

# A Linked Open Data-Oriented Sustainable System for Transparency and Open Access to Government Data: A Case Study of the Public's Response to Women's Driving in Saudi Arabia

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Received: 24 August 2020; Accepted: 13 October 2020; Published: 17 October 2020

**Abstract:** Due to the wide-ranging development of data-oriented sustainable systems in the government and the public sectors, the development of such sustainable systems is replete with potential. The ultimate focus of developing these sustainable systems is to provide citizens with transparency, accountability, awareness as well as a single point of query for asking integrated and smart queries. In view of these benefits, the Saudi government has taken the initiative to publish and develop sustainable open data-oriented information systems. However some major challenges in the Saudi Government Open Data are that the (1) data are published and available in different formats such as Excel sheets, CSV files (Comma Separated Values), images, scanned documents and social media sources such as Twitter, (2) datasets from different government departments are not linked with each other or to existing datasets in Linked Open Data Cloud (even though they have strong links with each other), and (3) there is no SPARQL Endpoint that can be used to pose smart semantic-based queries to Saudi Government Data. This paper is part of an ongoing research project to present a framework that can be used to transfer the government data from different sources to RDF format. The framework can also be used to clean and classify/map the data according to the Saudi Government Ontology. We also describe our approach for semiautomatically linking Saudi Government Datasets with one another as well as with other existing open datasets, thus resulting in the Saudi Linked Open Government Data Cloud (SLOGDC). Finally, taking the topic “Public's Response to Women's Driving in Saudi Arabia” as a case study, we demonstrate the SLOGD SPARQL Endpoint as a data-oriented system by executing different queries and analyzing results of these queries. This work also contributes new insights into women's driving in Saudi Arabia using the SLOGDC, thus suggesting the way forward in shaping policies for decision-making.

**Keywords:** sustainable systems; linked open data; policy-making; smart queries; machine reasoning

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## 1. Introduction

The trend in developing data-oriented sustainable systems is rapidly shifting to open data-oriented sustainable systems, thus resulting in the production of Open Data (OD) and linkage

with other Open Datasets to create Linked Open Data (LOD), which can be used to ask sophisticated queries. Some governments have led the initiative to produce Open Government Data (OGD)-oriented solutions [1]. However, despite major efforts in OGD publishing and consuming, the full value of OGD-oriented sustainable systems has yet to be realized. OGD sustainable systems do have some major issues. For instance, the chaotic organization of published OGD results in the same data being found within different data sources. Further, there tends to be a dearth of links between OGD datasets, and due to missed links, we are not able to develop open data-oriented sustainable systems and get new insights from different domains. Therefore, this situation calls for a solution that can transform Open Government Data (OGD) into Linked Open Government Data (LOGD) so that LOGD-oriented sustainable systems can be launched to produce better knowledge graphs for customers.

A number of initiatives have been undertaken in LOGD-driven systems such as the US Government Linked Open Data Available: Data.gov, UK Linked Open Government, and Singapore linked Open Data. These initiatives bring about government transparency and public participation. Moreover, people can access data sources without any restrictions, query multiple data sources, and develop valuable citizens' applications. The Saudi Arabian government has made a major effort towards the establishment of e-government [2] and development of the Open Data portal (<http://www.data.gov.sa/>), which is an important initiative for the country [3].

However, in comparison with developed countries, Saudi Arabia is lagging behind in accessing the benefits of data-oriented sustainable systems [4]. The government data in the Saudi government portal has some limitations. For instance, not only is the OGD available on different official portals and websites, but also the links between OGD datasets and related datasets are missing. Some of the data provide an abstract which cannot be used for analysis and studies purposes, thus resulting in many hindrances to this data-oriented sustainable system. To address these limitations, we present the Saudi Linked Open Government Data Cloud (SLOGDCF) framework that can be used to produce Saudi OGD-oriented sustainable systems for improving transparency, encouraging public participation, querying multiple data sources, and supporting better decision-making. The main contributions of study are as follows:

1. Development of a Saudi Linked Open Government Data Cloud (SLOGDCF) framework that extracts and processes data from various sources such as *General Authority for Statistics (GaStat)*, *Ministry of Human Resource and Social Development (HRSD)*, *Ministry of Interior (MOI)*, *Ministry of Civil Service (MCS)*, *Ministry of Justice (MOJ)*, and *Twitter datasets*.
2. Design and development of an ontology for Saudi Open Government Data and then mapping of the data according to the Saudi Linked Open Government Data Ontology (SLOGDO).
3. Production of the Saudi Linked Open Government Data Cloud (SLOGDC) as a data-oriented sustainable system by semiautomatically linking Saudi Government Datasets with one another and with other existing open datasets.
4. Enabling of the SLOGDC SPARQL endpoint and executing of different queries and analysis of the results of these queries vis-à-vis the topic "Public's Response to Women's Driving in Saudi Arabia" as a case study.
5. Use of the results of analysis to get new insights into the factors that influence the public response to women's driving in Saudi Arabia.

The rest of the paper is organized as follows: the related work is discussed in Section 2. Section 3 describes the SLOGDCF framework that we developed to extract the data to produce SLOGD Cloud. In Section 4, the Saudi Linked Open Government Data (SGLOD) Ontology is explained. The creation of Saudi Linked Open Government Data Cloud is discussed in Section 5. In Section 6, we present the SLOGDC SPARQL endpoint, perform different queries via the SPARQL endpoint, and discuss the results of queries. In Section 7, we present our case study analysis of the public's response to women's driving in Saudi Arabia from the SGLODC. Finally, Section 8 presents the conclusion to our work.

## 2. Related Work

The development of data-oriented sustainable systems has attracted considerable attention due to the potential benefits of such systems. Further the development of Open Government Data (OGD)-oriented sustainable systems have transformed into a global movement for open and smart government systems. Most governments [5–8] around the world publish their data in open data formats to enable public reuse of this data. Different government bodies also provide open data portals as a single point of access to open government datasets (OGD) in multiple domains [9]. Recent analysis shows that the public reuse these open datasets to add value and innovation in economic domain that they can undertake [10]. Linking and making these datasets openly available can improve transparency and support citizens, public sectors, and decision-makers in making sophisticated queries, analyzing the results, and using them in decision-making and policy formulation.

There are many data-oriented sustainable systems that have been developed based on linked open data (LOD) in various fields. For example, in the tourist field, researchers used linked open data (LOD) to support tourism within the local community system [11]. The authors described their approach to transferring tourism-related data into RDF data format and storing it as LOD in the tourism local community system. However, tourist information on temples, shrines, temples and historical facilities was not collected as part of this LOD. Additionally, in this study, a SPARQL endpoint to evaluate the quality of their data were not provided. In other research [12], the authors proposed a two-pronged method to creating LOD. This comprised first transferring the data sources into RDF documents and creating links between RDF datasets and then transferring the RDF documents back into original formats of data sources. However, as this method lacked the semantics in CVS files (Comma Separated Values), there was absence of a tool to discover and understand links in CVS data. In another work [13], the authors presented a model designed to classify government public information with support of ontologies by transforming Brazilian government open data into linked open data. However, there are massive volume of daily generated data with different formats, which are not open to processing under the proposed model. Similarly, a platform termed GovLOD is presented in another study [14]. The GovLOD platform is developed over linked open data principles to transform the open data sources into RDF triples which can be used to make queries. However, the main limitation of this work is that a manual mapping process is used in data transformation.

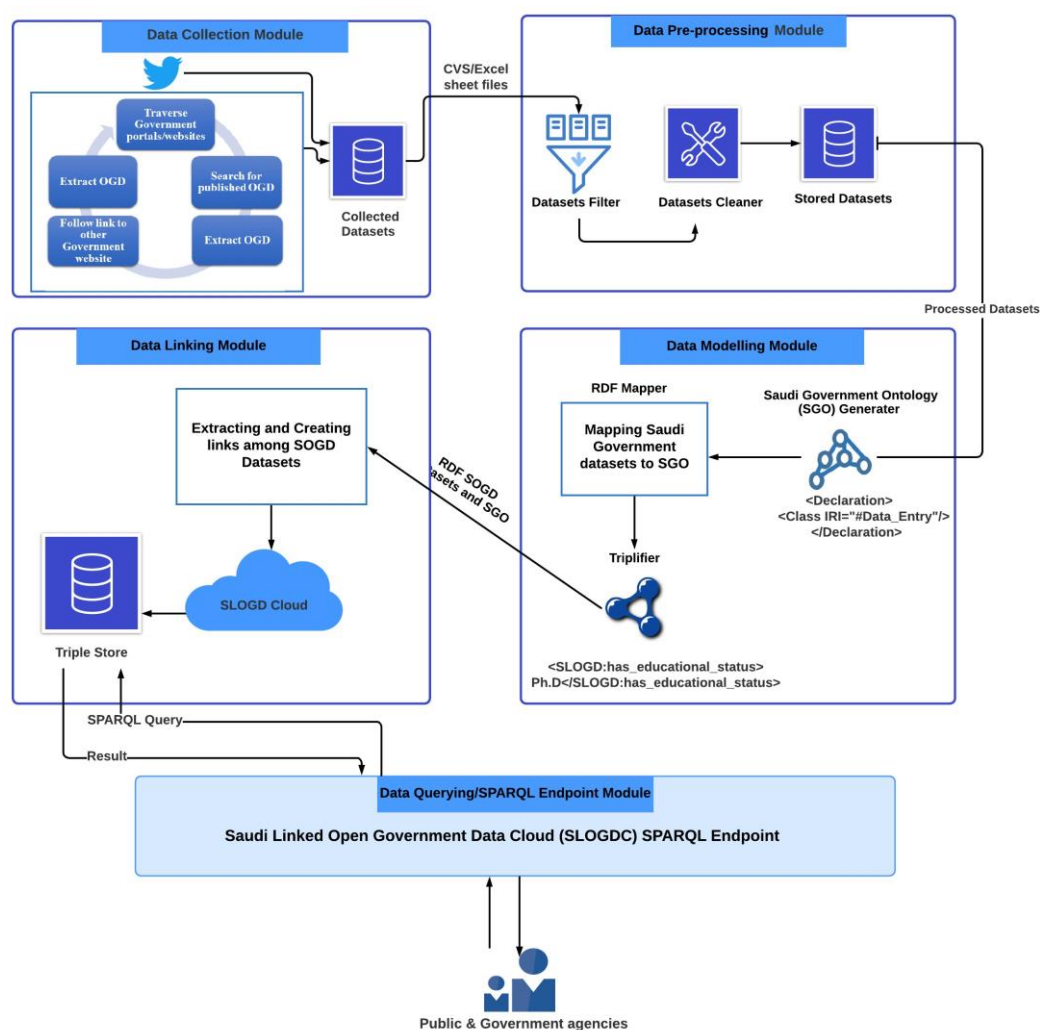
There are studies [15,16] that have used LOD to solve some urban problems. In Japan, they used LOD to detect the causality of urban problem and the related cost information of their budget sheets. They designed the RDF schema to these data and immediate actual causes and effects using crowdsourcing. They also used Semantic Web Rule Language (SWRL) for inferencing and SPARQL queries to detect problems. However, in some cases, it proved difficult to understand the causalities. In addition to this, the city government of Tokyo used the LOD to solve the urban problem of illegal parking of bicycles by raising social awareness. They extracted data based on factors and LOD and collected data from social networking services. They also published LOD and provided a web application to visualize the distribution of the illegal parking of bicycles in the city. However, in this study, there was a need to improve their estimation accuracy and to provide SPARQL endpoint to monitor the use of the illegal parking of bicycles LOD.

