

A Survey on a Conceptual Model of Enterprise

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Abstract

Enterprise ontology serves as a foundational framework for semantically comprehending the nature of organizations and the essential components that uphold their integrity. The systematic and conceptual understanding of organizations has garnered significant attention from researchers due to its pivotal role in various domains, including business modeling, enterprise architecture, business process management, context-aware systems, application development, interoperability across diverse systems and platforms, knowledge management, organizational learning and innovation, and conflict resolution within organizations. Achieving a consensus on the concepts related to the fundamental elements that constitute an organization is therefore critical. This study aimed to conduct a comprehensive analysis and comparison of the existing conceptual models of enterprises as documented in scholarly articles published over the past decade. The comparison revealed significant variations in coverage, adaptability, and maturity across models, with many lacking completeness or alignment with comprehensive frameworks like Zachman's framework. The strengths and weaknesses of each model were discussed and a robust framework for their evaluation was introduced. To facilitate this evaluation, we proposed several pertinent criteria derived from established methodologies for assessing the ontologies. Furthermore, we identified contemporary challenges and issues that have been overlooked in prior studies, offering insights and suggestions for future research directions in enterprise modeling. Ultimately, a roadmap for enhancing the systematic understanding of organizations through refined enterprise ontology frameworks was presented.

Keywords

Enterprise ontology, Conceptual model, Enterprise dimension, Enterprise architecture.

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1. Introduction

Scholars have provided numerous definitions for the term organization in literature. Most defined an organization as a group of individuals who have come together to achieve a specific goal (Daft, 2020). An organization is a phenomenon whose most important constituent is human beings. According to postmodernist beliefs shared by several philosophers over the past couple of decades, enhancing interactions among humans is one of the most important areas for achieving high-performance organizations (Stacey et al., 2000). One relevant topic in this area is semiotics, which concerns interactions formed through signage and sign processes, including modeling languages (Mingers, 2006).

On the other hand, according to systems theory, an organization is also one of the many systems around us. Most scholars whose ideas are based on Newtonianism and systematic thinking believed that an organization is a system consisting of elements between which distinct relationships exist; thus, understanding organizations depends on grasping these elements and their relationships (Robbins, 1990). Despite these scientific approaches, there is still a lack of a common language that would help bring about a general consensus in the research community (Senge, 1990).

Management scholars have developed models to better understand organizations, their organizational problems, and to help classify and interpret their data systematically (Rock & Crawford, date?). Some studies (e.g., Burke & Litwin, 1992; Nadler & Tushman, 1995; Porras & Robertson, 1986; Waterman Jr et al., 1980; Weisbord, 1976) modeled the relationships between organizational components. For example, Levitt (1965), in his diagnostic organizational model, introduced organizational components such as structure, technology, people, and tasks. Weisbord presented a six-box organizational cognitive model (Saleem & Ghani, 2013; Weisbord, 1976) which includes purposes, structure, relationships, rewards, leadership, and helpful mechanisms. Janicijevic (2010) examined and compared the organizational cognitive model, dividing organizational elements into two categories of static and dynamic. Static elements include organizational structure, systems, culture, informal groups, and power structure, whereas dynamic elements are business processes, group processes, leadership, conflicts, political processes, and communication. Having reviewed the literature, he concluded that the existing diagnostic organizational models are imperfect because they do not include dynamic formal organizational components like business processes. According to him, a complete and comprehensive diagnostic model should encompass business processes and related parameters such as process owners and participants, organizational competence, indicators of key performance, shortcomings and problems of business process, key paths to change business processes, and priorities of business process.

On the other hand, information technology researchers want to align information technology with the goals of the organization and also develop information systems after the organization's structured recognition. Artificial Intelligence (AI) researchers also seek to understand the structure of organizations with the aim of creating a suitable environment for their own systems. Ontology is the most relevant area of science that aims to recognize these aspects of organizations. This field was first introduced by AI

experts in order to make sense of human semantic treasure for machines. The field of ontology has developed methods and tools to build different conceptual models for verbal and non-verbal concepts in various subject domains, one of which includes that of organizations. [Rosing \(2015\)](#) reviewed business ontology research and examined how business ontology is used in organizational development. He used the potential of ontology and semantics to develop standards that describe objects, relationships, and rules for enterprise modeling, organizational engineering, and enterprise architecture.

Enterprise ontology provides a uniform representation of similar semantic content ([Dietz, 2006](#)). Modellers use different methods to develop models. These models are created with different languages and modeling tools. There may even be various styles and different techniques used within a single method. In addition to this, products created by different organizations and disciplines use different terms to analyze organizations, leading to various perceptions of the organization. Therefore, a standardized format is needed to translate data among different systems of the organization and to understand different models of organizational analysis ([zur Muehlen, 2009](#)).

Enterprise ontology provides a data structure that facilitates the reader's understanding of data usage in an organization description document. For example, [Rajabi et al. \(2013\)](#) presented the methodology for enterprise architecture development based on enterprise ontology. The ontology of the enterprise provides the necessary information to collect, organize, and store data in an easy way to understand ([Kindrick, 2009](#); [Rajabi & Abade, 2012](#)). For example, the Dodaf Data Meta Model (Model) indicates that the goal of a conceptual model is to support the integrity and semantic accuracy of architectural descriptions.

On the other hand, the enterprise ontology helps to model more efficiently by describing the building blocks of enterprise and their relationships. The enterprise ontology is a proper basis for an integrated understanding of an organization's elements. The enterprise ontology actually models the building blocks of organizations with their relationships according to the perception of entities from two parties ([zur Muehlen, 2009](#)). The relationships among all elements of the organization are modeled precisely, transparently^{*,**}, and are formulated in the ontology of the organization. Then, a common model which has the necessary precision for all parties within the organization and systems is created.

