta-model ontologies plus the defined mapping rules, where example models from a case study were instantiated. To support integration of the three ontologies, an e3Value ontology was created. The ontologies were validated through a case study via logical reasoning techniques. The linkage between the three meta-models allows automatic consistency validation of models of the three meta-models. Therefore, a consistency validation application was created. It receives as input a set of aligned models in OWL representation and outputs a report containing answers to queries that search for potential inconsistencies between the models.


One paper was submitted in the journal Springer Knowledge and Information Systems. This paper describes in detail the proposal and the case study presented in the dissertation.

This proposal is relevant not only to the enterprise ontology community but also to the communities that are using each used meta-model: business model idealization, value network analysis and the enterprise architecture community. This research work shortens the gap between those communities.

In order to clearly state the contributions of this
thesis, we have: a set of integration mapping rules between BMC, e3value and Archimate; an OWL representation for e3value; an OWL for integrated ontology that aggregates BMC, e3value and Archimate plus the mapping rules; a set of models for the ePharmcare research project; a set of SPARQL queries to validate the integrated ontology; a set of SPARQL queries that can validate the consistency between models of BMC, e3value and Archimate for a value network; an application that uses the Jena framework to validate some given models (as ontology individuals) by executing the consistency validation SPARQL queries on the given individuals.

Limitations within the implementation and demonstration of the solution were also identified and they should be addressed in the future:

Because of the different perspectives of each meta-model, automatic ontology mapping techniques were not applied and the mapping rules between concepts were defined manually.

The manual process of transforming BMC, e3value and ArchiMate models is a slow, particularly because a value network origins many different model components. This difficulty is even bigger for e3value models, where many components (like value interfaces or value ports) have abstract identifiers an its traceability is based on the relations with other components, making harder the manual management of individuals in the ontology. To manually transform the models is not scalable.

Another subsequent limitation raises on the fact that the definition of mapping rules on the model level is also manual, that is, mapping between individuals is done one by one.

We have only mapped class-to-class (C2C). Other types defined in [27]: attribute-to-attribute (A2A), relationship-to-relationship (R2R), attribute-to-class (A2C), attribute-to-relationship (A2R), and relationship-to-class (R2C) are also potentially interesting.

Despite using an BMO OWL ontology we use BMC for all the analysis. BMC does not explicitly model relationships between building blocks. Thus, querying on BMC relations is limited. [15] proposes a BMC meta-model with extensions that could be used for the development of a OWL representation specific to BMC. The extraction of relations from a BMC model could be investigated through the usage of colors in the elements of the model, the only property that can be represented in BMC.

Future work should follow multiple vectors, beginning with overcoming identified limitations. An automated process for transforming models into ontology individuals can be developed: OWL is based on XML language and therefore, XML techniques like XSLT can be applied to transform XML representations of models to OWL representations, assuming we have already XML representation of models, which we can by using modelling software for the models.

Automatic similarity techniques [17] can be applied to detect mappings in the individuals level, by analyzing their names and descriptions. These techniques would shorten the time of defining mappings on individuals level manually.

Additional mapping variants defined in [27] can be performed, like relationship-to-relationship (R2R) and relationship-to-class (R2C). Other variants do not apply since attributes are not present in the meta-models.

We have not performed any comparative analysis between the implementation with ontologies with other technique, such as graph databases [25] and linked data [5].

Another point for future work is the application of this approach to additional case studies, as well as to develop a set of competency questions related to the multiple domains, and their validation with experts. The development of a front-end application could take advantage of the developed consistency validation application, for instance for a web-based front-end application.

References