In the context of the Saudi government, there is very limited research in the field of Open Government Data (OGD) and Linked Open Government Data (LOGD). In one study [17], the authors proposed a model to measure openness level of data in Saudi Arabian Open Data Portal using a scoring model based on Global Open data index. They applied this model to measure the openness level of Saudi Open Government Data portal along with other five data portals in Taiwan, United Kingdom, Denmark Colombia, and Finland. The result of this model showed that Saudi Arabia's final score as 32.23% points, which flagged the need for more improvements. They also recommended developing strategies to spread awareness of Open Government Data among citizens in Saudi Arabia.

Therefore, in this research, we proposed the use of SLOGDCF framework to create our Saudi Linked Open Government Data Cloud (SLOGDC), which includes data sources from different domains. Then we performed different SPARQL queries by integrating data from different domains, which retrieved data from our RDF datasets and then retrieved data from other open datasets in the SLOGDC. This was done in order to get further and related information that would not have been possible if we had not created our SLOGDC. Besides the SPARQL queries, we present the quantitative and qualitative analyses of the resulting data.

### 3. Saudi Linked Open Government Data Cloud Framework (SLOGDCF)

In this section, we describe the Saudi Linked Open Government Data Cloud Framework (SLOGDCF) that automates the process of producing LOGD from different data sources available in different formats and in different domains. The SLOGDCF framework can be used to collect, extract, process, generate RDF datasets and to map them to Saudi Linked Open Government Data Ontology (SLOGDO) so as to produce Saudi LOGD and Saudi LOGD cloud. The architecture of SLOGDC Framework consists of five modules: The Data Collection Module, Data Pre-processing Module, Data Modelling Module, Data Linking Module, and Data Querying/SPARQL Endpoint Module as shown in Figure 1. The following sections describe each of these modules in detail.



**Figure 1.** The architecture of Saudi Linked Open Government Data Cloud (SLOGDC) framework.

### 3.1. Data Collection Module

This module collected, traversed, and extracted Saudi Open Government Data (SOGD) datasets from various data sources in different domains such as *General Authority for Statistics (GaStat)*, *Ministry of Human Resource and Social Development (HRSD)*, *Ministry of Interior (MOI)*, *Ministry of Civil Service (MCS)*, *Ministry of Justice (MOJ)*, and *Twitter datasets*. Those data were available in different formats such as CVS files (Comma Separated Values) and Excel sheets. It was used to traverse different data sources, such as government portals and websites, and extract necessary data entities from these data sources. In addition, child data sources such as links to nested pages of portal or CSV files were traversed and useful data entities were extracted from them. As part of this module, we also investigated the relations between different data entities of various government organizations. This process was done recursively until open data were collected. The collected datasets exist in Excel sheet and CVS forms. In the context of our case study, we extracted the data from different Saudi OGD sources as well as from Twitter about women's driving in Saudi Arabia. The data from Twitter was extracted on the basis of different data attributes such as used hashtags, users' tweets about the topic, user information, and number of tweets per day. The data from Twitter was extracted in structured format. The module resulted in the production of two types of datasets: Saudi OGD datasets from different sources in various domains and Twitter datasets. These datasets were prepared and processed in the next module of the framework.

### 3.2. Data Preprocessing Module

This module consisted of two submodules: *Datasets Filter*, and *Datasets Cleaner*. Each extracted and collected dataset from the previous module was subjected to data filtering and data cleaning. In the first submodule (i.e., *datasets filter*), we extracted, defined, and filtered data items that were required and related to our case study in this work. This module also dealt with inconsistency in data such as duplicated data and contradictory data, in addition to checking for missing data. The data consistency check was performed both on Saudi OGD datasets and Twitter datasets. Finally, this module produced the filtered Saudi OGD and Twitter datasets in Excel sheet and CVS formats. The second submodule was the *dataset cleaner* that removed any error and noise in both the datasets and transformed them in a consistent and structured format to prepare them for use in the next module. The module resulted in clean and processed datasets within a structured format.

### 3.3. Data Modelling Module

This module was responsible for adding semantics to processed datasets, i.e., cleaned Saudi OGD and Twitter datasets. This module consisted of three submodules: *Saudi Government Ontology (SGO) Generator*, *RDF Mapper*, and *Triplifier*. The first submodule (i.e., *Saudi Government Ontology (SGO) Generator*) took the filtered and cleaned datasets as input, identified the concepts or classes based on the filtered and cleaned datasets and also identified the semantic relationships between data entities within Saudi Government datasets as shown in Figure 2. We also investigated different existing vocabularies and reused them to the maximum extent. In addition to this, we utilized OWL reasoning features such as *cardinality constraints* and *complex restrictions* on properties as well as property type and *equivalent* and *disjoint classes*. The second submodule (i.e., *RDF Mapper*) was used to map datasets to SGO. We automatically classified and mapped the Saudi Government datasets according to SGO. The *Triplifier* submodule generated RDF triples of extracted data items in the form of *Subject—Predicate—Object* (as shown in Figure 3). In this module, we used the third-party tools and APIs such as OWL APIs that automatically generate RDF datasets in N-triples format.

| Category                                                     |         |         |
|--------------------------------------------------------------|---------|---------|
| Transportation                                               |         |         |
| Dataset                                                      |         |         |
| Driving Licenses Issued by Region 2017-2018                  |         |         |
| Year                                                         | 2018    | 2017    |
| Region                                                       |         |         |
| Al-Riyadh                                                    | 493,224 | 495,307 |
| Makkah Al-Mokarramah                                         | 144,873 | 142,487 |
| Al-Madinah Al-Monawarah                                      | 23,335  | 36,165  |
| Al-Qaseem                                                    | 4457    | 6318    |
| Eastern Region                                               | 131,639 | 126,816 |
| Aseer                                                        | 22,362  | 39,133  |
| Tabouk                                                       | 7613    | 10,232  |
| Hail                                                         | 39,575  | 22,035  |
| Northern Borders                                             | 3661    | 5280    |
| Jazan                                                        | 12,265  | 18,345  |
| Najran                                                       | 7431    | 13,825  |
| Al-Baha                                                      | 2575    | 4131    |
| Al-Jouf                                                      | 6834    | 8091    |
| Total                                                        | 899,844 | 928,165 |
| Source: Ministry of Interior- General Directorate of Traffic |         |         |
| Organization                                                 |         |         |

Figure 2. Captured entities of Saudi Government Ontology from Saudi Open dataset.

| Predicate      |               |        |                                                                                 |
|----------------|---------------|--------|---------------------------------------------------------------------------------|
| Retweeted_By   | Original User | Tweet  | Tweets                                                                          |
| Fhggv1Gff      | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| dlaal_i        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| Olil           | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| QX_9           | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| njoudfi        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| castle14n      | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| M_7am1         | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| khaled5033     | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| xiba101        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| reem_almona    | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| QasemAlamari   | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| _ws5sw5        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| ghamdi22       | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| _LMessi        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| iBsh_10        | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| smaalen99      | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| m_ss31         | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |
| abo_Mohammed89 | SaudiNews50   | 108549 | عاجل امر سام السماح بقيادة المرأة للسيارة في السعودية الملك ينتصر لقيادة المرأة |

Figure 3. Captured RDF (Resource Description Framework) triples from Twitter dataset.

### 3.4. Data Linking Module

In this module, we used the RDF datasets and SGO from the previous module to create Saudi Linked Open Government Data (SLOGD) as part of the Saudi Linked Open Government Data Cloud (SLOGDC). In data linking process, we first examined the information that describes datasets to determine the type of data and their relations. Next, we established more relations between data entities within dataset as well as relations between different datasets such as population datasets, transportation datasets, job statistics datasets, education datasets, and Twitter datasets. The data items in the SLOGDC were extracted from various data sources. All these data sources contained data that were directly or indirectly related to our case study. In addition to this, we semiautomatically created, managed, and determined the type of relations between data entities and within the dataset as well as the type of relations between different datasets. As a last step, we

semiautomatically managed the linkage rules between different data sources then the RDF links were generated automatically between these data entities to one another in order to create SLOGDC. Including data from multiple data sources helped to create bigger knowledge graphs, which ultimately proved to be useful for the purpose of effective analysis.

### 3.5. Data Querying/SPARQL Endpoint Module

This module served as a front end for the final users. Our SLOGD SPARQL endpoint was available as a public access point that could be used to execute different queries and analyze results by considering the different factors influencing the public's response to female drivers in Saudi Arabia. Our framework hid the complexity of linked data technology from end users.

## 4. The Saudi Linked Open Government Data Ontology (SLOGDO)

The Saudi Government Ontology (SGO) was the core step and key for building SLOGD. The Saudi government data lacked structural support for constructing the Saudi Linked Open Data (SLOD). In this section, we introduced our Saudi Linked Open Government Data Ontology (SLOGDO) based on the nature of SOGD datasets. The generation of Saudi Government Ontology did not require user intervention. Further, based on SGO, we automatically generated RDF datasets. The resulting RDF data were at the 4-star level of 5-star open data model [18]. In addition, based on the ontology design patterns, we provided a solid model and rich semantic vocabularies for promoting the goal of opening Saudi OGD with linked data technologies. The SLOGD includes mixed datasets, which were created using our SGO in order to infer new knowledge as well as bigger knowledge graphs. Based on the nature of Saudi Open datasets, we realized the following patterns: *Organization*, *Category*, *Datasets*, and *Data Entry*.

In the section below, we describe the process of generating Saudi Linked Open Government Data Ontology (SLOGDO) based on ontology design patterns:

**Classes:** the classes refer to the vocabularies related to our data domains such as the driving, job statistics, education, population, economic, and social or public impact/response to women's driving in Saudi Arabia. The ontology concept extracted were such that they represent right and valid group of concepts domain of government data [19]. The description of core ontology classes is as follows:

- **Data\_Entry:** this class is used to represent a set of dimensions.
- **Organization:** this class is used to represent the public or private agencies that published the dataset.
- **Dataset:** this class is used to represent the statistical datasets, which are the container of data, e.g., population datasets or economic datasets.
- **Category:** this class is used to represent the category or type that the dataset belongs to, e.g., transportation and Labor\_Market\_&\_Social\_Security.