The advantages and successful applications of ontology in business and various applications are quite clear for researchers ([Feilmayr & Wöß, 2016](#)). The ontology development for organizations is the proper basis for enterprise architecture methods ([Hinkelmann et al., 2016](#); [Rajabi et al., 2013](#); [Rajabi & Abade, 2012](#)), automatic analysis of models at enterprise architecture, querying and inference in architectural data ([Antunes et al., 2014](#)), business process management ([Jung, 2009](#); [Rao et al., 2012](#); [Santos Jr et al., 2010](#)), business modeling ([Gassen et al., 2017](#)), business process re-engineering ([AbdEllatif et al., 2018](#); [Rao et al., 2012](#)), implementation of applications ([Villela et al., 2005](#)), context-aware systems ([Aguilar et al., 2018](#)), interoperability between different systems and platforms ([Chen et al., 2008](#)), and knowledge management in the

organization (Villela et al., 2005). Therefore, it is of paramount importance to identify a suitable ontology that has the necessary comprehensiveness, proper coverage, accuracy, compatibility, and extensibility for several applications.

This study aimed to evaluate and compare enterprise ontology models from the conceptual view and then analyze their results. O'Leary (2010) reviewed the enterprise ontology according to activity theory but he does not consider many other aspects of the enterprise ontology. Besides O'Leary's work, it could be said that there are no other proper comparisons and classifications of enterprise ontology models available. Therefore, researchers who need to use the enterprise ontology models in different domains may become confused as the domain of relevance of each model is not clear.

In this paper, a conceptual framework is proposed to compare the enterprise ontologies. Relevant evaluation criteria are identified and applied to analyze the existing ontology models. Based on these analyses, key insights are derived and a roadmap for future research on conceptual models of enterprise ontology is presented.

2. Related Works

2.1 Ontology

According to Gruber's definition in 1993 (Gruber, 1995), an ontology is a formal, explicit specification of shared conceptualization. On the basis of this definition, "conceptualization" refers to an abstract model of phenomena in the world along with the detection of related concepts to those phenomena. "Explicit" means that the types of used concepts and their limitations are defined explicitly. "Formal" refers to the fact that the ontology should be readable to a machine and "shared" indicates that the ontology must acquire agreed and acceptable knowledge by related societies (Antunes et al., 2014). Although this definition emphasizes the formal and explicit description of concepts, these descriptions need to first agree on selected concepts and an acceptable conceptual model. If the concepts are not chosen appropriately, the ontology usage will not be efficient. A well-defined conceptual model is useful in many research studies and applications independently.

2.2 Conceptualization

A formal model is implemented in an ontology language such that the ontologist observes a gradual transition from the knowledge level to the implementation level. The formalization grade of the knowledge model increases gradually until it is able to be understood by the machine. Figure 1 shows this gradual movement.

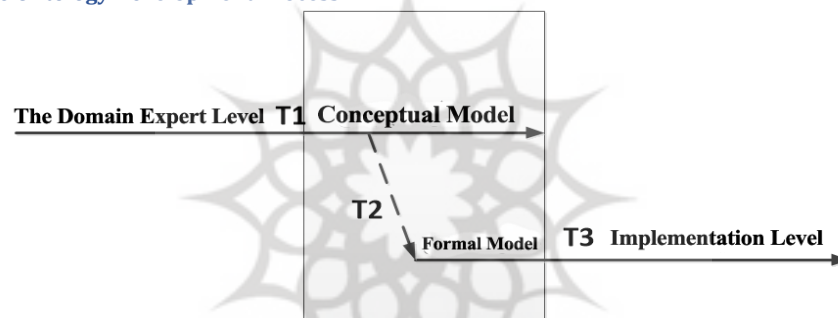
The ontology development activities generally include: specification, conceptualization, formalization, implementation, and maintenance. Conceptualization is a crucial activity in the ontology development process (Gómez-Pérez, 1996). Some studies emphasized this and provided some methods for conceptualization. The conceptualization activity constructs meaningful knowledge models from the domain knowledge. The conceptualization activity is similar to collecting puzzle pieces provided by the knowledge acquisition activity, and it is completed during the conceptualization process. The conceptualization activity must be done rigorously; otherwise, the error will propagate into the next steps.

The purpose of conceptualization is to prepare a domain model with a lower degree of formality than a formal model but still more formal than the definition of the model in natural language. Other motivations for the conceptualization process include:

1. Domain experts, human users, and ontologists may struggle to interpret or understand the ontology proposed in the ontology language.
2. Domain experts may not be able to construct ontologies within their domain of expertise.

This activity deserves special attention because it plays an important role in the ontology development process. In ontology development methodologies, after the conceptual model has been designed, the conceptual model is transformed into a formal model and implemented in an ontology language such that the ontologist observes a gradual transition from the knowledge level to the implementation level. The formalization grade of the knowledge model increases gradually until it is able to be understood by the machine. Figure 1 shows this gradual movement.

Figure 1.
Knowledge in the Ontology Development Process



(Gomez-Perez et al., 2006)

T1 transformation refers to the conceptual modeling process that transforms the domain expert's subjective model into a conceptual model. T2 refers to the conceptual model progressing into a formal model. T3 refers to the formal model progressing into a model that can be understood by a machine. As the figure shows, T1 and T3 transformations are drawn by a continuous line, while the T2 transformation is indicated by a dashed line. This indicates that there may be some loss of domain knowledge when a conceptual model is developed into a formal model. This happens when the components and tools used to create conceptual models are more meaningful and expressive than those that are used to create the formal model.

