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Using Knowledge Graphs to provide public service information

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Public authorities all over the world publish an increasing amount of information about the Public Services (PS) they provide to facilitate discovery and use by citizens and businesses. Proper management (storing, processing, querying) of this information is necessary to make it fully exploitable. This includes adopting a common PS data model to facilitate interoperability, such as the Core Public Service Vocabulary (CPSV) developed by the European Union. In addition, the choice of technology is important as it is closely related to the quality of information. The aim of this paper is to investigate the benefits of adopting knowledge graphs to manage PS information that are structured using CPSV data model. For this purpose, we capitalize on previous research enriching CPSV and using RDF to develop a relevant knowledge graph and evaluate its use by employing various usage scenarios. The results suggest the use of knowledge graphs can provide benefits by exploiting domain-specific rules however there is still work to be done before the public sector widely adopts their use.

CCS CONCEPTS •Applied computing~Computers in other domains~Computing in government~E-government

Additional Keywords and Phrases:

CPSV, Knowledge Graphs, eGovernment, public service descriptions, Grakn.ai

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1 Introduction

Over the years, the volume of published open government data on the internet is rapidly increasing. Public authorities publish their data to both improve the transparency of public administration and provide high quality information. However, lack of organization, lack of interoperability as well as the form of the data (non-machine-readable), do not allow their full exploitation.

Although public services are publishing more and more public service descriptions online, there is no commonly accepted relevant data model [1]. In 2013 and 2014, European Commission took an important step towards resolving this issue by introducing the Core Public Service Vocabulary (CPSV) [2] and Core Public Service Vocabulary – Application Profile (CPSV-AP) which exploits the Resource Description Framework (RDF) as an

underpinning technology [3]. CPSV has so far been implemented using various technologies, including HTML, relational databases [4] and RDF stores.

Knowledge graphs is a recently introduced technology that has attracted significant attention [5]. Because of reasoning ability and structure, they can solve problems that are difficult or even infeasible to be solved otherwise [6]. This reasoning ability derives from the use of rules. A good example is the following rule. If a person **x** is born in a place **y**, and the place y is a **country,** then y is the country of birth of x [7]. Despite their increasing use in the private sector, the use of knowledge graphs as a modeling tool for CPSV has not been exploited.

The aim of this paper is to investigate the benefits of adopting Knowledge Graphs to manage PS information that are structured using CPSV data model. Specific aims include (a) to develop a knowledge graph compliant to the CPSV model (b) to investigate the potential benefits of using knowledge graphs for public service description. For this purpose, we capitalize on previous research enriching CPSV and using RDF to develop a relevant knowledge graph and evaluate its use by employing various usage scenarios

The rest of this paper is structured as follows. Section 2 outlines background work and Section 3 presents the methodology. Section 4 presents the results of our work while section 5 provides the conclusions, limitations and future work. Finally, the Appendix presents listing of part of the code that was used in this study.

2 Background work

In this section, we outline previous work related to CPSV and knowledge graphs.

2.1 Core Public Service Vocabulary (CPSV)

The extensible and technology-neutral model Core Public Service Vocabulary (CPSV) first released in 2013 by the European Commission in the framework of ISA and ISA² programs. [2]. The goal was to facilitate the exchange of information between the various individual public services. Based on the observed shortcomings and in order to describe any type of public service effectively, in 2014, the Core Public Service Vocabulary – Application Profile (CPSV-AP) [3] was launched. This model (Figure 1) also introduces the concepts of life and business events. The core class of the model is the *Public service* class that represents the service itself. Some other important classes are the *Evidence* class that represents any type of document needed for executing the Public service, the *Output* class that represents any type of document produced by the Public Service, the *Public Organization* class that represents the authority organization of the public service. [8]