Based on core ontology classes and reuse of ontology design patterns, the core classes and their relations were extended to obtain the semantic structure of ontology for Saudi Open Government Data (SOGD). The use of ontology design patterns based on our case study in this work was as follows: (1) use of *Data\_Entry Pattern*, (2) use of *Organization Pattern*, (3) use of *Datasets Pattern*, and (4) use of *Category Pattern*.

### A. Use of Data\_Entry Pattern:

In the Saudi Government field, data entry represents a set of dimensions such as region, year, and measurements, e.g., number of driving license, number of accidents, and violation. Therefore, based on our case study in this work, we define the following as subclasses of *Data\_Entry*: *Driving\_Licenses*, *Traffic\_Violations*, *Traffic\_Accidents*, *Divorce\_Documents*, *Marriage\_Contract*, *Labor\_Market*, and *Household\_Income*. We also define *relations belong\_to\_Dataset*, and *has\_region*, *number\_of\_Accident*, *number\_of\_Violations*, *total\_Female\_Employed\_Persons*, *total\_Female\_Employment\_Rate*, *total\_Female\_Unemployment\_Rate*, *divorced\_Income*, *educational\_Status\_Bachelors*, *married\_Income*, *saudi\_Female\_Job\_Seekers*, *number\_of\_Divorce\_Documents*,

and *number\_of\_Marriage\_Contracts*. In order to enable the SGO to be automatically processed and understood by machine, we represented the Saudi Government Ontology in machine-understandable language (i.e., OWL). Example of the results of encoding of *Data\_Entry Pattern* and its property in Turtle format is given below.

```
http://www.semanticweb.org/afnan/ontologies/SGO#Data_Entry
SGO:Data_Entry rdf:type owl:Class
http://www.semanticweb.org/afnan/ontologies/SGO#belong_to_Dataset
SGO:belong_to_Dataset rdf:type owl:ObjectProperty ;
                      rdfs:domain SGO:Data_Entry ;
                      rdfs:range SGO:Datasets .
```

### B. Use of Organization Pattern:

The *Organization* is government agencies or private agencies that are published open dataset such as *Ministry\_of\_Interior-General\_Directorate\_of\_Traffic*, *General\_Authority\_for\_Statistics*, and so on. Therefore, this class has the following as relations: *include\_Category* and *owner\_Of*. Once mapped and structured, the data were inferred using reasoning practices of SLOGDO. The encoding of *Organization Pattern* in Turtle format is shown below.

```
http://www.semanticweb.org/afnan/ontologies/SGO#Organization
SGO:Organization rdf:type owl:Class .
http://www.semanticweb.org/afnan/ontologies/SGO#owner_Of
SGO:owner_Of rdf:type owl:ObjectProperty ;
             rdfs:domain SGO:Organization ;
             rdfs:range SGO:Datasets .
http://www.semanticweb.org/afnan/ontologies/SGO#include_Category
SGO:include_Category rdf:type owl:ObjectProperty ;
                    owl:inverseOf SGO:related_To_Org ;
                    rdfs:domain SGO:Organization ;
                    rdfs:range SGO:Category .
```

### C. Use of Datasets Pattern:

Saudi Open Government Portal provides the statistical datasets of different departments and ministries for public access and reuse. These datasets act as the containers of data in different domains such as *Main\_data\_and\_indicators\_of\_the\_labor\_market\_for\_2018*, *Traffic\_Violations\_By\_Region*, *Traffic\_Accidents\_By\_Region*, and *Driving\_Licenses\_Issued\_By\_Region*. We defined the following as relationships *belong\_to\_Category* and *has\_Owner* to link different data items. The example of the results representing the Datasets Pattern in Turtle format is shown below.

```
http://www.semanticweb.org/afnan/ontologies/SGO#Datasets
SGO:Datasets rdf:type owl:Class .
http://www.semanticweb.org/afnan/ontologies/SGO#has_Owner
SGO:has_Owner rdf:type owl:ObjectProperty ;
              owl:inverseOf SGO:owner_Of ;
              rdfs:domain SGO:Datasets ;
              rdfs:range SGO:Organization .
http://www.semanticweb.org/afnan/ontologies/SGO#belong_to_Category
SGO:belong_to_Category rdf:type owl:ObjectProperty ;
                      owl:inverseOf SGO:include_Dataset ;
                      rdfs:domain SGO:Datasets ;
                      rdfs:range SGO:Category .
```

### D. Use of Category Pattern:

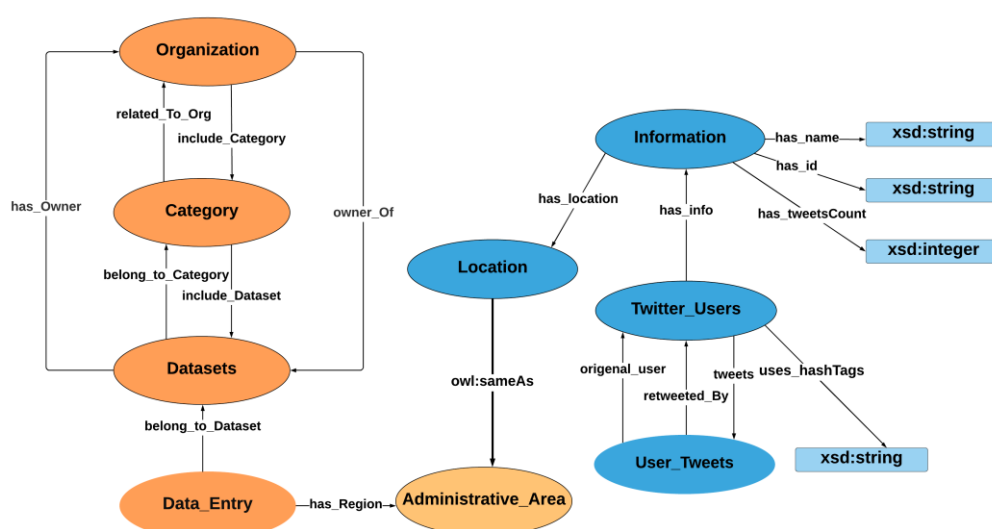
The *Category* is used to represent the category or type that the dataset belongs to, e.g., transportation and Labor\_Market\_& Social\_Security. We also define relation *related\_To\_Org* and *include\_Dataset*. The example below shows some of the encoding of *Category Pattern* in Turtle format:

```

http://www.semanticweb.org/afnan/ontologies/SGO#Category
SGO:Category rdf:type owl:Class .
http://www.semanticweb.org/afnan/ontologies/SGO#related_To_Org
SGO:related_To_Org rdf:type owl:ObjectProperty ;
                    rdfs:domain SGO:Category ;
                    rdfs:range SGO:Organization .
http://www.semanticweb.org/afnan/ontologies/SGO#include_Dataset
SGO:include_Dataset rdf:type owl:ObjectProperty ;
                    rdfs:domain SGO:Category ;
                    rdfs:range SGO:Datasets .

```

The overview of SGO is shown in Figure 4, which shows the *classes: Organization, Category, Datasets, and Data Entry* and relations between *classes* and the integration between our SGO ontology and Twitter ontology based on the case study in this work.



**Figure 4.** An overview of Saudi Government Ontology (SGO) in the perspective of our case study (i.e., women driving).

**Relations and properties:** apart from the definition of classes, the semantic relations between classes are important to meaningfully link the different resources in linked data [20]. This semantic link between resources was described with URIs when we used RDF object properties as predicate and due to the diversity of concepts of the Saudi Government field. We refined the initial semantic implementation of our ontology in alignment with the government data structure in general and our case study in specific. The relations of classes are shown in Table 1. In addition, the data type properties are used to describe the characteristics of classes wherein the range could be *string*, *integer*, and *numbers*.

**Table 1.** Relations of classes.

| Classes      | Relations                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Data_Entry   | <i>belong_to_Dataset</i> , and <i>has_region</i> , <i>number_of_Accident</i> , <i>number_of_Violations</i> , <i>total_Female_Employed_Persons</i> , <i>total_Female_Employment_Rate</i> , <i>total_Female_Unemployment_Rate</i> , <i>divorced_Income</i> , <i>educational_Status_Bachelors</i> , <i>married_Income</i> , <i>saudi_Female_Job_Seekers</i> , <i>number_of_Divorce_Documents</i> , and <i>number_of_Marriage_Contracts</i> . |
| Organization | <i>include_Category</i> , and <i>owner_Of</i>                                                                                                                                                                                                                                                                                                                                                                                             |
| Datasets     | <i>belong_to_Category</i> , and <i>has_Owner</i>                                                                                                                                                                                                                                                                                                                                                                                          |

| Category | related_To_Org and include_Dataset. |
|----------|-------------------------------------|
|----------|-------------------------------------|

We automatically processed and represented the machine-understandable semantics of SGO. In addition to this, we evaluated it using the various reasoners to check the correctness and consequences of ontology as well as to detect any logical errors.

### Reasoning and Inference

Ontologies are used to describe the concepts in the domain and also the relationships among those concepts [21]. The OWL ontology consists of *classes*, *properties*, and *individuals* [22]. We have modelled SLOGD semiautomatically and verified its semantic and syntactical consistency using OWL reasoners such as *Pellet* and *Jena* reasoners. We also used the SWRL to encode the different relationships. Some of these relationships are shown in Equations (1) and (2), which represent the fact that the *Datasets belong to Category* and *Category is related To Organization*. Thus, we can infer that the *Organization is owner of Datasets*. *Organization include\_category* and *Category include\_Dataset*. Thus, we can infer that the *Datasets has\_Owner Organization include\_Category*, which is shown in Equation (2). Without the inferencing power of the OWL, the machine has no way of understanding these relations and restrictions between classes.

$$\text{Datasetss}(?d) \wedge \text{belong\_to\_Category} (?d, ?c) \wedge \text{related\_To\_Org} (?c, ?o) \rightarrow \text{owner\_Of} (?o, ?d) \quad (1)$$

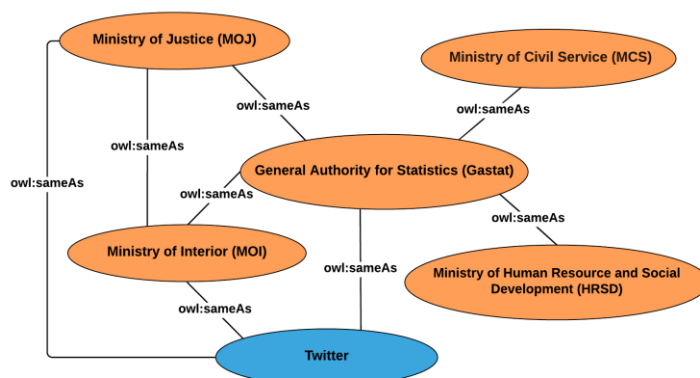
$$\text{Organization} (?o) \wedge \text{include\_Category} (?o, ?c) \wedge \text{include\_Dataset} (?c, ?d) \rightarrow \text{has\_Owner} (?d, ?o). \quad (2)$$

## 5. Saudi Linked Open Government Data Cloud (SLOGDC)

The five-star open data model promotes the publishing of open data using linked data principles such as publication of data in RDF format and integration of data into linked data web [9]. We made use of the best practices of LOD to link related datasets within the SLOGDC from different data sources in different domains such as *General Authority for Statistics*, *Ministry of Interior*, *Ministry of Labour and Social Development*, *Ministry of Justice*, *Ministry of education*, and *Twitter*. As an example, the LOD Cloud contains 1234 datasets and 16,136 links from various domains [23]. Some of these datasets can be accessed through SPARQL endpoint, which is a way to retrieve and publish data [24]. In order to link our SOGD to one another, we represented SOGD using semantic web technologies such as RDF, triples, URIs, and OWL as explained in the previous section. The URIs are used to describe resources; a triple has the form subject-predicate-object [25].