In the methodology development process (Fernández-López et al., 1997), the conceptualization activity uses a set of intermediate representations (IRs) through table and graph notations, organizing and converting an informal representation of a domain into specifications that can be understood by domain experts and ontology developers. In this study, we aimed to compare the enterprise ontology models from a conceptual perspective.

A conceptual model is designed for human understanding and explanation of domain knowledge, often represented using diagrams like ER or UML. These models are simple, intuitive, and suitable for analysis and communication among stakeholders. A formal

ontology, in contrast, provides a precise, machine-processable representation using logical languages such as OWL or RDF. Its purpose is to enable automated reasoning, consistency checking, and knowledge sharing. The conceptual model usually serves as a preliminary step, providing a foundation for building a formal ontology.

2.3 Ontology-Based Enterprise Modeling

The enterprise ontology contains a set of well-defined terms that are widely used as common descriptions of enterprises, as it accurately covers concepts related to the enterprise field. The enterprise ontology acts as an interactive medium or platform between different people, such as users, designers, and planners in various organizations (Uschold et al., 1998).

An important issue in achieving integration and performing effective business planning is that all operators and stakeholders (from planning managers to low-ranking contractors involved in software production) must have a common understanding of different dimensions of an organization. When a particular word is used from the domain, the concept it refers to should be clear. In other words, it is necessary to overcome the “semantic heterogeneity” associated with implicit perceptions of common words’ meanings in the domain.

The enterprise ontology has been created for this purpose and contains a set of well-defined words that are widely used as general descriptions of an organization, covering concepts related to the domain of the organization carefully. This set facilitates a shared understanding of an organization and can serve as a fixed basis for identifying the functional requirements and creating the organizational models. Thus, perceptual errors are reduced in cases where the same concepts may be referred to by different terms, as it improves and facilitates the interaction between stakeholders, which is an important step in increasing efficiency.

The purpose of applying an ontology in an organization is to determine the relationships between the tasks and activities of that organization with organizational knowledge and their tools. It also participates in the acquisition, representation, and manipulation of organizational knowledge, organized and structured libraries of the existing knowledge, rationalized descriptions of inputs and outputs of involved components, and a vocabulary exchange format for an enterprise (Ciocoiu et al., 2001).

3. Investigating the Conceptual Models of the Enterprise Ontology

Researchers represented different ontology models for different applications. This article selects the pioneering research such as TOVE¹ ((Fox et al., 1995; Gomez-Perez et al., 2006), context-based enterprise ontology (Leppänen, 2007), and the enterprise ontology TEO² (Uschold et al., 1998). These projects and other researchers are recognized as pioneers in this article. In addition, the enterprise architecture frameworks require a conceptual model of an organization. Therefore, some

1. Toronto Virtual Enterprise

2. Time Event Ontology

frameworks and methodologies provided conceptual models of enterprise ontology for developing enterprise architecture, such as the Dodaf¹ Data Meta Model ([Officer, 2009](#); [Thakor & Sasi, 2015](#)), "DoDAF PLUGIN user guide" ([2010](#)), Modaf² ([Aue & Gamon, 2005](#)), and the Togaf³ Content Meta Model ([Pereira & Almeida, 2014](#)). ArchiMate ([Pereira & Almeida, 2014](#)) was also investigated in this study. Some researchers focused only on one dimension of an organization and presented an enterprise ontology model for it, as referred to in Table 1. For example, Almeida and Gizzareti, [Pereira and Almeida \(2014\)](#), [Santos et al. \(2013\)](#), [Abramowicz et al. \(2008\)](#), and [Pereira \(2015\)](#) have modeled the organizational structure ontology and represented extensive details. Some other studies constructed an enterprise ontology model for a specific type of organization. In this regard, [Silva and Belo \(2018\)](#) have presented an enterprise ontology model specifically for higher education institutions.

Table 1.

The Enterprise Ontology Which has Examined the Concepts of One of the Dimensions of the Organization

Dimension	References
Structure	(OMG, 2009), (Santos Jr et al., 2013), (Almeida & Guizzardi, 2008), (Pereira & Almeida, 2014), (Abramowicz et al., 2008), (Diorbert Corrêa Pereira, 2015), (Carvalho & Almeida, 2015)
Purpose	Business Motivation Model (BMM) (OMG, 2015)
Rules and Time	Date-Time Foundation Vocabulary Request For Proposal (OMG, 2008)

(Source: The Researcher's Findings)

The best examples of such research can be found in the documentation provided by the Object Management Group (OMG). Several OMG documents serve as valuable references for analyzing the conceptual model of enterprise ontology, presenting concepts in an organized manner and detailing their relationships with one another. One notable document is the Business Motivation Model (BMM) ([OMG, 2015](#)), which offers a structured set of concepts that model elements of a business plan. This document is particularly useful for identifying the purpose and motivation of an organization, including concepts such as purpose, mission, perspective, and strategy. Additionally, OMG has published a comprehensive document on business process modeling known as BPMN⁴. This document not only covers conceptual control flow modeling but also provides precise definitions of components such as activities, events, gateways, and the sequences between them. It also explores the relationships between various organizational components and activities. For example, it represents capital resources using Pools and Lanes while defining consumable resources with a symbol called the Data Object. Furthermore, the Organization Structure Meta-model (OSM) ([OMG, 2009](#)) document from OMG offers metamodeling for organizational structures. It includes modeling elements that represent organizational entities, subgroups, features, and the relationships between organizational units and their assigned individuals. The concepts used in the organizational structure are clearly defined within the OSM document. The Semantics of Business Vocabulary and Rules (SBVR) ([Kang et al., 2010](#)) takes this a step

1. Department of Defence Architecture Framework

2. Ministry of Defence Architecture Framework

3. The Open Group Architecture Framework

4. [<https://www.omg.org/spec/BPMN/2.0/PDF>]

further by expressing business vocabularies with formal logic, providing a specific language for business descriptions. It defines a set of terms, each with a specific technical meaning relevant to the field of business. The rules defined by formal logic closely resemble natural language, making SBVR a business ontology that machines can understand (Kang et al., 2010). Lastly, the Date Time Foundation Vocabulary Request for Proposal (OMG, 2008) is another OMG document that articulates concepts related to time and dates in business using SBVR.