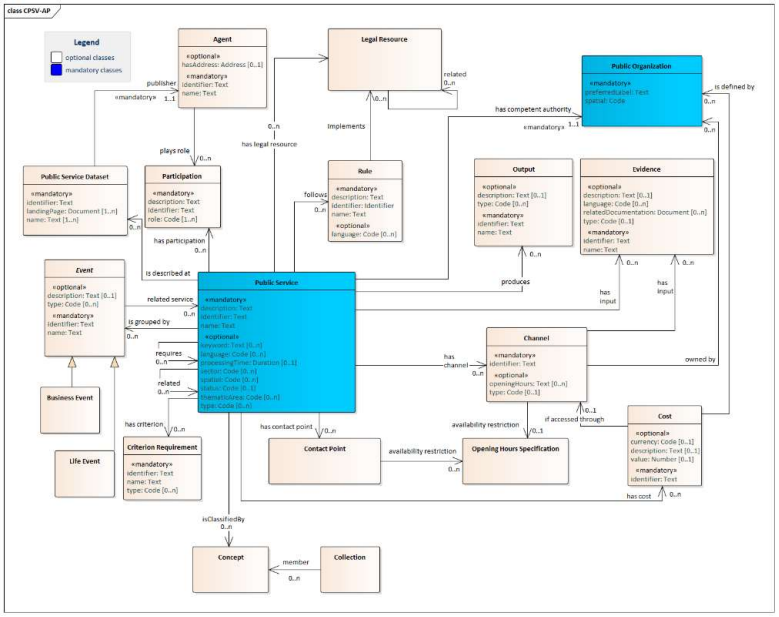

Figure 1. CPSV-AP v2.2 model adapted from [8]

2.2 Knowledge Graphs

According to [9] *A knowledge graph acquires and integrates information into an ontology and applies a reasoner to derive new knowledge.* The most important feature of knowledge graphs are the rules. A set of rules leads to the creation of logical conclusions. It applies reasoning over the data and allows the discovery of hidden information, thus answering complex queries. For reasoning, they can use deductive reasoning. It is the most suitable type of reasoning for knowledge graphs because of its well-defined conclusions. Other types of reasoning are inductive and abductive reasoning. Finally, the knowledge stored in a knowledge graph takes the form of a graph with entities as nodes and relations as edges.

3 Methodology

The methodology employed in this work includes the following steps.

Step 1. Identify relevant work. In this step, we study the literature for relevant research and data. We are particularly interested in research on the use of CPSV and open public service descriptions that we could potentially reuse.

Step 2. Design knowledge graph schema. In this step, we design the knowledge graph schema based on the model of the selected research.

Step 3. Introduce rules. In this step, we create and introduce the rules in the knowledge graph schema.

Step 4. Populate knowledge graph with data. In this step, we migrate the data of the selected research and populate the developed knowledge graph.

Step 5. Construct Usage scenarios. In this step, we present three scenarios for better understanding the benefits of the main characteristic of knowledge graph, namely the employment of rules.

Step 6. Evaluate results. In this step we evaluate the results.

For the development of the knowledge graph, we choose Grakn.ai for two main reasons. It is a free-to-use software application and we are already accustomed to using it because of previous research [10, 11]. Grakn supports object-oriented programming but also offers a flexible knowledge graph schema with entities and their relations, automated reasoning of data during execution and a high-level query language (Graql) using deductive reasoning [12]. It is worth mentioning that our research carried out before the acquisition and conversion of Grakn.ai to Vaticle.

4 Results

This section presents the main results of our work.

4.1 Identify relevant research

The review of relevant literature culminated in selecting [13] as a basis for our work. This work is deemed suitable for our purposes as (a) it contains a systematic literature review of all PS models in the academic literature and compares them with CPSV, and (b) it contains RDF data about public services compliant with the CPSV model. In that work, the authors after conducting a systematic literature review, concluded in integrating additional concepts in CPSV-AP model resulting in the so-called *CPSV-AP enriched model* (Figure 2). Some important additional concepts of CPSV enriched along with their descriptions are presented in table 1 (adapted from [13]).