To create SLOGDC, we identified relationships and possible links between data entities from different data sources to link these entities together using different interlinking approaches. These approaches enable access and are used to retrieve related and detailed information. The interlinking approaches result in the SLOGDC as shown in Figure 5, which includes different interlinked data sources in different domains and ministries. We examined the properties of the datasets to determine links based on certain conditions. In our SLOGDC datasets, there are three types of links between datasets. The first type of link is the links between datasets that belong to the same organization; this link will establish if the number of same or similar properties between two datasets is one or more and also if the two datasets belong to the same organization. The second type of links are links between datasets that belong to different organizations; this link will establish if the number of same or similar properties between two datasets is one or more and also if the two datasets belong to different organizations. The third type of links are links between SLOGD and other existing open datasets; this link will establish if the number of same or similar properties between two datasets is one or more. So, there are many technologies to link resources such as machine learning, natural language processing (NLP), entity disambiguation. In addition, there are other tools with these technologies to link resources among multiple knowledge bases such as SILK, LINES, and Linked Data Integration Framework (LDIF). These datasets were extracted, produced,

and linked during different stages of this project, which resulted in gradual growth and expansion of these interlinked datasets as SLOGDC. However, the SPARQL Endpoint was available to perform different SPARQL queries to this cloud of Saudi Open Data as well as other open datasets to which SOD is linked. Table 2 lists the datasets and number of links between these datasets.



**Figure 5.** Saudi Linked Open Government Data Cloud (SLOGDC).

**Table 2.** Number of links between datasets in Saudi Linked Open Government Data Cloud (SLOGDC) in the perspective of our case study (i.e., women driving).

| Dataset      | Link Count  | Dataset          |
|--------------|-------------|------------------|
| GaStat       | 172         | HRSD, MCS        |
| MOJ          | 52          | GaStat           |
| MOI          | 91          | MOJ              |
| MOI          | 182         | GaStat           |
| Twitter      | 600         | GaStat, MOJ, MOI |
| <b>Total</b> | <b>1097</b> |                  |

## 6. Saudi Linked Open Government Data (SLOGD) SPARQL Endpoint

The SPARQL endpoint is a way to access and query SLOGDC. In this section, we describe the SLOGD SPARQL endpoint for querying the SLOGDC, which includes different datasets. We made use of SLOGDC to query different factors in different domains such as *the issued driving license, accidents, violations, job statistics, education, marital status, household income, and social or public impact/response to woman driving in Saudi Arabia*. Besides the SPARQL (RDF query language) queries, in the next section, we present the quantitative and qualitative analyses of the resulting data.

In this section, we also provide an evaluation of our SGO and the quality of SLOGDC by executing SPARQL queries through SPARQL endpoint. Thus, we created 20 competency questions to be answered by the knowledge base some of which are shown in Table 3. These questions were created in accordance with the case study in this paper. The SPARQL queries executed for each defined question in Table 3. Figure 6 shows the query for the question Q1, e.g., find the number of driving licenses issued in different regions of Saudi Arabia in a year wise pattern from SLOGDC. In addition, Figure 7 shows the results of the SPARQL query and shows the number of driving licenses issued in different regions of Saudi Arabia during the years 2017 and 2018.

**Table 3.** Competency questions for Saudi Government Linked Open Data Cloud (SLOGDC).

| Query | Competency Question                                                          |
|-------|------------------------------------------------------------------------------|
| Q1    | Find the number of driving licenses in Saudi Arabia per region and per year. |
| Q2    | Find the number of accidents and violations in Saudi Arabia per              |

|    |                                                                                                                                                                  |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | region and per year.                                                                                                                                             |
| Q3 | Find the job statistics such as the total employed, the rate of employed, the job seekers, and the rate of unemployment in Saudi Arabia per region and per year. |
| Q4 | What are the people's opinions and how they react to the women driving in social media, e.g., Twitter.                                                           |
| Q5 | Find the number divorce documents and marriage contracts in Saudi Arabia per region and per year.                                                                |
| Q6 | Find the average monthly income of household per region, per year, and per marital status.                                                                       |
| Q7 | Find the population of high education per region.                                                                                                                |

```

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-61#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT ?Region_name ?year ?Number_of_Driving_License
WHERE {
  ?Data_Entry rdf:type MOI:Driving_Licenses;
  MOI:has_Region ?Region;
  MOI:year ?year;
  MOI:number_of_driving_license ?Number_of_Driving_License.
  ?Region rdf:type MOI:Region;
  rdfs:label ?Region_name.
}

```

Figure 6. SPARQL query for Q1 in Table 3.

|    | Region_name             | year               | Number_of_Driving_License |
|----|-------------------------|--------------------|---------------------------|
| 1  | Tabouk                  | "2017""xsd:integer | "10232""xsd:integer       |
| 2  | Jazan                   | "2018""xsd:integer | "12265""xsd:integer       |
| 3  | Eastern Region          | "2017""xsd:integer | "126816""xsd:integer      |
| 4  | Eastern Region          | "2018""xsd:integer | "131639""xsd:integer      |
| 5  | Najran                  | "2017""xsd:integer | "13825""xsd:integer       |
| 6  | MakkahAl-Mokarramah     | "2017""xsd:integer | "142487""xsd:integer      |
| 7  | MakkahAl-Mokarramah     | "2018""xsd:integer | "144873""xsd:integer      |
| 8  | Jazan                   | "2017""xsd:integer | "18345""xsd:integer       |
| 9  | Hail                    | "2017""xsd:integer | "22035""xsd:integer       |
| 10 | Aseer                   | "2018""xsd:integer | "22362""xsd:integer       |
| 11 | Al-Madinah Al-Monawarah | "2018""xsd:integer | "23335""xsd:integer       |
| 12 | Al-Baha                 | "2018""xsd:integer | "2575""xsd:integer        |
| 13 | Al-Madinah Al-Monawarah | "2017""xsd:integer | "36165""xsd:integer       |
| 14 | NorthernBorders         | "2018""xsd:integer | "3661""xsd:integer        |
| 15 | Aseer                   | "2017""xsd:integer | "39133""xsd:integer       |
| 16 | Hail                    | "2018""xsd:integer | "39575""xsd:integer       |
| 17 | Al-Baha                 | "2017""xsd:integer | "4131""xsd:integer        |
| 18 | Al-Qaseem               | "2018""xsd:integer | "4457""xsd:integer        |
| 19 | Al-Riyadh               | "2018""xsd:integer | "493224""xsd:integer      |
| 20 | Al-Riyadh               | "2017""xsd:integer | "495307""xsd:integer      |
| 21 | NorthernBorders         | "2017""xsd:integer | "5280""xsd:integer        |
| 22 | Al-Qaseem               | "2017""xsd:integer | "6318""xsd:integer        |
| 23 | Al-Jouf                 | "2018""xsd:integer | "6834""xsd:integer        |
| 24 | Najran                  | "2018""xsd:integer | "7431""xsd:integer        |
| 25 | Tabouk                  | "2018""xsd:integer | "7613""xsd:integer        |
| 26 | Al-Jouf                 | "2017""xsd:integer | "8091""xsd:integer        |

**Figure 7.** Results of SPARQL query shown in Figure 6.

In addition to this, we also performed some other SPARQL queries through SLOGD SPARQL Endpoint to evaluate the quality of SLOGDC. Figure 8 and Figure 9 show another query and the results of this query from SLOGDC datasets are shown in Figure 10. This query retrieved data from different datasets that are interlinked with each other as SLOGDC. The queries shown in Figure 8 are related to the public's response to women's driving in Saudi Arabia according to a variety of factors.

The query shown in Figure 8a identifies the number of driving licenses issued in the Saudi Arabian regions in the years 2017 and 2018 to find the top three regions with the highest number of issued driving licenses in Saudi Arabia by retrieving the parameters of issued driving licenses in each region in Saudi Arabia in year-wise pattern. In the same manner, the query in Figure 8b for question Q2 identifies the number of accidents and the number of violations in different Saudi Arabian regions in the year 2018. The results of this query show the regions that have the highest number of accidents and violations in Saudi Arabia. It also retrieved results in combination of different parameters such as region and the number of accidents and violations in each region. Figure 8c shows the query for the question Q3, e.g., identify job statistics such as the total employed, the rate of employed, the job seekers, and the rate of unemployment in Saudi Arabia per region in year 2017–2018 to find the relationship between the women's driving and other factors such as employed females, rate of employed females, female job seekers, and rate of unemployed females. It

retrieves parameters such as the total number of employed females, rate of employed females, and rate of unemployed females.

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-61#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT ?Region_name ?year ?Number_of_Driving_License
WHERE {
  ?Data_Entry rdf:type MOI:Driving_Licenses;
  MOI:has_Region ?Region;
  MOI:year ?year;
  MOI:number_of_driving_license ?Number_of_Driving_License.
  ?Region rdf:type MOI:Region;
  rdfs:label ?Region_name.
}
```

(a)

```
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-61#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT ?Region_name ?Number_of_Accidents ?Number_of_Violations
WHERE {
  ?Data_Entry1 rdf:type MOI:Traffic_Accidents;
  MOI:has_Region ?Region;
  MOI:year 2018;
  MOI:number_of_Accident ?Number_of_Accidents.
  ?Data_Entry2 rdf:type MOI:Traffic_Violations;
  MOI:has_Region ?Region;
  MOI:year 2018;
  MOI:number_of_Violations ?Number_of_Violations.
  ?Region rdf:type MOI:Region;
  rdfs:label ?Region_name.
}
```

(b)

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX GaStat: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-62#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/2020/8/untitled-ontology-60#>
PREFIX MOJ: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-64#>

SELECT ?Total_Female_Employed_Persons ?Total_Female_Employment_Rate ?Total_Female_Unemployment_Rate ?
Saudi_Female_Job_Seekers
WHERE {
  ?Data_Entry rdf:type GaStat:Labor_Market;
  GaStat:total_Female_Employed_Persons ?Total_Female_Employed_Persons;
  GaStat:total_Female_Employment_Rate ?Total_Female_Employment_Rate;
  GaStat:total_Female_Unemployment_Rate ?Total_Female_Unemployment_Rate;
  GaStat:saudi_Female_Job_Seekers ?Saudi_Female_Job_Seekers;
  GaStat:year 2018.
}
```

