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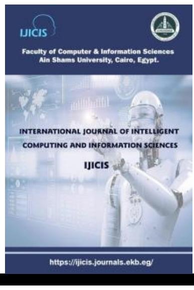


# ONTOLOGY-DRIVEN CONCEPTUAL MODEL AND DOMAIN ONTOLOGY FOR EGYPTIAN E-GOVERNMENT

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***Abstract:*** *In recent years, online services have received considerable attention worldwide. One crucial online service during the coronavirus disease (COVID-19) pandemic was e-governance. In which governments provides various services to their citizens using information and communication technology. However, the residents of Arab countries have faced numerous of obstacles and have not received the full benefits of e-governance. One of the main reasons is the absence of integration and information sharing. Therefore, in this study, a novel domain ontology for the Egyptian e-government has been proposed. The developed ontology can be used to solve a variety of interoperability problems. The development process starts with building ontology-driven conceptual model using OntoUML. It is one of the most used ontology-driven conceptual modeling languages. The proposed model is then converted to a computable web ontology via the Web Ontology Language. The resulted ontology is evaluated by the OntoMetrics quality metrics. Results are compared with the metrics collected from 20 e-government ontologies and proved that the proposed ontology has better understandability measurements.*

***Keywords:*** *Artificial intelligence, digital government (e-government), ontology-driven conceptual modeling, ontology engineering, OntoUML, semantic web.*

## 1 Introduction

Artificial intelligence is a key component of the United Nations' 2030 Agenda for Sustainable Development [1]. The authors also identified the decade roadmap. One of its fundamental aspects is enhancing the conversation between science, industry, and government. The term digital government or electronic government (e-government) involves providing public services to citizens solely by means of information and communication technologies, such as computers and the Internet. E-governance is efficient, innovative, and cost-effective and provides access to information and services provided by the government [2]. Paper-based contact between residents and government has been substituted by electronic information collection and technological services. Egypt's Ministry of Communications and Information Technology, in collaboration with the Ministry of State for Administrative Development,

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launched an e-government project. The first stage lasted from 2001 to 2007, and the second stage was from 2007 to 2012 [3]. Egypt's e-government has the following objectives:

1. To deliver services to citizens, companies, and investors
2. To speed up Service Delivery
3. To improve performance and efficiency
4. To ensure transparency between service consumers and providers
5. To encourage investors and remove all the barriers that they face

In 2020, the United Nations ranked Egypt as 111th out of 193 nations in terms of using e-government to provide public services; Egypt was ranked ninth in the Arab world [4]. This is because of the numerous obstacles faced in the growth of e-government [3]. A few of these challenges are as follows:

1. There are no standards or specifications, which makes it difficult for government Entities to communicate and integrate.
2. The government agencies are not able to share information that prohibits them from performing e-government efforts properly and effectively.
3. There is no unified standard for repeated inquiries made by citizens to the various government agencies.

Conceptual modeling is defined as the act of capturing the key characteristics of the physical and social reality for communicating, learning, understanding, and problem resolution among stakeholders [5]. Clearly, conceptual models are required, particularly in complicated areas such as e-governance. Ontologies are used to facilitate semantic interoperability activities [6]. They are defined as “explicit specification of a conceptualization”. Researchers have proposed a new method known as ontology-driven conceptual modeling (ODCM). In [7] the authors described ODCM as the application of ontological ideas from various fields, such as formal ontology, cognitive science, and philosophical logics, to engineering objects that improve conceptual modeling theory and practice. According to [7], OntoUML is one of the most used languages in ODCM. OntoUML is “a language whose meta-model has been designed to comply with the ontological distinctions and axiomatization of a theoretically well-grounded foundational ontology named UFO (Unified Foundational Ontology)” [8]. UFO is “an axiomatic formal theory based on contributions from Formal Ontology in Philosophy, Philosophical Logics, Cognitive Psychology, and Linguistics” [9].

Consequently, the aim of the proposed research is to use OntoUML to create a novel ODCM for the Egyptian e-government. The model is then converted into an OWL (Web Ontology Language) ontology. After that the ontology is evaluated and compared with other e-government ontologies. The proposed research makes the following contributions:

- A novel ontology-driven conceptual model for Egyptian E-government.
- List of suggested Domain-Related Ontology Patterns (DROPs) from the proposed model.
- A novel ontology for Egyptian E-government.
- Evaluation of the proposed ontology via OntoMetrics quality metrics

The remainder of the paper is as follows. Section 2 gives a review of the related work. A description of the suggested model is offered in Section 3. Section 4 discusses the results of the experiments. Finally, Section 5 states the conclusions and future work.

## 2 Related Work

Many studies have discussed the use of conceptual modeling in various areas, especially in e-government. In this section, the literature of two distinct regions will be covered. ODCM and the e-government space itself.

### 2.1 Ontology-Driven Conceptual Modeling

Ontology and conceptual modeling have a lot in common because both deal with the comprehension of real-world concepts. Therefore, as previously stated, ODCM is the use of ontological theories to improve the theory and practice of conceptual modeling [7]. Papers such as [10], [11], [12], [13], [14], and [15] have used OntoUML because it is one of the most widely used languages in ODCM. Moreover, its growing .user base has applied it to numerous crucial and complex sectors. However, certain studies ([16], [17]) employ a language different from OntoUML. A summary of these studies is given below.

The authors of [10] used OntoUML to create CargO-S, a well-founded legal domain ontology. This ontology is used to track products across logistical maritime corridors. They used ontology layering to ease the development process by separating CargO-S into three layers with different granularity levels: upper, core, and domain. A dual assessment approach was used to assess the performance and accuracy of the proposed ontology.

In [11], the authors presented a core ontology for economic exchanges, which formed the basis of service management, accounting information systems, and financial reporting. Economic exchanges are also prevalent in frameworks such as the ISO standard for resource-event action, service core ontologies, and finance standards. They rely on the action theory of economic exchanges, which is a viewpoint from the field of economic philosophy; this theory has been applied to develop an ontological account of the financial transactions. It serves as a road map for laying out the fundamental elements of a basic ontology of economic interactions. The UFO serves as the foundation of the core ontology. As a result, their research is accurate and appropriate to the development of well-founded information systems.