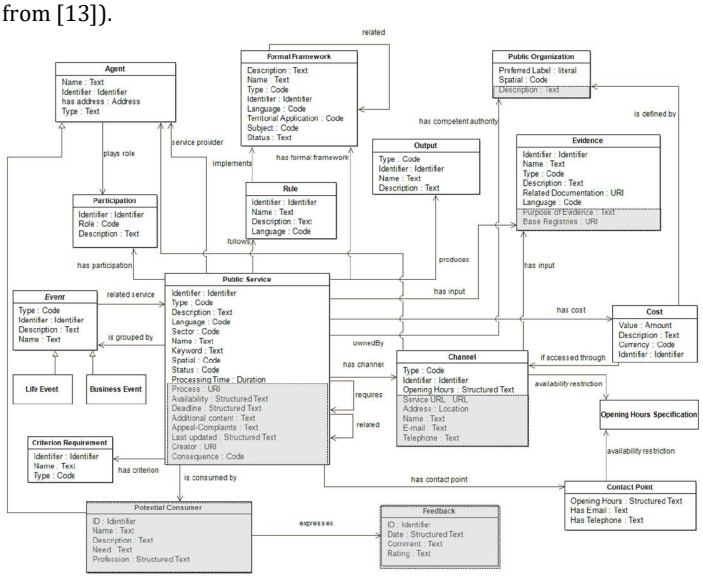

Figure 2. CPSV-AP enriched model (adapted from [13])

Table 1. Additional concepts of CPSV-AP enriched model (adapted from [13])

Concept	Description
Consequence	Information about the executed PS that needs to be forwarded to interested parties
Purpose Of Evidence	The purpose served by a piece of evidence
Potential Consumer	Information about potential consumer(s) of the public service
Need	The need(s) of a societal group that targeting by the public service

Concept	Description
Feedback	Host any type of feedback
Rating	Rating of the quality of the public service description
Profession	The targeting profession(s) by the public service
Comment	Text of any feedback

Finally, to demonstrate the added value of the CPSV-AP enriched model they created usage scenarios based on data in RDF format. These data were from 45 public services of Epirus as well as some additional data from the Greek official portal of public administration in html format, for those insured by the Social Insurance Institute (IKA) [13].

4.2 Design Knowledge Graph schema

4.2.1 Creation of Entities

A crucial step in developing the knowledge graph is the creation of Entities with their Attributes. Each class of Figure 2 is an entity in the knowledge graph schema and each field is an attribute to the corresponding entity. In total there are 18 entities and 39 attributes in our schema.

4.2.2Creation of relations between entities

Next step is the creation of the relations that connect the entities of the schema. These relations are based on the CPSV-AP enriched model (Figure 2). In addition to these, we add extra relations that serve our need of creating rules. In total there are 28 relations from CPSV-AP enriched model.

4.3 Introduce rules

Once the process of creating entities and relations is complete, we can introduce the rules in the knowledge graph schema. Rules are an integral part of knowledge graphs. Their creation requires the appropriate level of understanding of the model and the margins it give us. Another important factor when designing rules is the purpose of the use of the knowledge graph. In this case our interest revolves around the provision of PS descriptions and we are looking for ways to improve this through rules. Once we have decided which rules to insert into the schema of the knowledge graph, one last step is to create relations that will allow the concepts of the graph to be connected when the conditions of each rule are met. Finally, to use these rules we just need to query the knowledge graph with the corresponding relation.

In total, the knowledge graph contains 8 rules. Table 2 presents the rules with a brief description and the potential recipient of their use. A potential recipient could be a citizen/business, the public authorities themselves or both. The following subsections present brief descriptions of the introduced rules. Also, figure 3 presents the part of the class diagram with the classes and fields that participate in the rules of the knowledge graph.

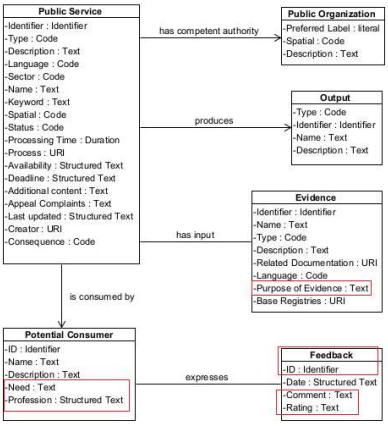

Figure 3. Classes that participate in the rules

Table 2. Rules with their description and the potential recipient of their use

Rule	Description	Potential recipient
Consequence	Relates public services	Both
Multiplicity check: Has Competent Authority 1-1	Relates public services with public authorities	Public Authorities
Matching a public service with a purpose	Relates public services with purposes of evidence	Citizen/Business
Matching a public service with a need	Relates public services with potential consumer needs	Citizen/Business
Matching a public service with feedback	Relates public services with potential consumers feedback	Public Authorities
Matching a public service with rating	Relates public services with ratings given by potential consumers through feedback	Public Authorities
Matching a public service with a profession	Relates public services with potential consumers professions	Citizen/Business
Matching a public service with comment	Relates public services with comments given by potential consumers through feedback	Public Authorities