(c)

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX TDS: <http://www.semanticweb.org/afnan/ontologies/2020/1/untitled-ontology-50#>
PREFIX SLOGD: <http://www.semanticweb.org/afnan/ontologies/2019/10/untitled-ontology-49#>

SELECT ?Retweeted_Tweets ?Original_User ?Retweeted_By
WHERE {
  ?Retweeted_Tweets TDS:original_user ?Original_User;
  TDS:retweeted_by ?Retweeted_By.
}
```

(d)

**Figure 8.** Sample of queries: (a) driving licenses issued per region, (b) accidents and violations per region, (c) job statistics, and (d) retweeted tweets.

Similarly, Figure 8d shows the query for question Q4, i.e., identify the public response and reactions on Twitter after the decision to allow women to drive in Saudi Arabia. This query retrieved parameters such as *retweeted tweets*, *hashtags*, *people's tweets*, and *rate of tweets* of Saudi woman driving in *per hour*, *per day*, and *per minute* patterns. In addition, the query in Figure 9a is related to Q5 in Table 3, namely, identify the marital status such as divorce and married women in different Saudi Arabian regions in the year 2018 to find the top regions that have highest number of divorce documents and marriage contracts. It retrieved the data based on different parameters, for instance, the number of divorce documents and marriage contracts for each region and their relation to the number of driving licenses issued to drivers in these regions. Similarly, the query in Figure 9b corresponds to question Q6 (identify the average monthly income of household per region and per marital status in 2018). This resulted in data about marital status and the household incomes per marital status and per region. Moreover, another factor (i.e., education) that can influence the decision of women to drive is considered in the query (as shown in Figure 9c) for question Q7. This query identifies the population per educational status and per region to find the relationship between the factors of education and women's driving. Some samples of the results retrieved from the previous queries are shown in Figure 10. Figure 10a shows the number of accidents and the number of violations per region of Saudi Arabia. Figure 10b shows the Twitter user's information such as user name, location, and tweets count, whereas the results of number of marriage contracts and divorce documents per regions of Saudi Arabia are shown in Figure 10c. Figure 10d shows results of household income of divorced and married people region wise in Saudi Arabia. The statistics that we got as a response to these queries were generated only after producing the Open

Data and linking these open datasets with one another, which might not have been possible without creating the SLOGDC.

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX GaStat: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-62#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/2020/8/untitled-ontology-60#>
PREFIX MOJ: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-64#>

SELECT ?Region_name ?Number_of_Marriage_Contracts ?Number_of_Divorce_Documents
WHERE {
    ?Data_Entry1 rdf:type MOJ:Divorce_Documents_Marriage_Contracts_Region;
                MOJ:has_Region ?Region;
                MOJ:number_of_Marriage_Contracts ?Number_of_Marriage_Contracts;
                MOJ:number_of_Divorce_Documents ?Number_of_Divorce_Documents.
    ?Region rdf:type MOJ:Region;
            rdfs:label ?Region_name.}
```

(a)

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX GaStat: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-62#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/2020/8/untitled-ontology-60#>
PREFIX MOJ: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-64#>

SELECT ?Region ?Married_Income ?Divorced_Income
WHERE {
    ?Data_Entry1 rdf:type GaStat:Household_Income;
                GaStat:has_Region ?Region;
                GaStat:married_Income ?Married_Income;
                GaStat:divorced_Income ?Divorced_Income.}
```

(b)

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX GaStat: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-62#>
PREFIX SGO: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-59#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX MOI: <http://www.semanticweb.org/afnan/ontologies/2020/8/untitled-ontology-60#>
PREFIX MOJ: <http://www.semanticweb.org/afnan/ontologies/untitled-ontology-64#>

SELECT ?Region ?Number_educational_Status_Bachelors
WHERE {
    ?Data_Entry1 rdf:type GaStat:Educational_Status_Region;
                GaStat:has_Region ?Region;
                GaStat:educational_Status_Bachelors ?Number_educational_Status_Bachelors.
    ?Region rdf:type GaStat:AdministrativeArea;
            rdfs:label ?Region_name. }
```

(c)

**Figure 9.** Sample of queries: (a) divorced and married in different per region, (b) income of household per region, and (c) educational status per region.

|    | Region_name             | Number_of_Accidents     | Number_of_Violations    |
|----|-------------------------|-------------------------|-------------------------|
| 1  | Al-Riyadh               | "77884"^^xsd:integer    | "12347822"^^xsd:integer |
| 2  | Jazan                   | "19572"^^xsd:integer    | "541"^^xsd:integer      |
| 3  | Najran                  | "3124"^^xsd:integer     | "5454"^^xsd:integer     |
| 4  | Al-Baha                 | "1764"^^xsd:integer     | "567"^^xsd:integer      |
| 5  | Al-Jouf                 | "7355.0"^^xsd:integer   | "566"^^xsd:integer      |
| 6  | Makkah Al-Mokarramah    | "103973.0"^^xsd:integer | "848565"^^xsd:integer   |
| 7  | Al-Madinah Al-Monawarah | "20549"^^xsd:integer    | "12233"^^xsd:integer    |
| 8  | Al-Qassim               | "17512"^^xsd:integer    | "26563"^^xsd:integer    |
| 9  | Eastern Region          | "65077"^^xsd:integer    | "673059"^^xsd:integer   |
| 10 | Asseer                  | "25944"^^xsd:integer    | "8813"^^xsd:integer     |
| 11 | Tabouk                  | "10334"^^xsd:integer    | "6326"^^xsd:integer     |
| 12 | Hail                    | "6955"^^xsd:integer     | "2100"^^xsd:integer     |
| 13 | Northern Borders        | "10709"^^xsd:integer    | "2752"^^xsd:integer     |

(a)

| Twitter_Users                       | Location                         | tweetsCount |
|-------------------------------------|----------------------------------|-------------|
| untitled-ontology-50:AbulazizQntba  | untitled-ontology-50:Dammam      | 56525       |
| untitled-ontology-50:AbulazizQntba  | untitled-ontology-50:Ar-Riyadh   | 1923        |
| untitled-ontology-50:FahadAlMalah   | untitled-ontology-50:Ar-Riyadh   | 3881        |
| untitled-ontology-50:JOKE1          | untitled-ontology-50:مكة المكرمة | 79071       |
| untitled-ontology-50:ShadyElDewaid  | untitled-ontology-50:جدة         | 169         |
| untitled-ontology-50:THEMAN         | untitled-ontology-50:Ar-Riyadh   | 26          |
| untitled-ontology-50:Zhai           | untitled-ontology-50:جدة         | 1763        |
| untitled-ontology-50:mohammedAlakwi | untitled-ontology-50:جدة         | 647         |
| untitled-ontology-50:yahya          | untitled-ontology-50:jeddah      | 3073        |
| untitled-ontology-50:نسيف           | untitled-ontology-50:Ar-Riyadh   | 5184        |
| untitled-ontology-50:أولياء         | untitled-ontology-50:Ar-Riyadh   | 34900       |
| untitled-ontology-50:هشامالحميدي    | untitled-ontology-50:Ar-Riyadh   | 776         |
| untitled-ontology-50:ألفان          | untitled-ontology-50:Ar-Riyadh   | 809         |

(b)

| Region_name               | Number_of_Marriage_Contracts | Number_of_Divorce_Documents |
|---------------------------|------------------------------|-----------------------------|
| 1 Al-Riyadh               | "30296"^^xsd:integer         | "12807"^^xsd:integer        |
| 2 Jazan                   | "8699"^^xsd:integer          | "2434"^^xsd:integer         |
| 3 Najran                  | "3358"^^xsd:integer          | "1044"^^xsd:integer         |
| 4 Al-Baha                 | "2472"^^xsd:integer          | "726"^^xsd:integer          |
| 5 Al-Jouf                 | "3598"^^xsd:integer          | "567"^^xsd:integer          |
| 6 Makkah Al-Mokarramah    | "41114"^^xsd:integer         | "8593"^^xsd:integer         |
| 7 Al-Madinah Al-Monawarah | "10709"^^xsd:integer         | "4069"^^xsd:integer         |
| 8 Al-Qassim               | "7399"^^xsd:integer          | "3058"^^xsd:integer         |
| 9 Eastern Region          | "18587"^^xsd:integer         | "7781"^^xsd:integer         |
| 10 Asseer                 | "13031"^^xsd:integer         | "5662"^^xsd:integer         |
| 11 Tabouk                 | "4165"^^xsd:integer          | "5005"^^xsd:integer         |
| 12 Hail                   | "4122"^^xsd:integer          | "5655"^^xsd:integer         |
| 13 Northern Borders       | "2327"^^xsd:integer          | "923"^^xsd:integer          |

(c)

| Region                 | Married_Income                    | Divorced_Income                   |
|------------------------|-----------------------------------|-----------------------------------|
| 1 GaStat.Riyadh        | "13017.773659953005"^^xsd:integer | "12457.179895304813"^^xsd:integer |
| 2 GaStat.Jazan         | "13810.444587911466"^^xsd:integer | "11576.22056060336"^^xsd:integer  |
| 3 GaStat.Najran        | "9075.865435805643"^^xsd:integer  | "7235.456053812368"^^xsd:integer  |
| 4 GaStat.AL-Baha       | "12272.182188420493"^^xsd:integer | "8997.18624484923"^^xsd:integer   |
| 5 GaStat.AL-Jouf       | "12053.14625979171"^^xsd:integer  | "7733.53136164798"^^xsd:integer   |
| 6 GaStat.Makkah        | "12039.569148523864"^^xsd:integer | "10684.850695794302"^^xsd:integer |
| 7 GaStat.Madinah       | "10243.679034295346"^^xsd:integer | "5112.066279301641"^^xsd:integer  |
| 8 GaStat.Qassim        | "12258.959419392491"^^xsd:integer | "11822.56250561427"^^xsd:integer  |
| 9 GaStat.Easte.Prov.   | "15603.420374882264"^^xsd:integer | "14960.39579058623"^^xsd:integer  |
| 10 GaStat.Asir         | "10370.297080239538"^^xsd:integer | "6611.062578410481"^^xsd:integer  |
| 11 GaStat.Tabuk        | "9697.89555629606"^^xsd:integer   | "8433.424054838408"^^xsd:integer  |
| 12 GaStat.Hail         | "10063.176039416772"^^xsd:integer | "6707.47038937745"^^xsd:integer   |
| 13 GaStat.Nor.th.Bord. | "11213.668153269988"^^xsd:integer | "13269.056216206463"^^xsd:integer |

(d)

**Figure 10.** Sample of results: (a) accidents and violations per region, (b) Twitter user's information, (c) marriage contracts and divorced documents, and (d) the household income per region.