In the field of sharing economy and marketplaces, the authors of [12] designed a marketplace domain ontology that allows dialogue and consensus. This ontology was built on the foundation of the UFO and the core ontology for services (UFO-S). Competence questions (CQs) are used to find fragmented sub-ontology parts known as foundational ontology patterns and domain-related ontology patterns. These reusable fragments are derived from foundational ontologies and reference domain/core ontologies, and they package their marketplace domain knowledge.

In [13], the researchers built a core ontology to suit the organizational structure of the Brazilian higher education system. This ontology was part of the OntoSINAES ontology network, which is part of the National Higher Education Assessment System. The NeOn methodology for building ontology networks was used to create this core ontology, which sits in between the foundational and domain ontologies. Domain specialists assist in the validation process, which is based on functional requirements expressed as CQs. This validation process checks the specified criteria of the NeOn methodology, which includes consistency, concision, correction, and the absence of ambiguities.

In [14], conceptual models were created to characterize the agriculture operations task ontology. Task ontologies describe the knowledge from the structural and behavioral perspectives. They use semantic strategies for task negotiation, recognition, and relocation to assist agents to infer knowledge about tasks. This task ontology was examined using EOntoUML, which is an OntoUML extension for modeling task ontologies. They offered task objectives, external event interferences, pre and post circumstances, and other solutions not covered by E-OntoUML.

Authors of [15] presented a model for describing the brand identity in the context of startups using OntoUML. This model has been formalized as an ontology to facilitate computerization. This ontology could help companies manage their brand identity by supporting their information systems. The report also laid the groundwork for the creation of a visual co-design tool for practitioners.

The authors of [16] presented a technique based on the ontology of microservices architecture concepts (OMSAC) for the modeling and evaluation of microservices-based systems. They demonstrate how OMSAC-based conceptual models stocked in a Stardog triple store helps stakeholders communicate, document, and reuse their work. The use of this technique in three open-source microservices systems is described by focusing on its discovery using similarity metrics. The retrieved similarity metrics are manually compared with the OMSAC models by experts.

Finally, [17] reported that in institutional contexts, the promise of ontologies, such as Bunge–Wand–Weber (BWW) and UFO, to model a domain remains elusive. Therefore, they proposed that the conceptual modeling should take an institutional turn. The authors examined the identity construct from a BWW viewpoint before demonstrating how the BBW conception of identity leads to different conceptual modeling rules and models than an institutional understanding of identity.

### 2.2 E-Government

For years, many efforts have been undertaken to overcome the barriers related to e-governance. Both [3] and [18] conducted research on Egypt’s e-government and its challenges. In addition, they proposed remedies for these problems.

In [3] the researchers achieved some progress, but more needs to be done to address the problems faced in the development of e-government. Moreover, Egypt is still behind a few Arab countries in delivering online information and providing government services.

In [18], the authors stated that the Egyptian information technology sector has been impacted by the political turmoil in recent years. Egypt’s e-government development index has been downgraded from high to medium in the global rankings. Its position plummeted 28 places from the 80th place in 2014 to the 108th place in 2016. The market can return to a healthy growth path if the domestic political situation is stable, and there is a supportive policy environment.

Also, [19] presented a study for Africa as a whole. The status of e-government research was examined using a qualitative approach based on online searches and literature reviews. The report demonstrates the participation of African countries in e-government research. The paper also presents the credentials and affiliations of authors conducting e-government research in Africa. The authors trace the growth trajectory of Africa’s e-government research during the last ten years beginning in 2002. Finally, the scholars in Africa explain the e-government development concerns that they are working on. Their findings can help African governments, industry, and academics plan for their future development.

In [20], the researchers demonstrate how semantic technology is critical for the development of e-government services. Semantic web services and ontologies, for example, add semantic information to the descriptions of e-government services. This allows for the automated processing of services and information and improves communication between the parties involved. Consequently, this article examined a set of available information, standards, and existing referenced models and certain semantic web service formalisms. The case study on the customs clearance of goods also proposed a knowledge-based modeling framework for Moroccan e-government services and its e-customs implementations.

In [21] e-governance was defined as a larger concept that encompassed e-government and e-democracy; the authors also provided the state-of-the-art technologies used in e-government ontologies. The Bulgarian e-hierarchical government's ontological model was also established. This model incorporates an e-society meta-ontology, an e-government domain ontology, and a collection of application and task ontologies.

Literature study and field research to date have shown that no ontology has been developed with the goal of overcoming the data interoperability concerns in the domain of e-government in Egypt. Consequently, in the proposed research, new OntoUML conceptual model and ontology are provided. Both aim specifically at assisting Egypt's e-government in data interoperability challenges.

## 3 Proposed Architecture

Although there is no universal consensus on the technique that can be considered ideal for ontology development, the goal of creating an ontology might help select the optimal methodology. METHONTOLOGY is an ontology-building methodology that specifies the life cycle of the ontology development process. The full explanation of the conceptualization activity is the key strength of this methodology [22]. Since the conceptualization activity is the focus of the proposed work, so METHONTOLOGY has been followed in the proposed architecture. Fig. 1 illustrates the proposed architecture. It consists of three main modules "System Analysis", "Ontology Development", and "Evaluation". They will be thoroughly described in the next subsections.