4.3.1 Rule consequence

The consequence rule allows the detection of public services that triggers other public services as the output of the first is an input of the second. An example is the 'obtaining a birth certificate' service which could launch the service 'payment of child benefit'. In natural language the rule states that **if** a public service has an input (evidence) **and** a different public service has an output **and** the input is the same document (same identifier) with output. **Then,** through the rule, these two public services relate to each other with the consequence relation.

4.3.2 Multiplicity check: Has Competent Authority 1-1

The use of this rule detects if a public service is connected with two public authorities i.e., it has two competent authorities at the same time. If this is the case, then the condition that a public service can have only one competent authority is violated. With this rule, public servants can check whether this CPSV model constraint is violated and take relevant actions.

4.3.3 Matching a public service with a purpose

Each "Evidence" document that is required as input in public service serves a specific purpose (attribute of entity evidence). For this reason, linking a public service to the purposes derived from the documents it accepts as inputs could be useful. This rule makes this connection when evidence serves a purpose and this evidence is an input to a public service. So, anyone potentially interested in public services related to a particular purpose could easily identify them.

4.3.4 Matching a public service with a need

A potential consumer has a need that leads him to use a public service. Therefore, it is useful to know what needs a public service can serve. When a potential consumer uses a public service and that consumer has a specific need then this need is linked to the public service. So, citizens or businesses with a particular need could easily find which public service is suitable for them based on their needs.

4.3.5 Matching a public service with feedback

This rule applies when a potential consumer uses a public service and leaves feedback. We suggest this feedback should be directly related to the public service because it is useful for public authorities to know what potential consumers think on specific public services. The conditions required for this connection to take place include (a) the potential consumer uses a public service and (b) that consumer leave feedback. We thus enable potential stakeholders to be informed on the feedback concerning any public service.

4.3.6 Matching a public service with rating

This rule is closely linked to the previous. We suggest it is useful for public authorities to know what the ratings of specific public services are. The rating contained in feedback is related directly with the public service. The conditions required for this connection to take place are these listed in sub-section 4.3.5, plus the existence of rating in feedback.

4.3.7 Matching a public service with a comment

This rule is also linked to that of sub-section 4.3.5. We suggest that it is useful for public authorities to know what the comments of specific public services are. The comment contained in feedback is related directly with the public service. The conditions required for this connection to take place are these listed in sub-section 4.3.5, plus the existence of comment in feedback.

4.3.8 Matching a public service with a profession

When a potential consumer of a public service has indicated a profession in their profile, we suggest that the service can serve the specific profession and thus we connect the two with a relation. The conditions required for this connection to take place are (a) the potential consumer uses the public service and (b) the consumer indicates a profession in their profile. Using this rule, citizens or businesses related to a particular profession can easily find which public service are suitable for them based on their profession.

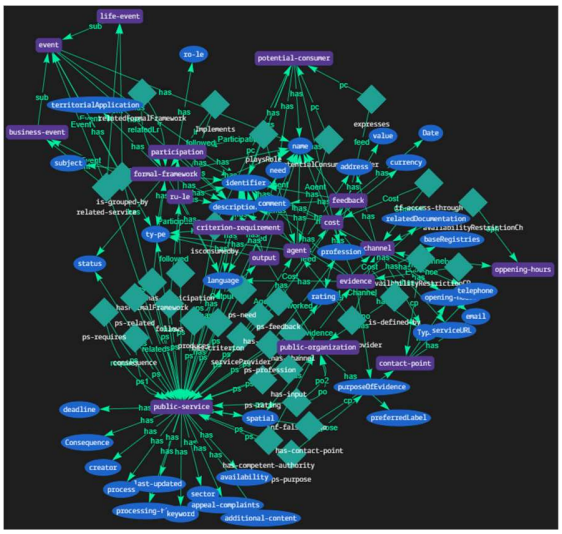

Figure 4. The developed knowledge graph in Grakn Workbase

4.4 Populate knowledge graph with data

In order to populate the knowledge graph, we used public service descriptions that were developed in previous research and was freely provided [13]. More specifically, we started from 1751 lines of RDF data included in the RDF store and ended up with 1160 lines describing all data in the knowledge graph database. It is noted that blank lines were not counted in both measurements.