3.1 Providing a Framework for Comparison

There has been no existing frameworks to compare the conceptual models of enterprise ontology until now, making our study the first to address this issue. In this regard, we presented a framework for evaluating the conceptual models of enterprises. Two perspectives have been considered in formulating this framework, which includes various comparison parameters. The first perspective aims to identify the closest semantic frameworks to enterprise ontology and draws inspiration from their parameters for comparison. The second perspective identifies and applies general parameters for evaluating ontologies, supported by detailed research in the field. In first perspective, the most significant research was conducted by Osterwalder (Gordijn et al., 2005), who presented a framework for comparing business model ontologies based on earlier works (e.g., Jasper & Uschold, 1999; Pateli, 2003). Our study generalized the Osterwalder's framework to facilitate the comparison of enterprise ontologies. This generalization seeks to provide an acceptable framework for comparing ontologies that model organizations. In this framework, we introduced important parameters for the comparison of enterprise ontology, which are described as follows:

1. **Purpose:** This parameter reflects the primary motivation behind the enterprise ontology and the objectives of its development. Several studies (e.g., Officer, 2009), presented ontology models specifically for applications in enterprise architecture. Others (e.g., Poels et al., 2018), concentrated on ontology models tailored for business contexts. Additionally, some studies (e.g., Leppänen, 2007) offered a more general enterprise ontology aimed at enterprise modeling.
2. **Domain:** This parameter evaluates the domain of relevance for the conceptual model. The enterprise ontology model is capable of representing various types of enterprises, including business, military, and educational organizations.
3. **Implementation language:** This parameter indicates the programming languages used to implement the enterprise ontology and convert it into a machine-readable format. It encompasses the use of generic ontological technologies for representing ontologies, such as Ontolingua, RDF/S, and OWL, as well as ontology design tools like Protégé.
4. **Representation:** Representation distinctions form a core aspect of ontological classification. Lightweight ontologies focus on establishing a basic semantic structure by defining concepts, their taxonomies (e.g., Subclass-Of relationships), the relationships between them (e.g., part-of), and the properties (slots) that describe each concept. They are primarily concerned with vocabulary and a simple

hierarchy. In contrast, heavyweight ontologies extend this foundation by incorporating formal axioms and constraints. These logical rules explicitly define the intended meaning of the vocabulary and restrict its interpretation, enabling complex consistency checking and automated reasoning.

This distinction is best illustrated with an example. Consider an ontology for a corporate domain. A lightweight version might define concepts like Employee, Manager, and Department, with relationships such as worksIn (Employee, Department) and subClassOf (Manager, Employee). This is often represented using software engineering diagrams like UML Class Diagrams or Entity-Relationship Diagrams (ERD). The corresponding heavyweight ontology would add axioms like: $\forall x \text{ Manager}(x) \rightarrow \exists y \text{ manages}(x, y)$ (Every Manager manages at least one other Employee).

Disjointness constraints: Manager and Department are disjoint (no individual can be both).

A cardinality constraint: An Employee works in exactly one Department.

These axioms, typically implemented using AI-based formalisms like Description Logics (the foundation for OWL - Web Ontology Language), eliminate ambiguities and allow a reasoner to infer new knowledge like detecting an inconsistency if an individual is asserted to be both a Manager and a Department.

5. **Ontology content and components:** This parameter refers to the key dimensions addressed by each enterprise ontology. Each conceptual model of an organization encompasses various dimensions and the concepts associated with them. It is crucial to identify which dimensions are included at macro level and which concepts are most critical among all the concepts. Additionally, this parameter takes into account the types of relationships and the nature of the rules presented within the ontology.
6. **Ontology maturity and evaluation:** The degree of maturity of an ontology is determined by its evaluation. Various qualitative criteria and resources exist for assessing the ontological models that have been implemented (e.g., Brank et al., 2005; Hloman & Stacey, 2014; McDaniel et al., 2018). Several criteria possess significant capability for studying the evaluation of conceptual models. In this article, we selected specific criteria to understand and compare the existing ontological models of the organizations. If the evaluation criteria function effectively at the conceptual level, we can anticipate that the enterprise ontology will perform well at the formal level.

It should be noted that the relative importance of the evaluation criteria introduced in this study—such as extensibility, consistency, and completeness—is not the same across all applications. In fact, the weight and priority of each criterion depend on the purpose and domain in which the ontology is applied. For example, in architecture enterprise, completeness and consistency are of greater importance, whereas in applications such as context-aware systems or business process management, extensibility and adaptability may be more critical. Therefore, the proposed framework does not assume equal weighting of the

criteria; rather, it allows for contextual adjustment of their relative importance according to the specific application domain.