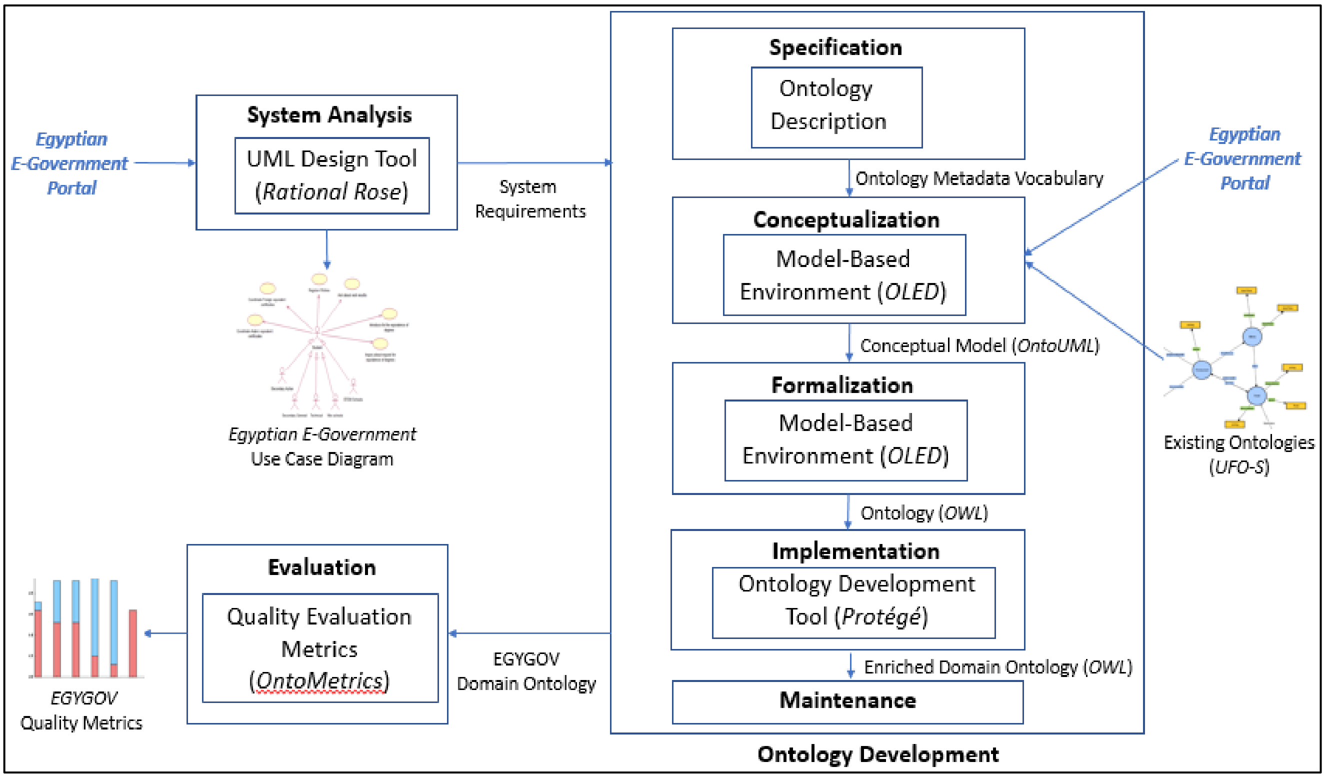



Figure. 1: Proposed architecture

The Egyptian portal should first undergo an analysis phase to establish system requirements in the form of a use case diagram. UML design tools are helpful for this. The ontology development process begins after the analysis. Finally, the generated domain ontology will be used as an input to the evaluation job, which allows quality metrics to be used to determine the evaluation results. The next subsections explain the specifics of how architecture tasks are performed.

## 3.1 System Analysis Module

Due to the shortage of documents describing the Egyptian e-government portal [23]. The portal first goes through the analysis stage of extracting the requirements. Then these requirements are converted into a use case diagram. This helps in the comprehension of system functionalities, the elimination of function redundancies, and the review of relationships between different actors and system functions.

The portal connects 14 consumers with 30 service providers. The citizen using the greatest number of services through the portal is the main consumer. The citizen services are presented as a prototype. Fig. 2 shows a use case diagram created using the Rational Rose tool [24]. As illustrated in the figure, the citizen module includes 35 unique services.

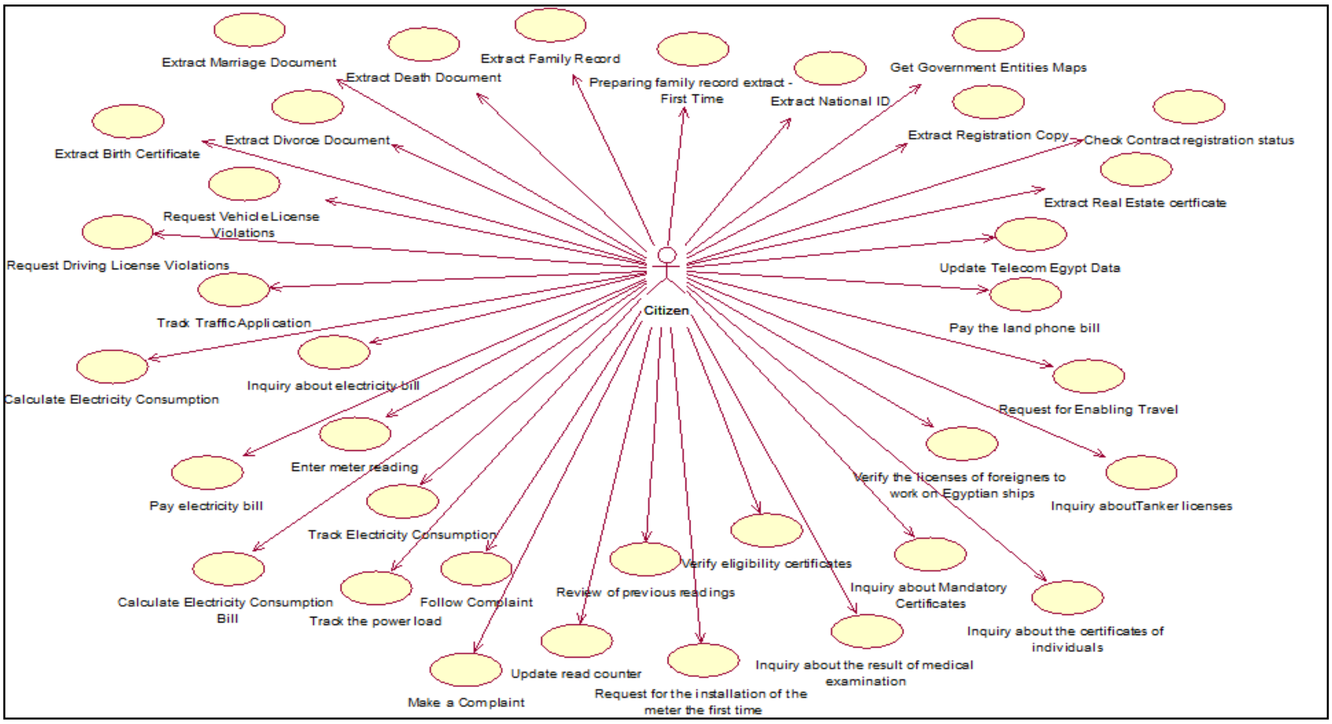



Figure. 2: Egyptian e-government - The Citizen use case diagram

## 3.2 Ontology Development Module

### *3.2.1 Specification*

A written document in natural language should be used to describe the ontology information in this activity. A common proposal for describing ontologies is the ontology metadata vocabulary (OMV). It allows for easy access to and exchange of ontologies across the Internet [25]. The OMV of the suggested ontology is given below.