4.5 Construct Usage scenarios

In this section we present three usage scenarios. For our purposes, we created some additional public service data that were not present in the selected research, i.e. [13]. These include potential consumers with specific needs to use a public service and feedback from each of them.

4.5.1 Usage scenario 1

The first scenario answers the following question: '*Which public service of "Having a baby" life event has as input documents that are outputs of other public service of the same event?'.* Using rules, we can easily answer this question because rules achieve the proactiveness of public services or otherwise no-stop government. The birth of a child triggers a series of interrelated public services of "Having a baby" life event. This correlation occurs because the output documents produced by one public service serve as inputs to another public service of the same life event. This way, the beneficiaries can receive the benefits automatically, without having to do anything themselves. An example presented in the following query. (Figure 5)

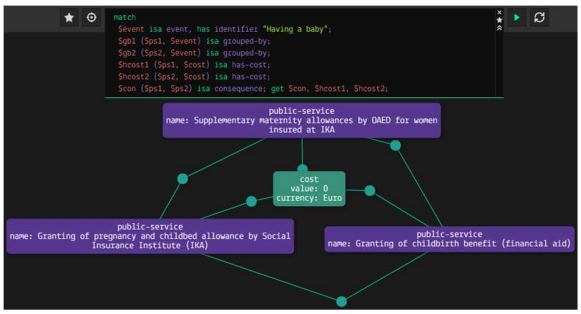

Figure 5. Results from Graql query in Grakn Workbase (Scenario 1)

4.5.2 Usage scenario 2

In the second scenario, a public servant is interested in what citizens think about the public service. For this purpose, they look at the comments left by citizens as well as relevant ratings (Figure 6). In this scenario, rules 4.3.6 (*Matching a public service with rating*) and 4.3.7 (*Matching a public service with a comment*) were applied.

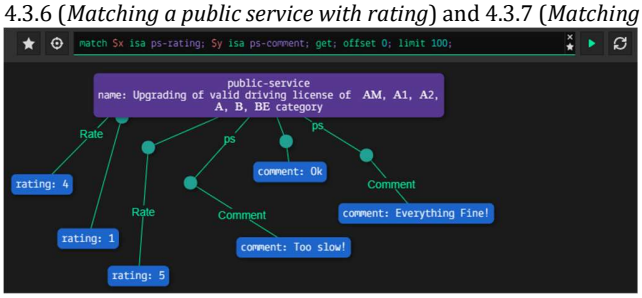

Figure 6. Public service with comments and ratings in Grakn Workbase (Scenario 2)

4.5.3 Usage scenario 3

In this last scenario, three citizens with specific needs used a public service. By using rule 4.3.4 (*Matching a public service with a need*) the used public service is connected to the specific needs (Figure7). It is therefore possible, through the rule, for interested citizens in the future to know what needs this public service serves.

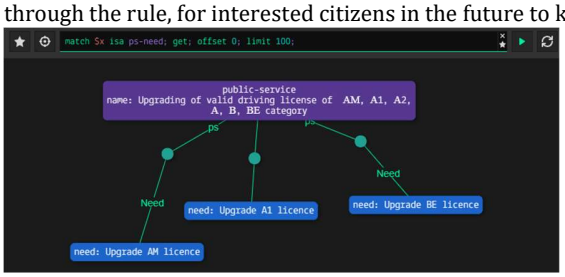

Figure 7. Public service with needs that serves in Grakn Workbase (Scenario 3)

4.6 Evaluate results

The results suggest that knowledge graphs can be a reliable and useful tool in storing, processing and managing all knowledge contained in public services information. Due to their structure, they can organize and categorize

entities with minimum effort. Portability is also a useful feature as it allows reusing a knowledge graph schema with minimal changes. Furthermore, imposing logic on data through rules allows knowledge graphs to produce new knowledge based on existing. Finally, querying knowledge graphs is an easy process since it approaches natural language.