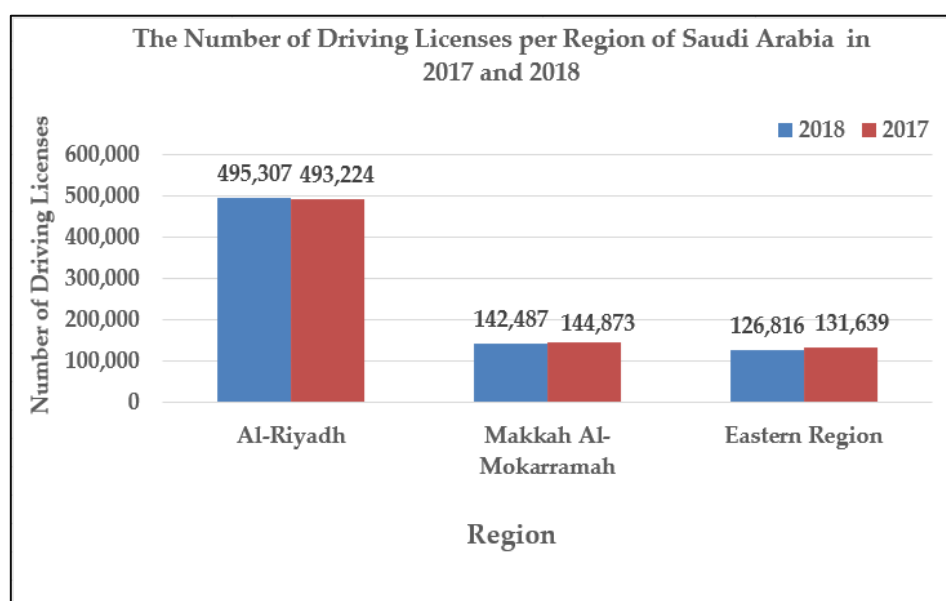
## 7. Analysis of Case Study

The decision to allow women to drive was taken in the wake of the Saudi government's ambitious reforms and in line with the government's determination to deliver the economic diversity and opportunity outlined in vision 2030 of the Saudi Arabian government. The country's plan includes an aim to increase female participation in the workforce from 22% to 30% by 2030. Taking this aspect of the Vision 2030 as a case study for our work, we used the SLOGDC to query different factors in different domains such as *the issued driving license, accidents, violations, job statistics, education, marital status, household Expenditure and household income, and social or public impact/response to find factors that influence the woman driving in Saudi Arabia*. The purpose was to demonstrate the role and contribution of Linked Open Data-oriented sustainable systems by analyzing the public's response to the decision to allow women to drive in the country and to refine the government policies accordingly. In this section, we present the qualitative and quantitative analyses of SLOGDC by analyzing the result of SPARQL queries that we discussed in previous section. The results of integrated and interlinked datasets enabled us to do a comprehensive analysis to get new insights into the public response to women's driving in Saudi Arabia, suggesting directions for future policies and decisions by decision-makers. We analyzed the results of SPARQL queries based on different factors and parameters that are described below.

### 7.1. Issued Driving Licenses

From the results and queries shown in the previous section, we can identify the number of driving licenses issued in 2017 and 2018 within different regions of Saudi Arabia. We can conclude that the top three regions with the greatest number of issued driving licenses in Saudi Arabia include the *Riyadh region, Makkah Al-Mokarramah region, and the Eastern region* (Figure 11). Moreover, we can observe that there is rapid increase in the number of driving licenses issued in these regions during the period of 2017 to 2018. The *Riyadh region* issued the most driving licenses (495,307 in 2017

and 493,224 in 2018) and when compared with different regions in Saudi Arabia, the issuing of licenses increased from 2017 to 2018. In terms of the number of licenses issued, Riyadh is followed by *Makkah Al-Mokarramah region*, which also has a high number of issued driving licenses (142,487 in 2017 and 144,873 in 2018) amongst different regions in Saudi Arabia. The *Eastern region* also issued the third highest number of driving licenses (126,816 in 2017 and 131,639 in 2018) to drivers. In addition to this, the number of issued driving licenses in other regions in Saudi Arabia are as follows: *Assir region* (39,133 in 2017 and 22,362 in 2018), *Madinah region* (36,165 in 2017 and 23,335 in 2018), *Hail region* (22,035 in 2017 and 39,575 in 2018), *Jazan region* (18,345 in 2017 and 12,265 in 2018), *Najran region* (13,825 in 2017 and 7431 in 2018), *Tabouk region* (10,232 in 2017 and 7613 in 2018), *Al-Jouf region* (8091 in 2017 and 6834 in 2018), *Al-Qaseem region* (6318 in 2017 and 4457 in 2018), *Northern Border region* (5280 in 2017 and 3661 in 2018), and *Al-Baha region* (4131 in 2017 and 2575 in 2018). The graph in Figure 11 presents a comparison between the numbers of driving licenses issued in various regions of Saudi Arabia in 2017 and 2018.



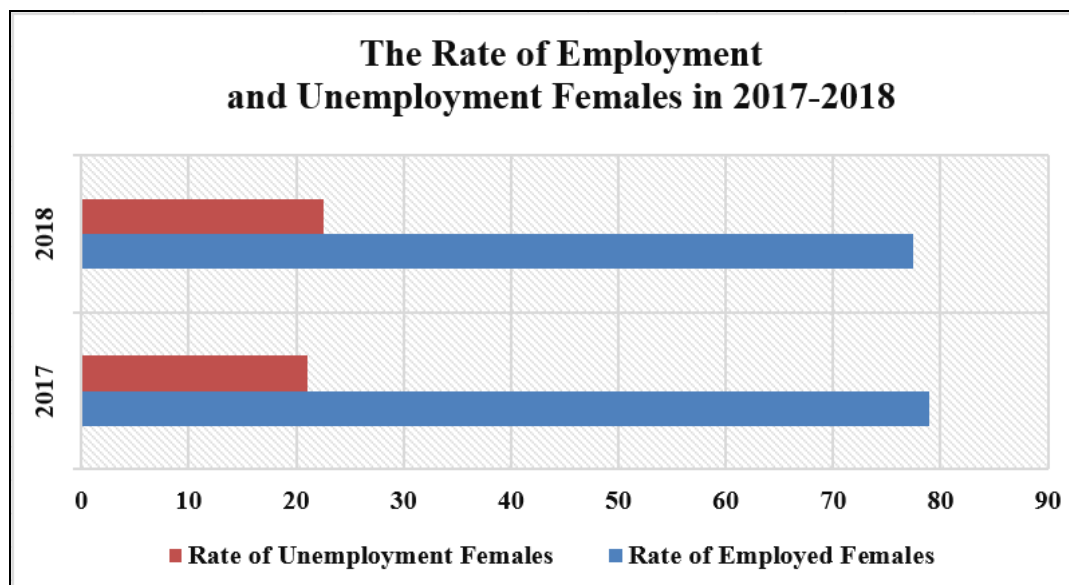
**Figure 11.** The number of driving licenses issued in different regions of Saudi Arabia during the years 2017 and 2018.

In addition, based on Figure 11, we can conclude the following. First, the top three regions that issued the highest number of driving licenses in Saudi Arabia are Riyadh region, Makkah Al-Mokarramah region, and the Eastern region, thus showing a reasonable increase subsequent to the decision to allow women to drive. Second, we can also observe that the issue of driving licenses increased in these top three regions from 2017 to 2018. Third, besides the top three regions, *Hail region* also show an increase in the number of driving licenses issued from 2017 to 2018.

## 7.2. Job Statistics

Using the SLOGDC, we were able to identify the relationships between women's driving and other factors such as *employed females*, *rate of employed females*, *female job seekers*, and *rate of unemployment females*, which would not have been possible without linking these different datasets together. From the results retrieved and queries shown in the previous section, we can identify the total employed females, rate of employed females, female job seekers, and rate of unemployment females in 2017 and 2018 in Saudi Arabia. Allowing the woman to drive is likely to lead to an increase in the number of women seeking jobs, in addition to increasing the size of the workforce and lifting the overall income and output. So, in 2017, the total employed females were 2,058,377, with a 78.9% employment rate, which is the number of employed persons in the labor force, and a 21.1% unemployment rate, which is the number of unemployed persons in the labor force. The

female job seekers were 911,248. In 2018, the total employed females numbered 2,142,933. The female employment rate, which is the number of employed persons in the labor force for females, was 77.4%, and the unemployment rate, which is the number of unemployment persons in the labor force for females, was 22.6%, whereas the female job seekers were 797,842. The graph in Figure 12 compares the rate of employment and unemployment for females in 2017 and 2018.

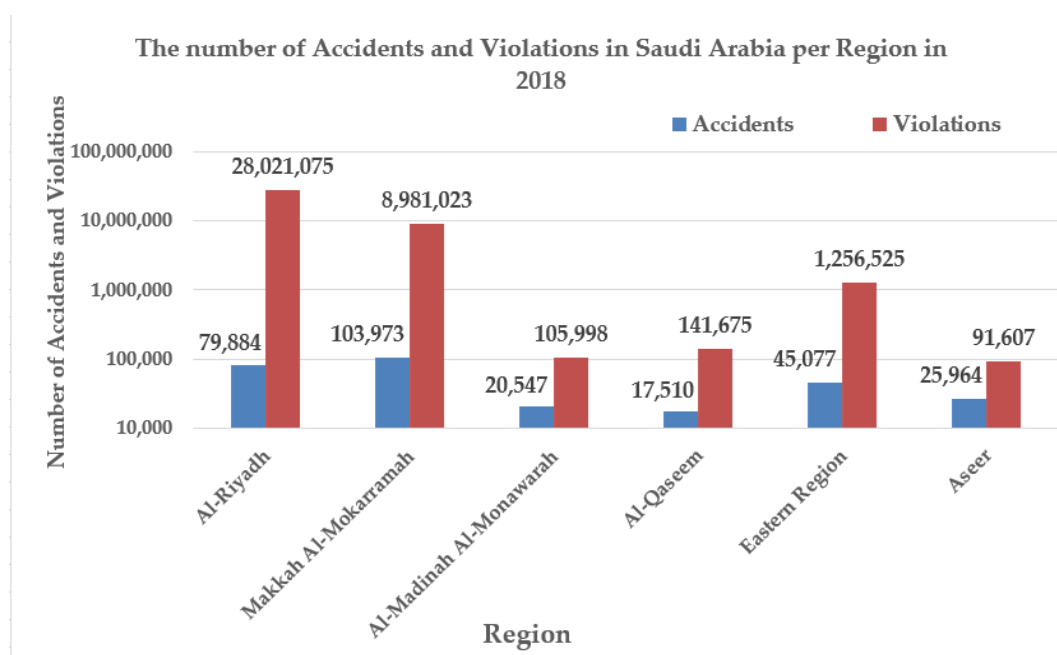


**Figure 12.** The rate of employed and unemployed females in 2017–2018 in Saudi Arabia.

Based on Figure 12 and the statistics that have been discussed, we can conclude the following. First, after the decision to allow women to drive, the total number of employed females increased from 2017 to 2018. Second, as the number of employed females increased in 2018, the total female job seekers decreased in 2018. Finally, the difference between the female unemployment rates in 2017 and 2018 is close, just as the difference between the female employment rates in 2017 and 2018.