**Egyptian E-government Ontology Specification Document**

**Ontology Name**: Egyptian E-government Ontology (EGYGOV)

**Location**: Ain Shams University, Cairo, Egypt

**Party (Organization)**: Ain Shams University

**License Model**: Academic research

**Ontology Type**: Domain Ontology

**Ontology Domain**: Electronic government (e-government)

**Ontology Engineering Tool**: OntoUML Lightweight Editor (OLED)

**Ontology Language**: OWL

**Ontology Syntax**: rdf xml Syntax

**Ontology Task**: The ontology describes data and services of Egyptian e-government. EGYGOV represents a model for the semantic description of governmental features such as domain concepts, services, regulations, and organizational structures.

**Ontology Engineering Methodology**: NeOn Methodology for Building Ontology Networks; EGYGOV follows different scenarios:

Scenario 1: From specification to implementation.

Scenario 2: Reusing and re-engineering non-ontological resources.

Scenario 3: Reusing and re-engineering ontological resources.

**Sources of Knowledge**: Non ontological resources (Egyptian e-government portal), Ontological resources (existing ontologies)

The NeOn methodology [26] provides versatile possibilities for the reuse and re-engineering of knowledge sources for developing ontology networks. The following three scenarios are used by EGYGOV:

- Scenario 1: From specification to implementation. The ontology is developed from scratch.
- Scenario 2: Reusing and re-engineering non ontological resources. Egyptian e-government portal [23] is the non-ontological resource used to build the ontology. Re-engineering entails transferring this resource to an ontology format and possibly modifying the class name.
- Scenario 3: Reusing and re-engineering ontological resources. EGYGOV reused UFO-S [27], which is a core reference ontology that captures a clear account of services and service-related concepts.

### *3.2.2 Conceptualization*

A model of the relevant domain knowledge is built in this step. Model can take any shape that domain experts accept and understand [22]. The proposed conceptual model has been implemented using OLED

[28], which is a model-based environment for formalizing, implementing, testing, and validating OntoUML models.

The following is a summary of the OntoUML class stereotypes (see [29] for additional information). The stereotypes are grouped into six major categories: rigid sortals, anti-rigid sortals, rigid non sortals, anti-rigid non sortals, semi-rigid non sortals, and moment.

Two alternative portions of the suggested conceptual model are shown in Figs. 3 and 4. In Fig. 3, the Service Delivery class consists of Request (of the consumer), Response (of the provider), Description, Conditions (to be accepted), and Actions (to be performed); this class may include Documents (to be extracted). For Service Delivery, two options are possible: Free or Paid. The request has three possibilities: Pending, Processed, or Cancelled. The Agent category includes Provider and Consumer; Provider has many Entities and each one has a Location. Note that Service, Agent, Provider, and Consumer are reused and reengineered from the UFO-S core ontology.

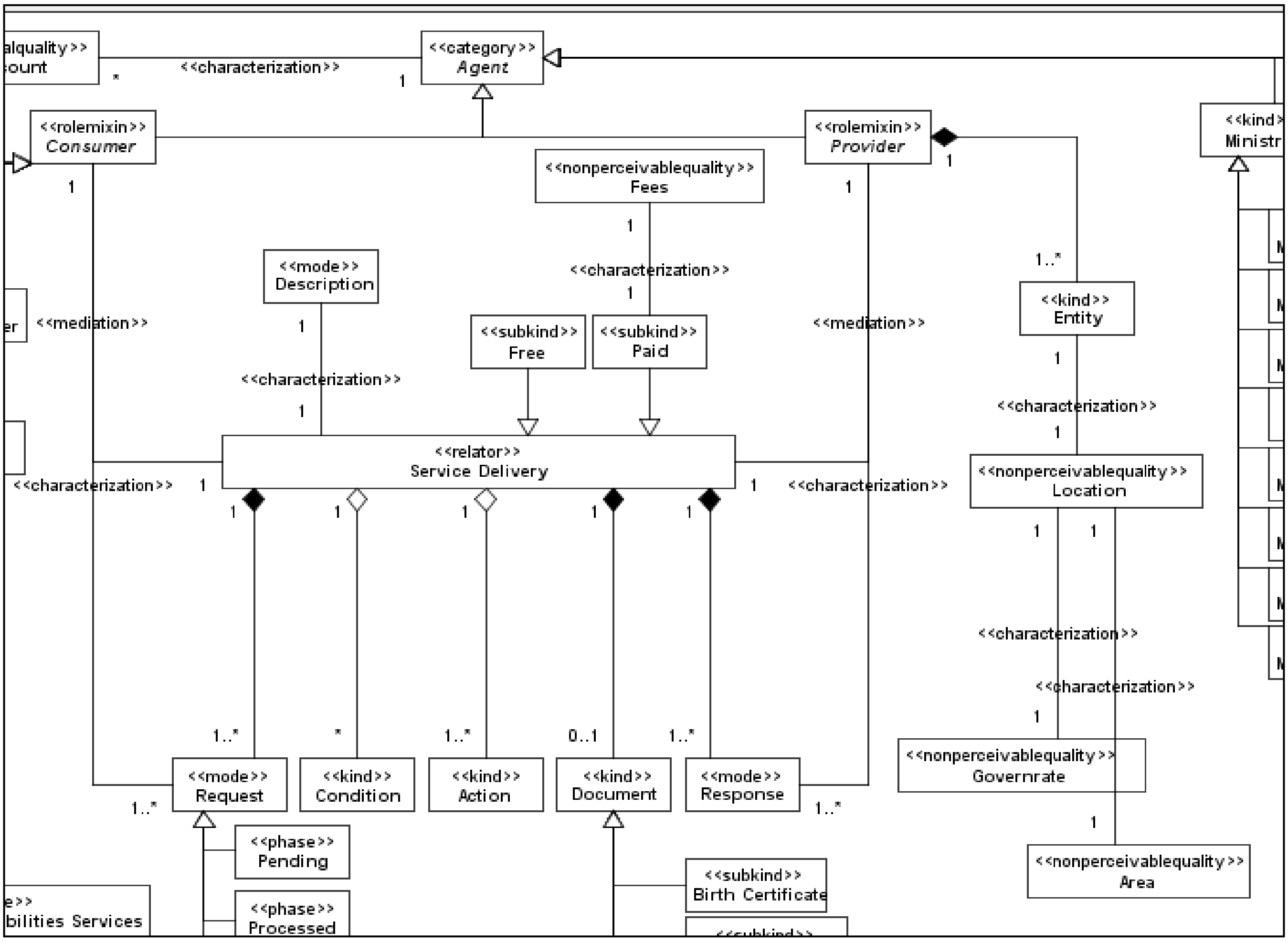


Figure. 3: A fragment of the proposed conceptual model - The Service Delivery class