The selected criteria for evaluation are as follows:

- a) Reusability:** Reusability refers to the extent to which the components of an ontology can be applied in developing another ontology for a different domain or purpose. This criterion assesses how modular and generalizable the ontology is. For example, if a “process” or “actor” concept from an organizational ontology can be directly reused in designing a project management ontology without major modifications, it demonstrates high reusability. Since ontology development is often complex and time-consuming, the ability to reuse the existing structures significantly reduces effort and promotes consistency across the related domains.
- b) Accuracy:** Accuracy refers to the degree to which the knowledge represented in the ontology reflects the real-world understanding of domain experts. An ontology should faithfully capture the actual entities, relationships, and constraints that exist in the domain it represents. For example, in an organizational ontology, the concept of “employee” must accurately include attributes such as *position*, *department*, and *reporting relationships*, consistent with how these elements are defined and used in the real organization. Even though ontologies inherently allow for interpretive flexibility, maintaining close alignment with expert knowledge ensures that the model remains valid and useful for real-world applications.
- c) Expandability:** Expandability refers to the ability of an ontology to be extended or enriched with new concepts and relationships without altering its existing definitions or structure. A highly expandable ontology provides a flexible foundation that can evolve as new requirements or related domains emerge. For example, an organizational ontology that defines general concepts such as “role”, “process”, and “resource” can later be expanded to cover domains like *human resource management* or *knowledge management* by adding new subclasses or relationships—without the need to modify the original definitions.
- d) Adaptability:** Adaptability refers to the extent to which an ontology can accommodate or anticipate future changes in its domain or environment. It evaluates whether the ontology offers a stable yet flexible foundation that can evolve as new requirements, technologies, or organizational structures emerge. For example, an organizational ontology that models communication channels in a generic way—like defining a general concept of “interaction” instead of specifying only “email” or “meeting”—can easily adapt to future developments like AI-driven collaboration tools or virtual workspaces without major restructuring. Many existing ontologies lack this level of flexibility, making them difficult to maintain or extend over time.
- e) Completeness:** Completeness measures the extent to which an ontology provides full coverage of its target domain, ensuring that it contains all essential concepts, relationships, and properties needed to answer relevant questions within that domain. An ontology is considered complete when it can represent the domain comprehensively without major conceptual gaps. For example, an organizational

ontology would demonstrate completeness if it includes all key elements such as *employees, departments, goals, processes, and resources*, enabling it to support queries like “which department is responsible for a specific goal?” or “what resources are involved in a given process?”. The parameters are summarized in Table 2. This table, along with its parameters, provides a framework for comparing the enterprise ontologies, which we will discuss in this section.

Table 2.
The Ontology Evaluation Parameters That are More Aligned with Conceptual Evaluation Model

Parameter		References	Description
Purpose		(Gordijn et al., 2005)	The main motivation of organizational ontology and the purpose of creating the ontology.
Domain		(Gordijn et al., 2005)	The domain of organization which the ontology is modeling, for example business, military or educational organization.
Implementation language		(Gordijn et al., 2005)	The implementation language and applied language used to create the enterprise ontology.
Representation		(Gordijn et al., 2005)	How the the enterprise ontology model is represented.
Ontology content and component		(Gordijn et al., 2005)	The dimensions of the domain considered by the conceptual model and the concepts underpinning them.
Ontology maturity and evaluation	Reusability	(McDaniel et al., 2018)	The degree to which the entire ontology or part thereof can be repurposed and reconstructed another ontology.
	Accuracy	(Burke & Litwin, 1992)	The degree of consistency of the ontology with the knowledge of a domain expert.
	Expandability	(Gómez-Pérez, 1996)	The ability to extend the ontology to other domains without changing definitions.
	Adaptability	(McDaniel et al., 2018)	Whether the model reacts predictably towards the small internal changes or not.
	Completeness	(Burke & Litwin, 1992)	The ability to how exhaustively the ontology can answer all questions that ontology should be able to answer.

(Source: The Researcher's Findings)

3.2 A Comparison of Enterprise Ontologies

In this section, we compare the conceptual models according to our framework presented in the previous section.

Purpose: The main motivation of organizational ontology and the purpose of creating the ontology. A number of studies such as TOGAF Content model (Awadallah, 2013; Weisman, 2011)), ArchiMate (Pereira & Almeida, 2014; Wierda, 2017), DODAF Data Meta Model (Officer, 2009), UAF¹(OMG, 2017a; OMG, 2017b) provided ontology models for applications of the enterprise architecture. Some studies such as context-based (Leppänen, 2007), The Enterprise Ontology (TEO) (Uschold et al., 1998), and TOVE (Fox & Gruninger, 1998) presented the enterprise ontology in general for enterprise modeling.

Domain: The domain refers to the specific type of organization that the ontology is designed to model. This could encompass various sectors such as business, military, or educational organizations. Each domain has its unique characteristics, structures, and processes, which the ontology aims to represent accurately. By tailoring the ontology to a particular domain, it becomes more relevant and useful for stakeholders within that field, facilitating better understanding, communication, and decision-making.

1. Unified Architecture Framework

The TOGAF Content Model (Awadallah, 2013; Weisman, 2011), ArchiMate (Wierda, 2017), and the Unified Architecture Framework (UAF) (OMG, 2017a; OMG, 2017b) are generic frameworks in the realm of enterprise ontology. In contrast, other models (Poels et al., 2018) focus specifically on ontology models for the business domain. Additionally, the DODAF Data Meta Model (Officer, 2009) provides an ontology model tailored for the military domain.

Implementation language: Most ontology models such as Dodaf Data Meta Model (Officer, 2009), TOGAF Content Model (Awadallah, 2013; Weisman, 2011), ArchiMate (Wierda, 2017), UAF (OMG, 2017a; OMG, 2017b) are represented at the conceptual level by UML diagrams. TOVE (Fox & Gruninger, 1998) is implemented by Prolog language and TEO (Uschold et al., 1998) is implemented by Ontolingua language (based on KIF).

