

THE OPENBUDGETS DATA STRUCTURE DEFINITION FOR PUBLIC FINANCE DATA: A GUIDE

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OpenBudgets.eu is a Horizon 2020 funded project that aims to provide a generic framework and concrete tools for supporting financial transparency, thus enhancing accountability within public administrations and reducing the possibility of corruption. A key challenge for OpenBudgets.eu is to provide a framework that is scalable, easy-to-use, flexible, and attractive. During the implementation of the project three pilot scenarios will run targeting three different applications related to public spending: journalism, anti-corruption initiatives and private citizenship engagement. OpenBudgets.eu involves various stakeholders, including but not limited to public administrations, citizens, NGOs, media organisations and public service companies. Find out more at <http://openbudgets.eu/about/>.

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Executive Summary

This report is to be used as a self-contained guide to modelling datasets according to the OpenBudgets.eu data model. It contains the RDF Data Cube Vocabulary guide showing how the vocabulary is used throughout the data model. There are also IRI patterns that should be followed when creating datasets and code lists in OpenBudgets.eu. The process of modelling a dataset is described through all necessary steps and is illustrated using examples. Also included are modelling patterns that are to be considered during dataset transformation as well as the recommended metadata and validation techniques. The data model is illustrated on two use cases. The last part of this deliverable is a data model reference which includes descriptions and usage examples of individual classes and properties in the core OpenBudgets.eu data model.

Abbreviations and Acronyms

CSV	Comma-Separated Values
DCV	Data Cube Vocabulary
DSD	Data Structure Definition
GDP	Gross Domestic Product
RDF	Resource Description Framework
SDMX	Statistical Data and Metadata eXchange
XML	eXtensible Markup Language

Introduction

Driven by the use cases of the OpenBudgets.eu project, we designed a data model for fiscal data published by the public sector, covering both planned budgets and executed transactions. It is expressed in RDF primarily in terms of the Data Cube Vocabulary (DCV) W3C standard, conceived as a set of reusable component properties that can be composed into dataset-specific data structures.

The design of the data model was informed by a survey of existing vocabularies, interviews with domain experts and prospective users, and a year-long use in the OpenBudgets.eu project, in which it was applied to more than 200 datasets ranging from the EU level to the municipality level.

The world of fiscal datasets is a diverse one. There are hardly any fiscal datasets conforming to the same structure, though many fiscal datasets share common elements. A fixed data schema would therefore find little reuse. Instead, we decided to adopt component properties as the basic units of reuse. Component properties represent dimensions, attributes, or measures (i.e. instances of `qb:ComponentProperty` in DCV). Using the OpenBudgets.eu data model, data structure definitions of specific datasets can be produced by cherry-picking component properties. The core component properties can be either reused directly or extended via subproperties, such as in the case of a local classification. Values of component properties can be constrained by code lists that enumerate their allowed values. The OpenBudgets.eu data model defines several core code lists, such as the one for budget phases.

We used RDF as an enabling technology for semantic grounding of the fiscal domain, allowing us to mint terms describing the domain, and as a way to integrate heterogeneous datasets. Data integration is enabled by the reuse of component properties, which in turn allows to use fiscal datasets in combination and perform comparative analyses. Moreover, RDF makes it straightforward to combine fiscal data with other statistical datasets, such as macroeconomical indicators from Eurostat, which can provide a relevant context. Datasets modelled using the common terms from the data model are self-describing. Since definitions of the terms describing the data can be found by following their links, it is possible to use the data without prior knowledge. Not needing to ask for explanation of the data thus removes a barrier to use the data.

DCV defines cardinality restrictions for its component properties. While values of dimensions must be provided for each observation to be able to locate it in the space of the data cube, attributes may be optional. Since we encountered many properties with missing values that did not match the semantics of attributes as measure's qualifiers, we created `obeu:OptionalProperty` as a new subclass of `qb:ComponentProperty` to represent optional properties. Although an arbitrary RDF property may be used to achieve the same goal, an `obeu:OptionalProperty` may be included in a dataset's data structure definition and guide the consumption of the dataset. An example of an optional property is location, which is applicable only to monetary amounts tied to a particular place.

The OpenBudgets.eu data model is based on the Data Cube Vocabulary. DCV is a vocabulary for describing multidimensional statistical data. It organizes measures, optionally qualified by attributes, in logical spaces coordinated by dimensions. Fiscal data typically consists of monetary amounts indexed by values of various dimensions, such as the fiscal year or the funded project. Amounts form the measures coordinated by dimensions in fiscal data cubes.