Although the results of our research are encouraging, there are several challenges to be addressed. Creating a knowledge graph is a relatively complex process and not supported by sufficiently mature tools to be used by public servants. The lack of easy-to-use knowledge graphs management tools combined with the lack of easy-to-use querying interfaces are factors that prevents their use on a large scale. Also, the subjectivity about rules is another challenge to be overcome. Although deductive logic is applied, it is largely influenced and based on the skills of the knowledge graph developer.

5 Conclusions and future work

The aim of this paper was to develop a knowledge graph compliant to the CPSV model and to discover the potential benefits of using knowledge graphs for public service description. For this purpose, we presented a knowledge graph for an enriched version of CPSV and populated it with pre-existing RDF data. Our results suggest that knowledge graphs could benefit the management of public service descriptions. Rules are the most important concept of knowledge graphs. Applying logic on data (reasoning) allows the extraction of knowledge that would be difficult to derive otherwise. The results are promising however the killer application that will make the big difference and lead to the widespread use of knowledge graphs is still to be identified.

The research presented in this paper has some limitations. First, for the selection of relevant research, we did not carry out a systematic literature review. Furthermore, our development experience was only gained from using Grakn.ai thus additional platforms should be investigated. Future work includes extending the knowledge graph schema with the Core Criterion and Core Evidence Vocabulary (CCEV) specification recently issued by the European Commission [14]. Also, the pilot application of the knowledge graph adapted to specific public services and the conduct of evaluation and interviews by both civil servants and citizens is something that can be further investigated. Finally, the creation of a platform for developing and managing knowledge graphs can lay the foundation for proving that knowledge graphs could be a useful tool for public administration.

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APPENDIX

This section present examples of code for the creation of the knowledge graph.

Listings

Public Service entity creation in Graql

The core class from the CPSV-AP enriched model is 'Public Service' and its creation is described in Listing 1. The rest of the entities in our schema are created in a similar way.

Listing 1. Public Service entity creation in Graql

```
1. Define
2. public-service sub entity,
3. plays require,
4. plays ps,
5. plays ps1,
6. plays related,
7. key identifier,
8. has name,
9. has description,
10. has spatial,
11. has processing-time,
12. has sector,
13. has keyword,
14. has ty-pe,
15. has language,
16. has status,
17. has thematicArea,
18. has process,
19. has availability,
20. has deadline,
21. has additional-content,
22. has appeal-complaints,
23. has last-updated,
24. has creator,
25. has Consequence;
```

The second line of code defines the name of the entity. Lines 3 to 6 indicate the roles that this entity can play in various relations with other entities. Line 7 defines the primary key of the entity. Finally, lines 8 to 25 define the attributes of the entity that are derived from the fields of the 'Public Service' class (Figure 1). Figure 2 illustrates the entities and their attributes of the knowledge graph.

Consequence relation creation in Graql

Listing 2 contains the code for creating the consequence relation. The rest relations are created in a similar way.

Listing 2. Consequence relation creation in Graql

```
1. define
2. consequence sub relation,
3. relates ps,
4. relates ps1;
```

Consequence rule creation in Graql

Listing 3 presents the creation of the consequence rule.

Listing 3. Consequence rule creation in Graql

```
1. inf-consequence sub rule,
2. when {
3. $ps isa public-service, has identifier $id1;
4. $ps1 isa public-service, has identifier $id2;
5. $out isa output, has identifier $idout;
6. $ev isa evidence, has identifier $idev;
7. (ps: $ps, Evidence: $ev) isa has-input;
8. (ps: $ps1, Output: $out) isa has-output;
9. $idev == $idout;
10. $id1 != $id2;
11. }, then {
12. (ps: $ps, ps: $ps1) isa consequence;
13. };
```

Data migration example from RDF to knowledge graph (graql)

In Listing 4 we present the process we followed for the migration of the data through an example.