Most ontology models, including the DODAF Data Meta Model, TOGAF Content Model, ArchiMate, and UAF, are typically represented at the conceptual level using UML diagrams. In contrast, TOVE is implemented using the Prolog programming language, while TEO is developed using Ontolingua which is based on KIF.

Representation: Most ontology models are implemented in a lightweight form, while only TOVE and TEO (Uschold et al., 1998) are classified as heavyweight ontology models.

Content and componentsb The core conceptual model identifies the main dimensions of an organization, followed by the detailed concepts that support each dimension. For example, TEO (Uschold et al., 1998) represents five key dimensions of activity, organization, strategy, marketing, and time.

Reusability: Most enterprise ontologies immediately transition into the implementation phase without first establishing a solid conceptual model. This oversight limits the users' ability to connect the abstract concepts of the model with the real-world elements they are intended to represent. A robust conceptual model is crucial for supporting reusability. Among organizational ontology models, both TOVE and TEO rush into implementation, leaving users without a comprehensive understanding of the models, which hampers effective usage. In contrast, the DODAF Data Meta Model offers a well-defined conceptual model that articulates relationships at a conceptual level, although it is specifically tailored for the United States Department of Defense. The Context-Based Enterprise Ontology starts with a conceptual level presentation, but many of its relationships remain unclear, limiting its reusability. Meanwhile, the UAF describes each concept precisely, supporting extensibility; however, it suffers from ambiguities at macro level, making reusability challenging.

Accuracy: TOVE and TEO exhibit ambiguous concepts, with their definitions and relationships not being clearly defined. This leads to varying interpretations of each concept. In contrast, the DODAF Data Meta Model provides a well-defined enterprise ontology aimed at representing the conceptual model of defense organizations. Additionally, the UAF, which originated from DODAF and MODAF, is designed to support non-defense organizations. The TOGAF Content Meta Model clearly defines concepts and their relationships, offering a solid foundation for enterprise ontology criteria; however, it does not implement the ontology model at a formal level.

Expandability: Context-based enterprise ontology, TOGAF Content Meta Model, ArchiMate, and UAF are generally defined in a way that allows for good expandability into specific domains. In contrast, the relationship between "activity" and "capability" in the DODAF Data Meta Model is tailored specifically for military organizations, which limits its applicability to other sectors despite its well-defined concepts.

Adaptability: TOVE and TEO transition abruptly into the formal phase without adequately defining their concepts. On the other hand, the DODAF Data Meta Model excels in defining the conceptual phase but is primarily suited for military organizations. The TOGAF Meta-Model considers strong concepts at micro level, yet it lacks a comprehensive ontological structure.

Completeness: Completeness refers to how thoroughly an ontology can address all relevant questions about the organization it represents. This means that the ontology should cover all dimensions of an organization. Given the social nature of organizations, researchers must consider multiple dimensions simultaneously. For instance, defining "service" requires acknowledging the roles of both service customers and providers. Similarly, a complete understanding of a "business process" necessitates describing the roles of its participants. To achieve this, the structure of organizational units and the roles within them must be framed within a broader organizational context. However, focusing on too many dimensions can lead to selecting concepts that may not be essential for a complete description of the domain. An ontology can be considered comprehensive if it effectively answers questions such as: who (performer) does what (task) for what reasons (goal), where (location), and when (time) (Leppänen, 2007)?

Table 3.

The Comparison of Enterprise Ontology According to the Proposed Framework

		TOVE	The Enterprise Ontology (TEO)	Context-based	DODAF Data Meta Model	TOGAF Content Model	ArchiMate	UAF
		(Fox & Gruninger, 1998)	(Uschold et al., 1998)	(Leppänen, 2007)	(Officer, 2009)	(Awadallah, 2013); (Weisman, 2011)	(Pereira & Almeida, 2014); (Wierda, 2017)	(OMG, 2017b); (OMG, 2017a)
Purpose		Enterprise modeling	Enterprise modeling	Enterprise modeling	Enterprise Architecture	Enterprise Architecture	Enterprise Architecture	Enterprise Architecture
Domain		Public and commercial	Commercial Enterprise	Public	Military	Public	Public	Public
Implementation language		Prolog	Ontolingua (Base on KIF)	At the conceptual level and UML	At the conceptual level and UML	At the conceptual level and UML	has provided its own modeling language	At the conceptual level and UML
Representation		Heavyweight	Heavyweight	lightweight	lightweight	lightweight	lightweight	lightweight
Ontology content and components		Organization, Resource, Activity, Time, Cost	Organization's Activity, Strategy, Marketing, Time	Purpose area, Actor area, Action area, Object area, Facility area, Location area, Time area	Activity, Capability, Resource (Information, Performer and Material), Location, Guide	Governance, Service, Process, Data, Infrastructure, Motivation	3 layers of business, application and technology that stand under each concepts	Taxonomy Structure, Connectivity Processes, States Interaction Scenarios, Information Constraints, Roadmap Traceability
Ontology maturity and evaluation	Reusability	Mid	Mid	High	Mid	Mid	Mid	Mid
	Accuracy	Low	Low	Mid	Mid	High	High	Mid
	Expandability	Low	Low	High	High	High	High	High
	Adaptability	Low	Low	Low	Mid	High	High	High
	Completeness	Low	Low	Mid	High	High	High	High

(Source: The Researcher's Findings)

3.3 Investigating the Ontology of Enterprise Completeness Using the Zachman Framework

Studies on enterprise ontology examined various dimensions of organizations. For instance, Leppanen introduced a context-based ontology (Leppänen, 2007) that encompasses seven dimensions of goal, actor, action, object, facility, location, and time. The TOVE project (Fox et al., 1995; Fox & Gruninger, 1998) considered four dimensions of ontology of organization (Fox & Gruninger, 1998), ontology of resource (Fadel et al., 1994), ontology of activity (Gruninger & Fox, 1994), and ontology of cost (Tham et al., 1994). ArchiMate (Wierda, 2017) presented a meta-model structured into three layers of business, application, and technology. Additionally, ArchiMate categorized its elements into three groups of active elements that perform actions, behavioral elements that represent the behavior of active elements, and passive elements that are acted upon by behavioral elements. The TOGAF Content Model (Awadallah, 2013; Weisman, 2011) outlined concepts such as motivation, infrastructure, data, process, service, and governance.