Fig. 4 displays a portion of the Citizen class and Violations (on a vehicle license) and Driving License. Both licenses are parts of the License class. Phone Line has Mobile Line and Landline as its descendants. Phone Line also includes Phone Subscription and Phone Bill. The other options are Electricity

Subscription, Electricity Meter, and Consumption Readout besides Complaints and Inquiries that can be made by citizens.

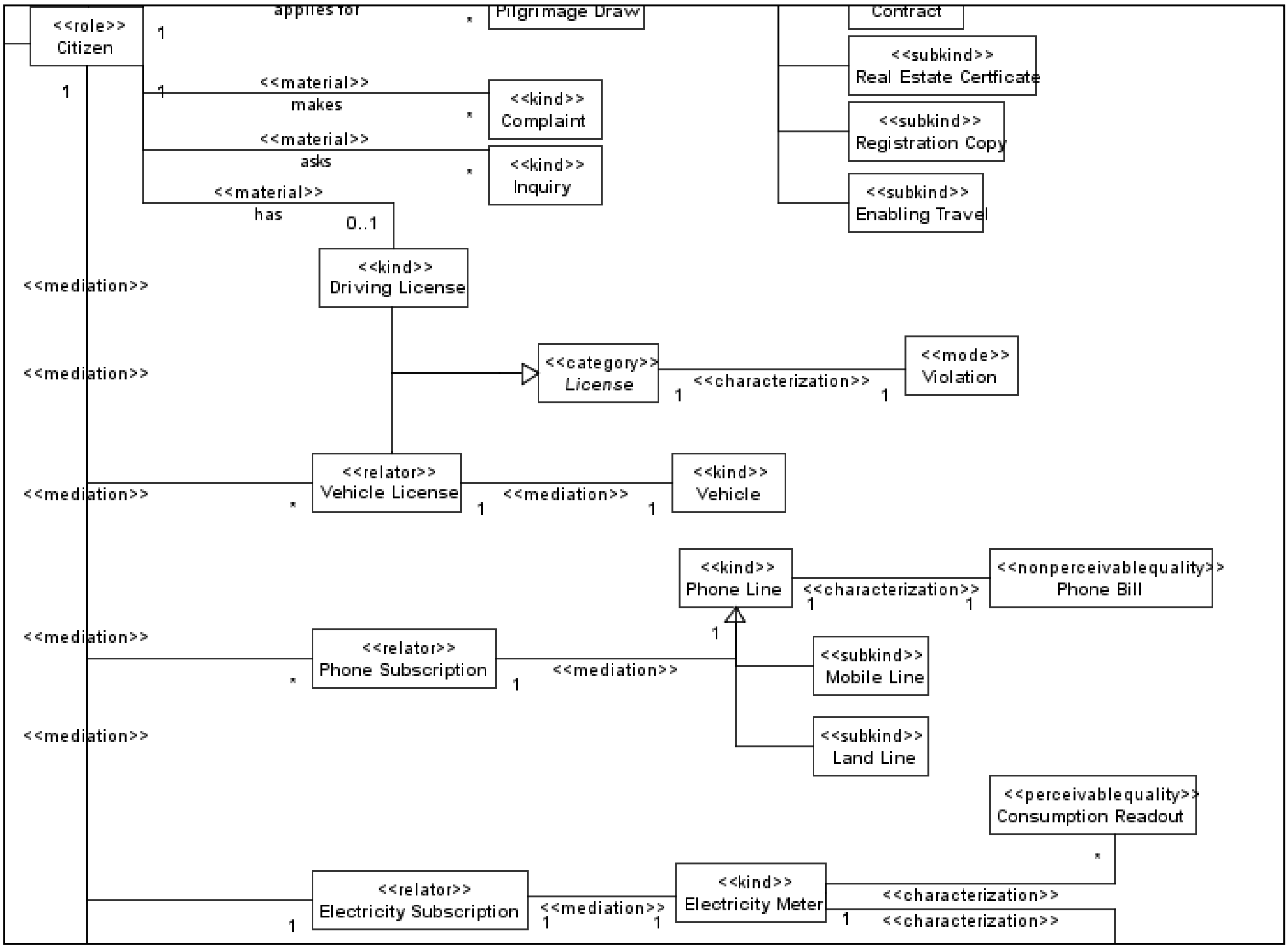


Figure. 4: A fragment of the proposed conceptual model - The Citizen class

In addition, figs. 5, 6, 7, and 8 display some of the suggested Domain-Related Ontology Patterns (DROPs) from the proposed model. DROPs are "modeling fragments extracted from domain ontologies" [30]. They are ontology patterns that can be used in reusing to accelerate the process of ontology development. Figure 5 shows "AGENT" category. Figure 6 displays the different phases of the "REQUEST". Different Roles of the "ACCOUNT" are displayed in figure 7. And in figure 8, the "PERSON" with his "ADDRESS" are illustrated.