Since the data model was designed to cater for a large variety of fiscal datasets in the scope of the OpenBudgets.eu project, you may find it applicable to a wide range of datasets beyond what we use it for. So far, it has served us well in the project, so it may do the same for other efforts that require modelling of fiscal data. The data model is released under the terms of an open licence, so you may take it, reuse it, and build on it.

This report describes the OpenBudgets data model in detail and contains exemplary applications of the data model to different datasets.

Data Cube Vocabulary primer

The RDF Data Cube Vocabulary¹ (DCV) is a W3C Recommendation for representing multidimensional data in RDF. Multidimensional data is any data that consists of observed values organized along a set of dimensions that describe the observed values. Statistical data is a typical representative of multidimensional data. In fact, the DCV is compatible with the cube model that forms the base of the SDMX (Statistical Data and Metadata eXchange) standard – an international standard for exchange of statistical data and metadata (Cyganiak & Reynolds, 2014).

As it is shown later in this document, budgetary and spending data also represent multidimensional data and therefore we decided to model such data as RDF data cubes using the DCV. In this primer, we introduce the DCV basics for better understanding of the way the budgetary and spending is represented in the OpenBudgets.eu project.

THE DATA CUBE VOCABULARY OVERVIEW

DCV represents datasets as data cubes, i.e. collections of data that comprises of observed values (observations), associated dimensions, and metadata. The DCV provides a set of classes and properties for representing the data cubes in RDF and publishing them according to the linked data principles (see Berners-Lee, 2006). Classes, properties and their relationships that are specified in the DCV are depicted on Figure 1.

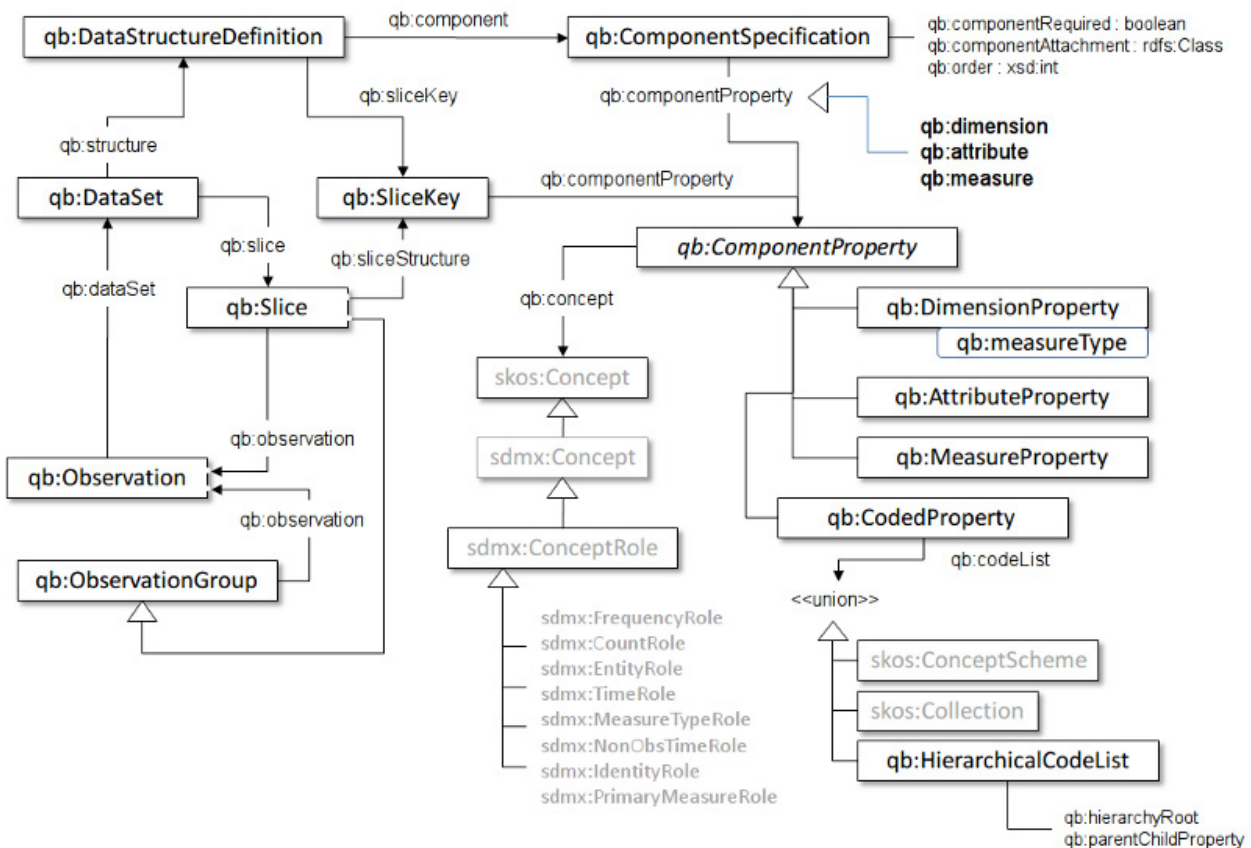


Figure 1: Classes, properties and their relationships in the DCV, source: (Cyganiak & Reynolds, 2014)