The Zachman Framework (Zachman, 1987; Sowa & Zachman, 1992) aimed to examine all dimensions of an organization, making it a suitable foundation for studying the models of enterprise ontology. The columns of Zachman's Framework represented various aspects (dimensions) of an organization, derived from the 5W1H questions of who (responsibilities), when (time), why (motivation), where (location), how (task), and what (data). A central question arises: does the ontology cover all dimensions of the enterprise? If it does, then the enterprise ontology will demonstrate good comprehensiveness. The six communication questions of 5W1H help clarify the dimensions of organizations, as noted by Caetano et al. (Caetano et al., 2012) and Zachman. Rajabi et al. (2013) presented an enterprise ontology model based on the factors in the columns of Zachman's Framework. By utilizing the 5W1H questions, Zachman clarified each dimension of the organization, providing a solid basis for understanding the existing ontologies and their covered dimensions. In this paper, we compared the completeness of the enterprise ontology models using the columns of Zachman's Framework.

In addition to reviewing the concepts of enterprise ontology (see Table 3), we also assessed their compatibility with Zachman's Framework. The selected ontologies for comparison are leading models that have sufficient documentation available. For instance, the TOGAF Content Meta-Model introduces important concepts such as data entity, value stream, constraint, role, organization unit, location, business service, process, function, and business capability. Each of these concepts is comprehensively defined along with their relationships to one another. Within the Zachman's Framework, the concepts can be categorized as follows: data entity and value stream fall under the "what" column; process, function, and business service are placed in "how" column; location is categorized under "where"; and organization unit is found in "who" column. Notably, there are no concepts represented under the "when" column. As illustrated in Table 3, the Context-Based Enterprise Ontology defines specific areas for each column of Zachman's Framework and outlines various concepts for each area. This model demonstrates better alignment with the columns of Zachman's Framework, enhancing its adaptability and relevance.

Some ontology models include "business product" as a key concept within the

enterprise ontology. For instance, ArchiMate (Wierda, 2017) considered "product" as an essential element of the organization, defining it as anything offered to the outside world. This definition also encompasses products that may be provided internally to different parts of the organization. Thus, the concept of "product" is crucial, yet it is overlooked in some other ontologies.

The concept of "location" is included in the ontology of organizations, but some models, such as DODAF, TOGAF, and ArchiMate, limit their definition to a single concept of "location". In contrast, the Context-Based Enterprise Ontology and the UAF consider multiple concepts related to location. On the other hand, both TOVE and enterprise ontology do not address any concepts for the "where" column. The concept of "business service" in TOGAF (Awadallah, 2013) supports business capabilities through an explicitly defined interface and is governed by an organization. Similarly, the UAF defines "service specification" as a set of functionalities provided by one element to be used by others. This indicates that the concept of "service" is significant within the enterprise architecture; however, it is absent from models that focus solely on organizational modeling. Table 4 summarizes these findings regarding the adaptability within Zachman's Framework, while Table 5 presents the final results for the adaptability of the existing models according to Zachman's Framework.

Table 4.

A Review of the Adaptability of the Existing Concepts in Enterprise Ontology Within Zachman's Framework

Enterprise ontology	Why	What	How	Who	Where	When
TOVE (Fox & Gruninger, 1998)		Goal, Sub goal	Activity, Constraint, Authority Communication link	Resource, Organization, Division, Subdivision, Team, Agent, Role, Skill		
The Enterprise ontology (Uschold et al., 1998)	Purpose, Mission	CSF, Objective, Vision, Goal	Activity, Activity Spec, Sub-Activity, Execute, Plan, Sub-Plan, Process Spec, Org. Structure, Strategy, Risk, Capability	Entity, Role, Relation Attribute Resource, Person, Corporation, Unit, Actor, Machine, Actor Role, Skill, Activity Owner, Doer, Authority		Time Point, Time Interval, T-Begin, T-End, Time Line, Calendar, Date, Duration
Context-based Enterprise Ontology (Leppänen, 2007)	Reason, Purpose	Goal	Function, Activity, Task, Action Structure	Facility, Resource, Tool, Human actor, Person, Group, Position, Role, Unit, Organization	Location Area, Physical Location Point, Spatial Thing Logical, Location Region, Geographical Dimension, Geographical System	Time, Time Point, Time Interval, Time Unit, Time System, Clock Time, Calendar Time
DODAF Data Meta Model (Officer, 2009)		Vision, Desired Effect	Project, Capability, Activity, Guidance, Condition	Personnel Type, Skill, Performer, Data, Information, Materiel	Location	
TOGAF Content Meta Model (Awadallah, 2013); (Weisman, 2011)		Business Service	Function, Process, Value Stream, Course of Action, Business Capability, Constraint	Organization Unit, Function, Role, Data Entity	Location	
ArchiMate (Pereira & Almeida, 2014); (Wierda, 2017)		Business Service, Business Product	Business Process, Business Function, Business Interaction, Business Event, Contract	Business Role, Business Actor, Business Collaboration, Business Object	Location, Business Interface	
UAF (OMG, 2017b); (OMG, 2017a)		Service, Service Specification, Enterprise Vision, Enterprise Goal	Capability, Project Kind, Project Activity, Project Milestone, Capable Element Project, Actual Milestone Kind, Operational Activity	Actual Organization, Organizational Resource, Person, Post, Responsibility, Natural Resource, Physical Resource, Resource Architecture, Resource Artifact, Resource Performer, Software System, Standard, Protocol, Protocol Stack	Location, Location Holder, Location Kind, Actual Location	

(Source: The Researcher's Findings)

Table 5.