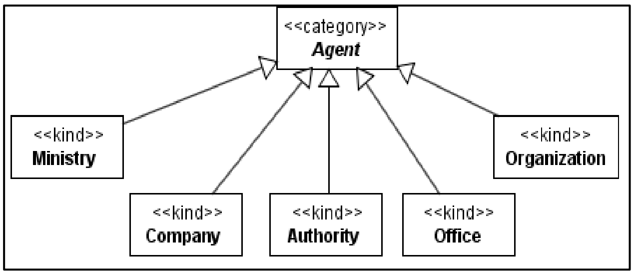



Figure. 5: Agent DROP

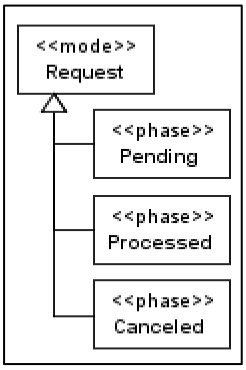



Figure. 6: Request DROP

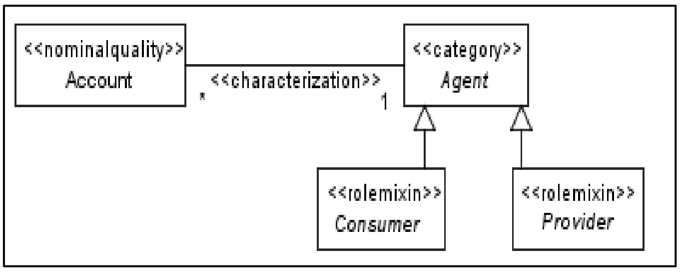



Figure. 7: Account DROP

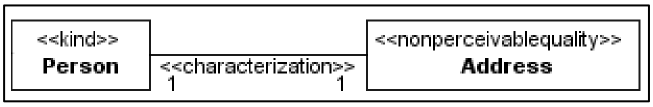
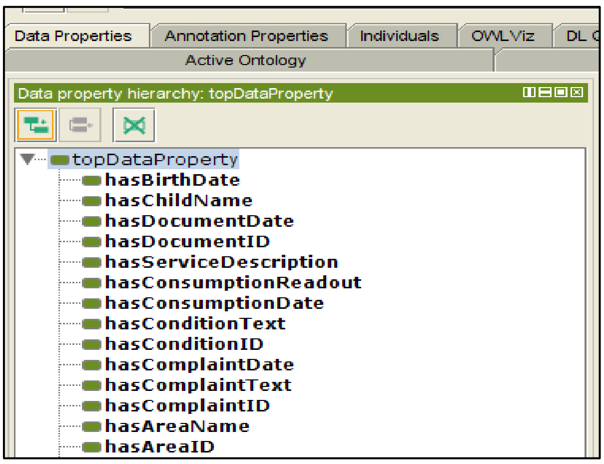



Figure. 8: Person DROP

### 3.2.3 *Formalization and Implementation*

The preceding phase's well-founded conceptual model is transformed into a computable model in this stage. The OLED code generation feature was used to convert the model from OntoUML to the OWL language.

Using the protégé tool [31] the resulting OWL ontology is enriched with data properties and individuals, as displayed in figs. 9 and 10, respectively. The properties in figure 9 include IDs, Texts Added to Condition, and Complaint and Area classes. Dates are added to the Birth Certificate, Document, and Consumption Readout classes. Description is added to the Service class. Individuals are assigned to classes, such as Ministry, Company, Authority, Office, Organization, Governorate, and Request. In figure 10, some individuals of companies and authorities are displayed.



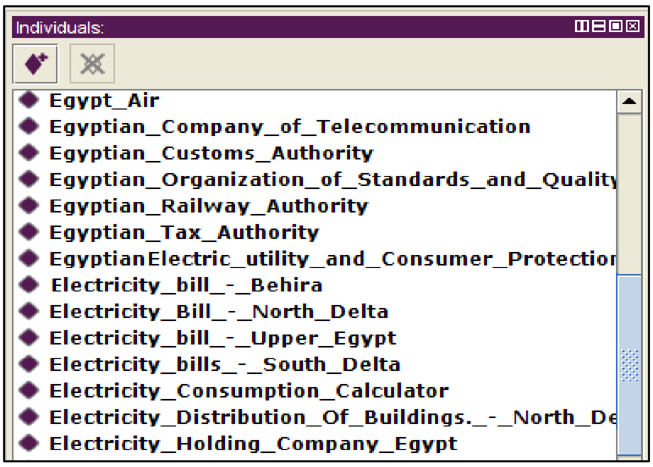



Figure. 9: A fragment of data properties

Figure. 10: A fragment of individuals

### *3.2.4 Maintenance*

This activity involves making any necessary updates or corrections to the ontology.

## 4 Experimental Results

In this section, the evaluation module is described in detail. In this module, the quality of the suggested ontology will be assessed. This can be accomplished in multiple ways. One way is the OntoMetrics quality evaluation measures given in [32]. These metrices are suggested in the proposed study. The findings will be compared to a dataset of 20 e-government ontologies that were also given in [32]. These metrics are quantitative and are divided into three main categories: schema metrics (Attribute Richness, Inheritance Richness, Relationship Richness), knowledge base metrics (Average Population and Class Richness), and graph metrics (Absolute Root Cardinality, Absolute Leaf Cardinality, Average Depth, Maximum Depth, Average Breadth, and Maximum Breadth). The following subsections provide more information on these metrics [32], including their calculations and mappings.

### 4.1 OntoMetrics Evaluation Metrics

#### *4.1.1 Schema Metrics*

- Attribute Richness (AR)

$$AR = \frac{|att|}{|C|} \tag{1}$$

where |att| is the total number of attributes, and |C| is the total number of classes in the ontology.

- Inheritance Richness (IR)

$$IR = \frac{|H|}{|C|} \tag{2}$$

where |H| is the number of subclass relations, and |C| is the total number of classes.

- Relationship Richness (RR)

$$RR = \frac{|P|}{|H| + |P|} \tag{3}$$

where |P| is the number of non-inheritance relations, and |H| is the number of inheritance relations.

#### *4.1.2 Knowledge Base Metrics*

- Average Population (AP)

$$AP = \frac{|I|}{|C|} \tag{4}$$

where |I| is the total number of instances of the knowledge base, and |C| is the total number of classes.

- Class Richness (CR)

$$CR = \frac{|C'|}{|C|} \tag{5}$$

where |C'| is the number of classes in the knowledge base, and |C| is the total number of classes.

### *4.1.3 Graph Metrics*

- Absolute Root Cardinality (ARC)

$$ARC = n_{ROO \subseteq g} \tag{6}$$

where $n_{ROO \subseteq g}$ represents the number of elements in the set of root nodes ROO in the directed graph g.

- Absolute Leaf Cardinality (AC)

$$AC = n_{LEA \subseteq g} \tag{7}$$

where $n_{LEA \subseteq g}$ represents the number of elements in the set of leaf nodes LEA in the directed graph g.

- Average Depth (AD)

$$AD = \frac{1}{n_{P \subseteq g}} \sum_{j}^{P} N_{j \in P} \tag{8}$$

where $N_{j \in P}$ represents the number of elements on the path j that belong to the set of paths P in the directed graph g.