### 7.3. Accidents and Violations

The datasets we extracted and interlinked as SLOGDC from different government bodies helped us to get more meaningful information related to women's driving such as *the number of accidents and the number of violations*. These results predict the initial impact of this decision on public and social aspects of the country. The results show that the increase in number of issued driving licenses in Saudi Arabian regions also resulted in an increased number of accidents and the number of violations in that region. For example, the three regions with the highest number of driving licenses issued in Saudi Arabia (i.e., *Riyadh region, Makkah Al-Mokarramah region, and Eastern Region*) recorded the highest ratio of accidents as well as violations. The results show that the number of accidents reported in the *Riyadh region* were 79,884 in 2018 and the number of violations comprised 28,021,075 in 2018. This was followed by *Makkah Al-Mokarramah region* where the number of accidents reported were 103,973 in 2018 and the number of violations numbered 8,981,023 in 2018. In the *Eastern Region*, the number of accidents reported were 45,077 in 2018 and the number of violations reported were 1,256,525 in 2018. The number of accidents reported in the other regions in Saudi Arabia were as follows: *Assir region* 25,964, *Madinah region* 20,547, *Jazan region* 19,572, *Al-Qaseem region* 17,510, *Northern Boarder* 10,705, *Tabouk* 10,034, *Al-Jouf* 7355, *Hail region* 6955, *Najran region* 3124, and *Al-Baha region* 1764. Additionally, the number of violations in the other regions in Saudi Arabia were as follows: *Al-Qaseem region* 141,675, *Madinah region* 105,998, *Assir region* 91,607, *Najran region* 64,743, *Hail region* 48,319, *Tabouk* 32,342, *Northern Boarder* 18,646, *Jazan region* 18,511, *Al-Jouf* 17,367, and *Al-Baha region* 7479. The graph in Figure 13 presents a comparison between the number of number of accidents and the number of violations in the regions of Saudi Arabia in 2018.



**Figure 13.** The number of number of accidents and the number of violations in regions of Saudi Arabia in 2018.

Moreover, based on Figure 13, we can conclude the following. First, the number of accidents and the number of violations also increased in the same top three regions with the greatest number of driving licenses issued in Saudi Arabia (*Riyadh region, Makkah Al-Mokarramah region, and Eastern Region*). Second, we also observe that there is a noticeable difference between the number of accidents and the number of violations in most of regions in Saudi Arabia. Third, in most of the regions in Saudi Arabia, the number of violations exceeded the number of the accidents. Finally, it is also evident that the number of accidents and the number of violations in *Jazan region* are close, and unlike the other regions in Saudi Arabia in *Jazan region*, the number of accidents exceed the number of violations.

#### 7.4. Social Media

The social media acts as a platform that facilitates the way people communicate, interact, and engage in exercising their influence by sharing their opinions, views, and experiences. Based on the results retrieved and queries shown in the previous section, after the decision to allow women to drive, the public response and reactions on Twitter showed the spectrum of public reactions to this decision. In the SLOGDC, we interlinked the different official data entities such as *number of driving licenses issued in Saudi Arabian regions, the number of accidents, number of violations, number of divorce documents and marriage contracts in Saudi Arabian regions with the public and social media parameters such as tweets from the Twitter, used hashtags, users' locations, people options through their tweets, and retweeted tweets*. The results from such diverse interlinked data sources led us to capture the societal reaction to government policies and decision through their retweeted tweets from different channels and news accounts that announced the decision, which are the original users of these retweeted tweets. As an example, from Twitter, we can see that many users retweeted tweets such as:

Urgent the Decision to allow women to drive in Saudi Arabia King Salman Granted Women the Right to Drive , A royal decree approving the application of the provisions of the traffic system, including the issuance of driving licenses to both males and females King Salman Granted Women the Right to Drive , and Urgent officially allowing women to drive a car in Saudi Arabia.

Also, these retweeted tweets were originally tweeted by different channels and news accounts such as *SaudiNews50, KSA24, Sabq.org, Al Eqtisadiah, and eastern\_RT*. In addition to retweeted tweets we can also identify the opinions of people through their tweets. Some of these tweets are:

Finally, King Salman Granted Women the Right to Drive, Congratulations King Salman Granted Women the Right to Drive, and the best news King Salman Granted Women the Right to Drive.

These tweets show support for the government's decision to allow women to drive which is why they tweeted positively about it. In addition to this, most users from *Riyadh region*, *Makkah region*, *Al-Qaseem region*, and *Madinah region* tweeted and retweeted about the decision to allow women to drive. In addition, these users used hashtags related to this decision and supported it as below:

Saudi Women Can Drive, allow women to drive, Congratulations to the Saudi Woman, Saudis welcoming the Woman's driving, King Salman Granted Women the Right to Drive, and The Saudi Women driving.

Table 4 summarizes some of these retrieved results.

**Table 4.** Sample of retrieved results about positive public reaction on Twitter about the decision to allow women to drive.

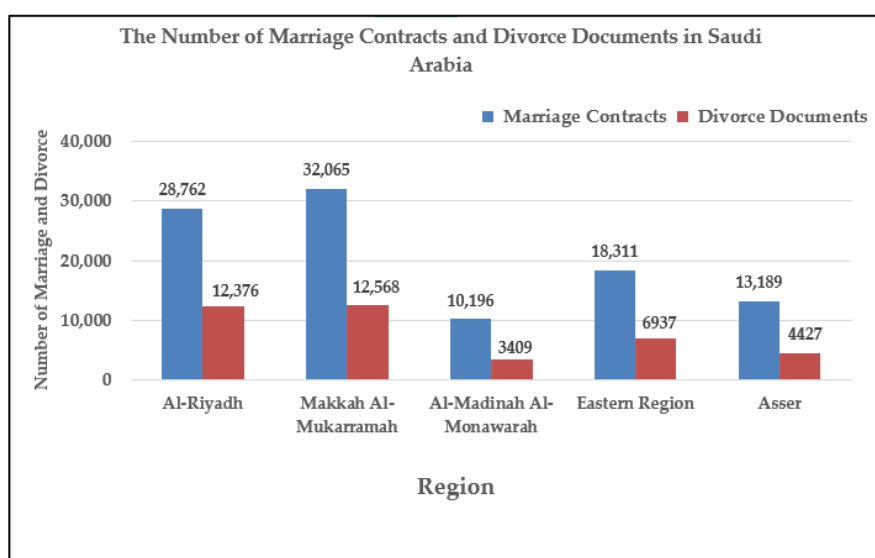
| Retweeted Tweets                                                                                                                                                                                    | Original Users | User's Tweets                                                | User's Location | Hashtags                                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------------------------------------------------|-----------------|----------------------------------------------|
| Urgent the Decision to allow women to drive in Saudi Arabia King Salman Granted Women the Right to Drive                                                                                            | SaudiNews 50   | Finally, King Salman Granted Women the Right to Drive        | Riyadh          | Allow women to drive                         |
| A royal decree approving the application of the provisions of the traffic system, including the issuance of driving licenses to both males and females King Salman Granted Women the Right to Drive | Sabq.org       | Congratulations King Salman Granted Women the Right to Drive | Makkah          | King Salman Granted Women the Right to Drive |
| Urgent officially allowing women to drive a car in Saudi Arabia                                                                                                                                     | Al Eqtisadiah  | the best news King Salman Granted Women the Right to Drive   | Al-Qaseem       | Congratulations to the Saudi Woman           |

Based on the discussion of the previous results, we can conclude the following. First, we identified the opinions of different people and their reactions to the decision to allow women to drive through the tweets and retweeted tweets. Second, different channels and news accounts announcing this decision were the original users for most of retweeted tweets. Finally, most of the users who tweeted and retweeted about the decision to permit women to drive belonged to the *Riyadh region*, *Makkah region*, *Al-Qaseem region*, and *Madinah region*.

### 7.5. Marital Status

The analysis of results from SLOGDC showed that there was a strong relationship between the *marriage status* and the public's response to women's driving. For example, from the results that we retrieved from the queries shown in the previous section (i.e., Figure 9b), we can easily identify that

the number of marriage contracts and divorce documents also increased in the same top three regions with the highest number of issued driving licenses, the number of accidents, and the number of violations. These regions were the *Riyadh region*, the *Makkah Al-Mokarramah region*, and the *Eastern Region*. From the results, we can conclude that the marriage contracts numbered 30,296 in the *Riyadh region*, 41,114 in the *Makkah Al-Mokarramah region*, and 18,587 in the *Eastern Region*. The marriage contracts in the other regions in Saudi Arabia were as follows: *Assir region* 13,031, *Madinah region* 10,709, *Jazan region* 8696, *Al-Qaseem region* 7399, *Tabouk region* 4165, *Hail region* 4122, *Al-Jouf* 3528, *Najran region* 3358, *Al-Baha region* 2475, and *Northern Boarder* 2327. In addition, the number of divorce documents totaled 12,807 in the *Riyadh region*, 15,593 in the *Makkah Al-Mokarramah region*, and 7761 in the *Eastern Region*. The divorce documents in the other regions in Saudi Arabia were as follows: *Assir region* 4562, *Madinah region* 4089, *AL-Qaseem region* 3,058, *Jazan region* 2434, *Tabouk region* 2025, *Hail region* 1665, *Al-Jouf* 1362, *Najran region* 1044, *Northern Boarder* 923, and *Al-Baha region* 726. The graph in Figure 14 presents the number of marriage contracts and divorce documents in Saudi Arabia in 2018.



**Figure 14.** The number of marriage contracts and divorce documents in Saudi Arabia in 2018.

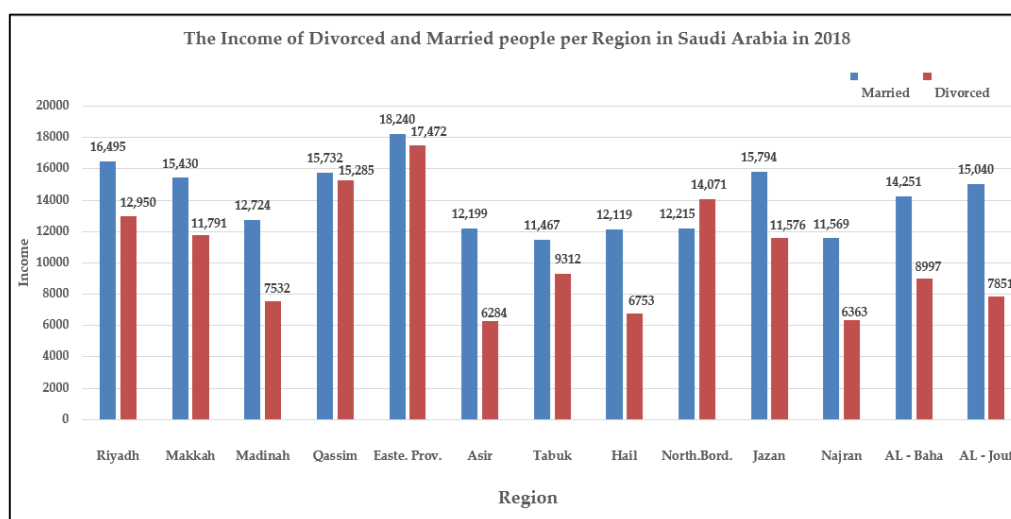
Moreover, based on Figure 14, we can conclude the following. First, the number of divorce documents and marriage contracts also increased in the same top three regions with the greatest number of issued driving licenses, the number of accidents, and the number of violations in Saudi Arabia. These regions were the *Riyadh region*, *Makkah Al-Mokarramah region*, and *Eastern Region*. Second, we observed that in the *Riyadh region* and the *Makkah Al-Mokarramah region*, the number of divorce documents exceeded 10,000. Finally, in most of regions in Saudi Arabia, the number of marriage contracts exceeded the number of divorce documents.