Listing 4. Public service 4 definition in RDF [13] and knowledge graph database

RDF store

```
<http://data.dai.uom.gr:8890/PublicServices/id/ps/ps0004> a cpsv:PublicService ;
    dct:title "Approval of application for the participation in exams for obtaining a construction machinery operator license" ;
    dct:description "Application submission for the participation in exams in order to obtain a construction machinery operator license" ;
    dcat:keyword "license" ;
    cv:sector "M71.1.2 - Engineering activities and related technical consultancy" ;
    dct:type "General public services n.e.c." ;
    dct:language "el" ;
    cv:isGroupedBy <http://127.0.0.1:3345/Starting+business%3A+Needing+a+license%2C+permit+or+certificate+to+start+or+continue+an+activity> ;
    cv:hasCompetentAuthority <http://data.dai.uom.gr:8890/PublicOrganization/id/nuts3/GRC_PRF_IPEIR> ;
    cpsv:hasInput <http://data.dai.uom.gr:8890/PublicServices/id/doc/BachelorDegree> ;
    cv:hasFormalFramework <http://data.dai.uom.gr:8890/LegalFramework/id/law/3982_2011> ;
    cpsv:produces <http://data.dai.uom.gr:8890/PublicServices/id/doc/Certificate0004> ;
    dct:spatial "http://publications.europa.eu/resource/authority/atu/GRC_PRF_IPEIR" ;
    cv:hasChannel <http://data.dai.uom.gr:8890/PublicServices/id/channel/ServiceBureau> ;
    cv:processingTime "P15D" ;
    cv:hasCost <http://data.dai.uom.gr:8890/PublicServices/id/cost/cost0003> ;
    dcat:keyword "Operator" ;
    cpsv:hasInput <http://data.dai.uom.gr:8890/PublicServices/id/doc/DrivingLicenseB> ;
    cv:hasFormalFramework <http://data.dai.uom.gr:8890/LegalFramework/id/pd/113_2012> ;
    dcat:keyword "Machinery" ;
    cpsv:hasInput <http://data.dai.uom.gr:8890/PublicServices/id/doc/HealthCertificate> ;
    cv:hasFormalFramework <http://data.dai.uom.gr:8890/LegalFramework/id/cmd/0005_2013> ;
    dcat:keyword "Construction" ;
    cpsv:hasInput <http://data.dai.uom.gr:8890/PublicServices/id/doc/Certificate0018> ,
<http://data.dai.uom.gr:8890/PublicServices/id/doc/Certificate0003> ,
<http://data.dai.uom.gr:8890/PublicServices/id/doc/ReceiptPayment> .
```

Knowledge graph	$ps4 isa public-service, has identifier "<http://data.dai.uom.gr:8890/PublicServices/id/ps/ps0004>", has name "Approval of application for the participation in exams for obtaining a construction machinery operator license", has description "Application submission for the participation in exams in order to obtain a construction machinery operator license", has keyword "license", has keyword "Operator", has keyword "Machinery", has keyword "Construction", has language "el", has spatial "http://publications.europa.eu/resource/authority/atu/GRC_PRF_IPEIR", has processing-time "P15D", has ty-pe "General public services n.e.c.", has sector "M71.1.2 - Engineering activities and related technical consultancy"; $gb4 (Event: $event1, ps: $ps4) isa grouped-by; $hau4 (ps: $ps4, po: $po1) isa has-competent-authority; $hop4 (ps: $ps4, Output: $op4) isa produces; $hco4 (Cost: $cos3, ps: $ps4) isa has-cost; $hch4 (ps: $ps4, Channel: $ch1) isa has-channel; $hin4-1 (Evidence: $ev3, ps: $ps4) isa has-input; $hin4-2 (Evidence: $ev14, ps: $ps4) isa has-input; $hin4-3 (Evidence: $ev5, ps: $ps4) isa has-input; $hin4-4 (Evidence: $ev50, ps: $ps4) isa has-input; $hin4-5 (Evidence: $ev9, ps: $ps4) isa has-input; $hin4-6 (Evidence: $ev8, ps: $ps4) isa has-input; $hlr4-1 (lr: $fr5, ps: $ps4) isa hasFormalFramework; $hlr4-2 (lr: $fr32, ps: $ps4) isa hasFormalFramework; $hlr4-3 (lr: $fr20, ps: $ps4) isa hasFormalFramework;

The example of Listing 4 concerns the fourth public service of our data set. This section defines its attributes and relations with the other entities.