- Maximum Depth (MD)

$$MD = N_{j \in P} \forall i \exists j (N_{j \in P} \geq N_{i \in P}) \tag{9}$$

where $N_{j \in P}$ is the number of elements on the path j, and $N_{i \in P}$ is the number of elements on the path i, which belong to the set of paths P in the directed graph g.

- Average Breadth (AB)

$$AB = \frac{1}{n_{L \subseteq g}} \sum_{j}^{L} N_{j \in L} \tag{10}$$

where L represents the set of levels in the directed graph g; $n_{L \subseteq g}$ is the number of elements in L, and $N_{j \in L}$ is the number of elements on the level j.

- Maximum Breadth (MB)

$$\mathrm{MB} = \mathrm{N}_{\mathrm{j}\in\mathrm{L}} \forall \mathrm{i} \exists \mathrm{j} \left(\mathrm{N}_{\mathrm{j}\in\mathrm{L}} \geq \mathrm{N}_{\mathrm{i}\in\mathrm{L}}\right) \quad (11)$$

where $N_{j\in L}$ and $N_{i\in L}$ are the number of elements on the level j and i respectively that belong to the set of levels L in the directed graph g.

## 4.2 Ontology Evaluation Dimensions

The previous quality metrics are correlated to the following ontology assessment dimensions [32]: accuracy, understandability, cohesion, and conciseness.

- Accuracy. This dimension determines how well the ontology represents the real-world domain. Eqs. (1), (2), (3), (8), (9), (10), and (11) can be used to calculate the accuracy.
- Understandability. This dimension indicates the comprehension of the elements of the ontology, and it is mapped to Eq. (7).
- Cohesion. This metric assesses how closely classes are related to one another. Eqs. (6) and (7) are mapped to this dimension.
- Conciseness. This criterion affects the extent to which the ontological information is beneficial. This dimension is related to Eqs. (4) and (5).

## 4.3 Experiments

The above-mentioned OntoMetrics equations are applied to the suggested ontology, and the results are compared to the ontologies addressed in [32]. The results are displayed in Table 1; however, certain values were not available, such as the graph metrics of $O_{18}$. Moreover, the evaluation dimensions of e-government ontologies are illustrated in Figs. 11, 12, 13, and 14. Measurements mentioned in Table 1 are discussed in the next subsections.

Table 1 OntoMetrics results of e-government ontologies

| Ontology | AR | IR | RR | AP | CR | ARC | AC | AD | MD | AB | MB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_1$ | 0.59099 | 0.136364 | 0.930233 | 0.681818 | 0.090909 | 19 | 19 | 1.136364 | 2 | 5.5 | 19 |
| $O_2$ | 0.315789 | 0.736842 | 0.222222 | 0.526316 | 0.105263 | 7 | 10 | 3.033333 | 5 | 2.142857 | 7 |
| $O_3$ | 0 | 1 | 0.346154 | 0.352941 | 0.058824 | 2 | 10 | 3.285714 | 5 | 2.33333 | 4 |
| $O_4$ | 0.076923 | 1.230769 | 0.407407 | 0 | 0 | 3 | 10 | 2.076923 | 3 | 3.25 | 6 |
| $O_5$ | 0.067797 | 0.779661 | 0.577982 | 0.016949 | 0.016949 | 15 | 42 | 2.836066 | 6 | 3.388889 | 15 |
| $O_6$ | 0.666667 | 1.333333 | 0.5 | 1.166667 | 0.333333 | 3 | 2 | 1.5 | 2 | 1.5 | 3 |
| $O_7$ | 0.033708 | 1.601124 | 0.2711 | 0.134831 | 0.02809 | 26 | 112 | 3.419162 | 6 | 3.604317 | 33 |
| $O_8$ | 0.666667 | 1.333333 | 0.5 | 1.166667 | 0.333333 | 3 | 2 | 1.5 | 2 | 1.5 | 3 |
| $O_9$ | 7.416667 | 7.333333 | 0.169811 | 26 | 0.583333 | 1 | 8 | 3.416667 | 4 | 2.4 | 4 |
| $O_{10}$ | 0.106061 | 1.515152 | 0.602386 | 1.386364 | 0.530303 | 26 | 92 | 2.447368 | 4 | 4.956522 | 26 |
| $O_{11}$ | 0.363636 | 0.818182 | 0.25 | 4.727273 | 0.272727 | 2 | 7 | 2.727273 | 4 | 2.2 | 3 |
| $O_{12}$ | 0.375 | 0.75 | 0.4 | 1.375 | 0.125 | 2 | 6 | 2.375 | 3 | 2.666667 | 5 |
| $O_{13}$ | 0.75 | 0.75 | 0.333333 | 1.875 | 0.125 | 2 | 6 | 2.25 | 3 | 2.666667 | 4 |
| $O_{14}$ | 0 | 0.984127 | 0 | 0.992063 | 0.007937 | 2 | 107 | 3.801587 | 4 | 6.3 | 17 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_{15}$ | 0 | 1 | 0.346154 | 0.352941 | 0.058824 | 2 | 10 | 3.285714 | 5 | 2.333333 | 4 |
| $O_{16}$ | 0.36 | 2.12 | 0.341615 | 0.54 | 0.12 | 22 | 22 | 1.3125 | 2 | 2.909091 | 22 |
| $O_{17}$ | 0.217391 | 1.978261 | 0.172727 | 0.652174 | 0.434783 | 16 | 56 | 3.009709 | 6 | 2.575 | 16 |
| $O_{18}$ | 0.042231 | 1.130279 | 0.003862 | 0 | 0 | | | | | | |
| $O_{19}$ | 0.133333 | 1.148148 | 0.093567 | 0 | 0 | 8 | 112 | 3.639706 | 5 | 5.666667 | 25 |
| $O_{20}$ | 0.4375 | 0.75 | 0.813956 | 1.90625 | 0.5 | 8 | 26 | 1.84375 | 3 | 4.571429 | 9 |
| **EGYGOV** | **0.436508** | **1.571429** | **0.171548** | **0.880952** | **0.055556** | **1** | **114** | **3.188976** | **4** | **9.769231** | **45** |

### *4.3.1 Accuracy*

Accuracy is measured using (1) to (3) and (8) to (11). For EGYGOV, AR equals 0.436508 and is ranked 7th among other ontologies. IR equals 1.571429 and is ranked as the 5th, whereas RR equals 0.171548 and is ranked as the 17th. The accuracy is relatively low because the number of inheritance relations is high in comparison with the non-inheritance relations. The AD equal to 3.188976 is ranked 7th, the longest taxonomic path (MD) is 4 ranked as 12th. However, EGYGOV is the highest in the depth-related features (AB = 9.769231 and MB = 45). The semantic accuracy of the knowledge modeled in the ontology increases with increase in the metrics. Therefore, it will be better to increase the non-inheritance relations in EGYGOV to make it more reliable.