The query identified the marital status such as divorced and married in Saudi Arabia regions by identifying the number of divorce documents and marriage contracts in 2018. Therefore, we can also conclude that the number of marriage contracts and divorce documents also increased in the same top three regions, namely, the *Riyadh region*, the *Makkah Al-Mokarramah region* and the *Eastern Region*, wherein the greatest number of driving licenses had been issued, the number of accidents, and the number of violations in Saudi Arabia. From the results, we can conclude that the marriage contracts numbered 30,296 in the *Riyadh region*, 41,114 in the *Makkah Al-Mokarramah region*, and 18,587 in the *Eastern Region*. The marriage contracts in the other regions in Saudi Arabia were as follows: *Assir region* 13,031, *Madinah region* 10,709, *Jazan region* 8696, *Al-Qaseem region* 7399, *Tabouk region* 4165, *Hail region* 4122, *Al-Jouf* 3528, *Najran region* 3358, *Al-Baha region* 2475, and *Northern Boarder* 2327. In addition, the number of divorce documents totaled 12,807 in the *Riyadh region*, 15,593 in the *Makkah Al-Mokarramah region*, and 7761 in the *Eastern Region*. The divorce documents in the other regions in Saudi Arabia were as follows: *Assir region* 4562, *Madinah region* 4089, *AL-Qaseem region* 3,058, *Jazan*

region 2434, Tabouk region 2025, Hail region 1665, Al-Jouf 1362, Najran region 1044, Northern Boarder 923, and Al-Baha region 726. The graph in Figure 14 provides a comparison between the number of divorce documents and marriage contracts in Saudi Arabia per region in 2018.

### 7.6. Household Income

Another factor that can influence or affect the adoption of driving by women in Saudi Arabia is the “Household Income.” From the results retrieved (Figure 10d) and queries (Figure 9b) shown in the previous section, we can observe the comparative effect of the household income and marital status in different regions in Saudi Arabia. Additionally, the other factors such as the number of driving licenses issued in Saudi Arabia regions, people opinion and how they react to woman driving in Twitter, and the number of divorce documents, and marriage contracts in Saudi Arabia regions are present. These factors identified the top three regions with the greatest number of driving licenses issued and the increasing number of marriage contracts and divorce documents in Saudi Arabia, namely, the *Riyadh region*, the *Makkah Al-Mokarramah region*, and the *Eastern Region*. In addition to other factors such as issued driving licenses and the increasing number of marriage contracts and divorce documents, we observed from the results (Figure 10d) that the household income for divorced and married people also had high impact on the adoption of women’s driving in regions with the greatest number of issued driving licenses, the number of accidents, and the number of violations, and the increasing number of marriage contracts and divorce documents in Saudi Arabia. The results also showed the comparative impact of household income on divorced and married people in the top three regions. So, in the *Riyadh region*, the household income for divorced people was 12,950 RS, whereas the household income for married people was 16,495 RS and in *Makkah Al-Mokarramah region*, the household income for divorced people was 11,790 RS, whereas the household income for married people was 15,430 RS. Finally, in the *Eastern region*, the household income for divorced people was 17,472 RS, whereas the household income for married people was 18,240 RS. The graph in Figure 15 compares the household income of divorced and married people per region in Saudi Arabia in 2018.



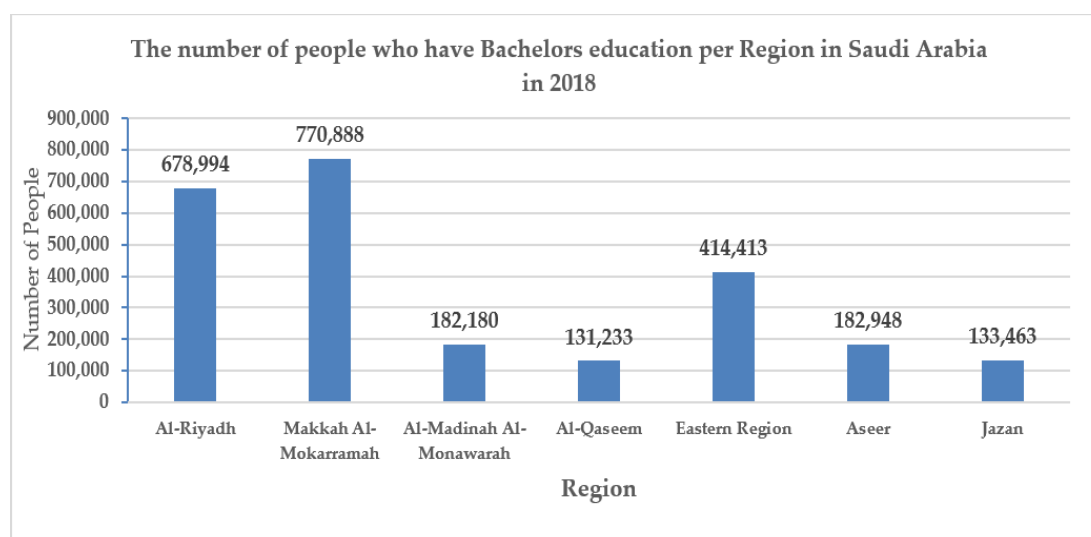
**Figure 15.** The household income of divorced and married people per regions in Saudi Arabia in 2018.

Moreover, based on Figure 15, we can conclude the following: First, the household incomes for divorced and married people are high in the same top three regions that have the greatest number of issued driving licenses, the number of accidents and the number of violations, the number of divorce documents and the number of marriage contracts in Saudi Arabia, namely, the *Riyadh region*, the *Makkah Al-Mokarramah region*, and the *Eastern region*. Secondly, we observed that in the same top three regions, the household income for married people exceeded the household income for divorced people. Thirdly, in most of regions in Saudi Arabia, the household income for married

people exceeded the household income for divorced people except in the *Northern Border region* where the household income for divorced people exceeded the household income for married people. Finally, in the *AL-Qaseem region*, the household income for divorced people and the household income for divorced people was approximately the same.

### 7.7. Educational Status

In the context of the discussion above, the statistics show that *Education* was also an important factor with direct influence on the acceptance of the decision to permit women to drive in Saudi Arabia. Due to the interlinked datasets in the SLOGDC, we were able to retrieve “Education” as an influential factor and impact/relationship between the education and women’s driving. From the queries shown in the previous section (Figure 9c), we identified the Saudi population by Administrative area and educational status. The results show that most of people in the top three regions such as the *Riyadh region*, the *Makkah Al-Mokarramah region* and the *Eastern region* also attained high education in comparison with citizens in other regions of Saudi Arabia. For instance, the number of people with Bachelor-level education in the *Riyadh region* totaled 678,994, whereas the number of people with Bachelor-level education in the *Makkah Al-Mokarramah region* totaled 770,888, and the number of people with Bachelor-level qualifications in the *Eastern region* numbered 414,413. The number of people with Bachelor-level education in other regions in Saudi Arabia were as follows: *Assir region* 182,948, *Madinah region* 182,180, *Jazan region* 133,463, *Al-Qaseem region* 131,233, *Tabouk region* 82,243, *Hail region* 65,280, *Al-Baha region* 64,581, *Al-Jouf* 55,206, *Northern Boarder* 40,034, and *Najran region* 36,949. The graph in Figure 16 compares the number of people with Bachelor-level education region wise in Saudi Arabia in 2018.



**Figure 16.** The number of people with bachelor’s degrees per region in Saudi Arabia in 2018.

Moreover, the other factors such as the number of driving licenses issued in Saudi Arabia regions, people opinion and how they react to woman driving in Twitter, the household income by their marital status and by regions and the number of divorce documents and marriage contracts in Saudi Arabia regions are present. Based on Figure 16, we can conclude that most of the people in the top three regions such as *Riyadh*, *Makkah Al-Mokarramah*, and the *Eastern region* are highly educated in comparison with residents in other regions of Saudi Arabia.

## 8. Discussion and Conclusions

Data-oriented sustainable systems provide the means to undertake intelligent data analytics that can ultimately be used for decision-making and policy formulation. Linked Open Data (LOD)-oriented sustainable systems are one step ahead in that they provide the means to catalyze transparency, confidence, and accountability for government and other public bodies in multiple

areas. In this paper, we presented our Saudi Linked Open Government Data Cloud Framework (SLOGDCF), which can be used for extracting data from different data sources in multiple domains such as *Saudi Open Data, General Authority for Statistics, Ministry of Transportation, Ministry of Labour and Social Development, and Ministry of Justice, Ministry of education, and Twitter*. Then we showed how the SLOGDCF framework can be used to produce RDF datasets and Saudi Government Ontology (SGO), in addition to semiautomatically mapping Saudi Government datasets to Saudi Government Ontology (SGO). We presented the Saudi Linked Open Government Data Cloud (SLOGDC), which we produced by creating links amongst Saudi RDF datasets and with other datasets in the LOD cloud. We also developed a SPARQL Endpoint as a point of contact to Open Government Data-oriented sustainable system that can be used to ask smart semantic-based queries to SLOGDC in different domains using SPARQL protocol. As a proof of concept to our work, we undertook quantitative and qualitative analyses of the results on the topic “Public’s Response to Women’s Driving in Saudi Arabia.” In our case study, we identified and analyzed different factors of influence on public opinion such as *education, social status, job statistics, and economic status* in terms of women’s driving in Saudi Arabia. The results that we retrieved from our Open Government-Oriented sustainable system and analysis of these results can be used by decision-makers to shape policies and guide decision-making in the implementation of new rules and policies. As future work, we will provide a dashboard or public interface that can be used by end users to query our SLOGDC and to produce results/charts for analysis. In addition, analyzing other factors related to accidents and violations such as accidents or violations during school start and end timings, office start, and end timings.

**Author Contributions:** Designed the study and prepared the first draft of the manuscript, AM.A, and MA.A; Methodology, AM.A, and MA.A; Formal Analysis and Visualization AM.A; writing—original draft, AM.A; writing—review and editing, AM.A, and MA.A; review and editing, K.S, and MS.M. All the authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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