The Results of the Adaptability of the Existing Concepts in Enterprise Ontology Within Zachman's Framework

Conceptual Model	TOVE	The Enterprise Ontology (TEO)	Context-based	DODAF Data Meta Model	TOGAF Content model	ArchiMate	UAF
Adaptability with Zachman's framework	×	×	✓	×	×	×	×

(Source: The Researcher's Findings)

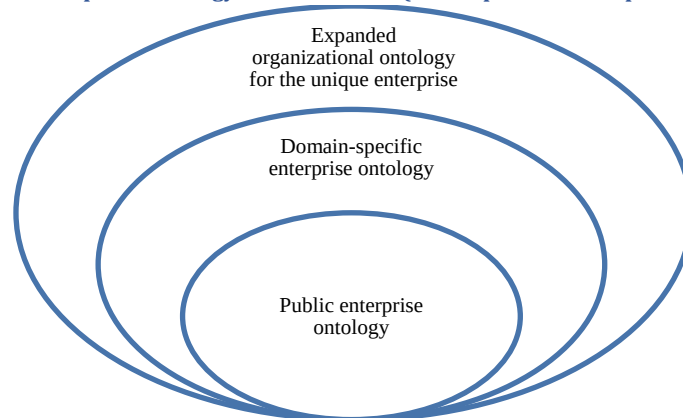
4. Findings

Numerous studies have explored the enterprise ontology; however, many exhibited significant weaknesses. A critical issue is the lack of consensus on which dimensions of an organization should be included in its ontological model. For instance, while one study (e.g., [Fox & Gruninger, 1998](#)) incorporated the time dimension, another study (e.g., [Officer, 2009](#)) overlooked it entirely. Establishing a common agreement on the conceptual model is essential before progressing to formal and logical construction phases. We require a foundational conceptual model that accurately represents key concepts and relationships, yet currently, there are no standard or reference models available for researchers to consult.

The existing enterprise ontology models often lack conceptual depth, leading to premature transitions into the implementation phase. This results in underdeveloped conceptual models, making their formal counterparts neither reusable nor expandable. Furthermore, comprehending the formal models becomes challenging without a robust conceptual framework.

Additionally, the concepts present in current ontologies do not adequately encompass all the components of an organization. If ontological models were better aligned with the columns outlined in Zachman's framework, they could more effectively cover various organizational dimensions. There is an urgent need for a powerful conceptual model that articulates fundamental concepts and relationships in an interpretable manner for diverse applications, including enterprise architecture, business architecture, business process management, context-aware systems, intercommunication, and automated production and analysis of the models. Moreover, there is no standardized approach to expand and customize a generic enterprise ontology model for specific domains or organizational needs.

The conceptual models of enterprises can be enriched progressively. Initially, a general enterprise ontology model is developed. Then, it is refined for specific industries. Ultimately, an enterprise-specific ontology emerges based on the previous models. This progression is illustrated in Figure 2. In general, all organizations share a set of common principles and concepts that form their foundation. In the second stage, these common concepts are detailed to suit various types of organizations—such as commercial entities, military organizations, and universities. Finally, in the third step, appropriate common concepts are tailored specifically to describe individual organizations.

Figure 2.**The Relationship Between Enterprise Ontology and Its Subsets (Development and Expansion of Ontology)**

(Source: The Researcher's Findings)

5. Limitations

Access to formal models: The lack of access to some formal organizational ontology models prevented a comprehensive analysis and comparison of all available models.

Comparability: Although the foundational models were considered, these models themselves were designed with different objectives, making direct and uniform comparison difficult and influencing the analysis of results.

Model scope: This study focused on foundational models, while purpose-specific models were excluded; therefore, some models were not considered in the analysis.

6. Conclusion

The enterprise ontology offered a comprehensive and systematic framework that enhances the understanding of organizations for both managers and stakeholders. By addressing ambiguities and contradictions, this framework empowered informed decision-making. The clarity it provided is invaluable not only for human users but also for machine processing. This structured understanding is applicable across various domains, including efficient modeling of enterprise architecture, business processes, and context-aware systems.

In this study, we examined and compared the conceptual models of enterprise ontology, highlighting their strengths and weaknesses. Future research should focus on developing a reference enterprise ontology model that encompasses all dimensions of an organization, ensuring it covers every component while identifying key elements and relationships. Moreover, future studies are encouraged to investigate the application of enterprise ontology within specific domains or organizational contexts, in order to evaluate its practical effectiveness and adaptability to particular use cases. Additionally, there is a critical need to establish reliable methods for adapting the reference enterprise ontology model to create tailored models for specific domains, organizations, or applications.

Conflicts of Interests

The authors did not receive support from any organization for the submitted work.

Author Contributions Statement

Seyed Mohsen Rahnamafard conceptualized the research idea, laying the groundwork for the study. Zeinab Rajabi further developed this concept, refining the initial ideas and enhancing the framework for analysis. Both authors, collaborated closely in conducting the analysis and comparisons presented in this study, ensuring a comprehensive evaluation of the existing literature on enterprise ontology.

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