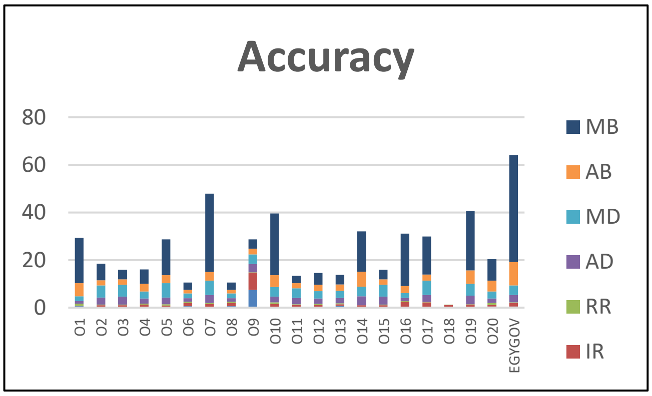



Figure. 11: Accuracy dimension

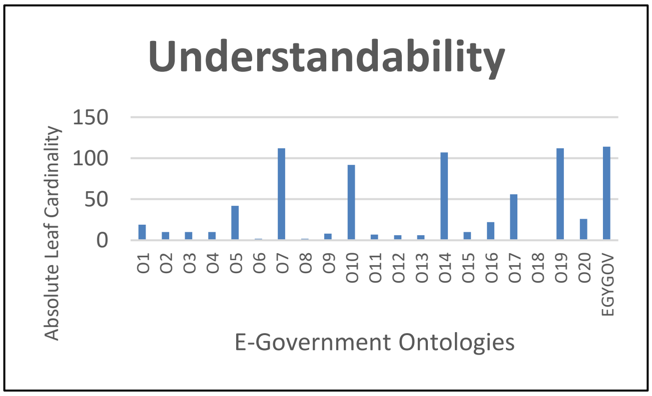



Figure. 12: Understandability dimension

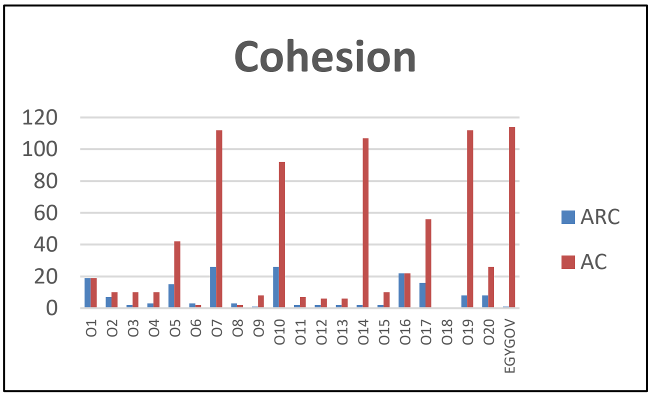



Figure. 13: Cohesion dimension

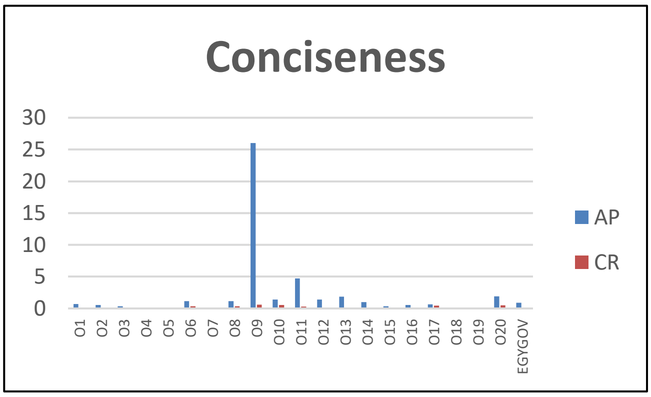



Figure. 14: Conciseness dimension

### *4.3.2 Understandability*

The leaf nodes (AC) of the EGYGOV ontology equals 114, which is the highest among other ontologies. This large number of leaf nodes resolves the ambiguity of the ontology classes and relations. This leads to good understandability that will help domain experts to easily understand the ontology.

#### *4.3.3 Cohesion*

The graph metrics ARC and AC correlate to this dimension. In EGYGOV, ARC and AC are equal to 1 and 114, respectively. The non-zero value of ARC and the high value of AC give the same conclusion that EGYGOV represents the e-government domain using an appropriate number of inheritance relations. This also confirms that classes are connected to each other.

#### *4.3.4 Conciseness*

This dimension is measured via the number of instances and their distribution among classes (which are AP = 0.880952 and CR = 0.055556), which are ranked as 10 and 15, respectively, among other ontologies. This means that EGYGOV has an acceptable number of instances, but not all classes have instances. This could be improved by enriching all the classes with instances.

## 5 Conclusion and Future Work

Developing countries face numerous obstacles in obtaining full benefits from e-governments. New conceptual model and ontology have been constructed in the proposed research with the goal of improving semantic interoperability in the Egyptian e-government area. OntoUML, which is based on the UFO ontology, was used to offer an ontological foundation for evaluating and providing real-world semantics to the proposed conceptual model. The quality metrics of OntoMetrics were used to conduct experiments on the proposed ontology. The schema metrics were 0.44, 1.57, and 0.17; the knowledge base metrics were 0.88 and 0.056, and the graph metrics were 1, 114, 3.19, 4, 9.77, and 45. These measures were then compared with 20 ontologies in the e-government sector. The results prove that the EGYGOV ontology has good understandability, accuracy, cohesion, and conciseness. The results can be enhanced by increasing the non-inheritance relations and by distributing the instances across all classes.

In the future, we plan to 1) design additional modules of the proposed ontology to cover all service consumers; 2) enrich the ontology with new constraints to increase its expressiveness; and 3) involve domain experts in the assessment process.

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