For every dataset (**qb:DataSet**) a definition of its structure (**qb:DataSetDefinition**) needs to be developed. This structure is made of specifications of its components properties (**qb:ComponentProperty**). The component properties may be optionally annotated with order (**qb:order**), which guides presentation of data in tables by recommending an order of columns. There are 3 types of components properties:

Measures (**qb:MeasureProperty**) – measure properties specify the types of the observed values in the dataset.
 Dimensions (**qb:DimensionProperty**) – dimension properties specify dimensions used in the dataset to organize the observed values in a multidimensional space.

1 - <http://www.w3.org/TR/vocab-data-cube/>

Attributes (qb:AttributeProperty) – attribute properties specify additional attributes of the observed values, such as currency or accuracy.

Datasets using the DCV are made of observations (qb:Observation). An observation might be seen as a record of measures (one or more observed values) and the respective values of the specified dimensions and attributes. By selecting specific values of one or more dimensions, a view on the data called slice (qb:Slice) can be defined. We provide a more detailed discussion of the key DCV terms in the following subsections.

OBSERVATIONS, DATASET, AND DATA STRUCTURE DEFINITION

The RDF Data Cube Vocabulary builds upon an abstract cube model, i.e. a multidimensional space where measured values are indexed by multiple dimensions. Let's illustrate this concept using an excerpt of the total general government expenditure expressed as percentage of GDP published by Eurostat (2015) as an example.²

Reference area\year												
EU (28 countries)	:	:	:	45,6	44,9	46,5	50,3	50	48,6	49	48,6	48,2
EU (27 countries)	:	:	:	45,6	44,9	46,5	50,3	50	48,6	49	48,6	48,2
Euro area (19 countries)	:	:	:	46	45,3	46,6	50,7	50,5	49,1	49,7	49,6	49,4
Euro area (18 countries)	:	:	:	46,1	45,3	46,6	50,7	50,5	49,1	49,8	49,6	49,4
Euro area (17 countries)	:	:	:	46,1	45,4	46,6	50,7	50,5	49,1	49,8	49,7	49,4

Table 1: Total general government expenditure (% of GDP, excerpt), source: excerpt from (Eurostat, 2015b)

The total general government expenditure expressed as a percentage of GDP is the measured phenomenon, as illustrated in Table 1, which is indexed by two dimensions: reference area and year. The total government expenditure in EU28 in 2010 represents a single observation. The collection of observations forms a dataset, i.e. a data cube.

Any dataset represented using the DCV is an instance of the class qb:DataSet which contains instances of the class qb:Observation. In order to specify the structure of the dataset, a data structure definition needs to be developed (an instance of the class qb:DataStructureDefinition).

A data structure definition specifies what dimensions index observations in a particular dataset and what values are measured in the observations. It might also specify what additional attributes of the observation are (or could be) provided in a dataset, such as the currency or unit of measure.

The following example shows a data structure definition for the dataset described in Table 1.

² - Only data for EU28, EU27 and Euro areas presented, data about the individual states omitted for the purposes of this example. Unavailable values are marked with ":". See the Eurostat website for detailed metadata: <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tec00023>.

```

@prefix rdfs:      <http://www.w3.org/2000/01/rdf-schema#> .
@prefix qb:       <http://purl.org/linked-data/cube#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd:      <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:      <http://data.example.org/resource/dsd/> .
@prefix ex-measure:  <http://data.example.org/ontology/dsd/measure/> .

ex-dsd:total-general-government-expenditure a qb:DataStructureDefinition ;
  rdfs:label „Total general government expenditure"@en ;
  # Dimensions
  qb:component [
qb:dimension ex-dimension:refPeriod ;
  qb:order 1 ;
  rdfs:label „Dimension representing a year for which the total general government expenditure is reported"@en
  ] ;
  qb:component [
  qb:dimension ex-dimension:refArea ;
  qb:order 2 ;
  rdfs:label „Dimension representing a state or group of states for which the total general government expenditure is reported"@en
  ] ;
  # Measure
  qb:component [
  qb:measure ex-measure:total-general-government-expenditure ;
  rdfs:label „Measure representing the total general government expenditure"@en
  ] ;
  # Attributes
  qb:component [
  qb:attribute sdmx-attribute:unitMeasure ;
  qb:componentRequired true
  ] .

```

Example 1: Data structure definition of the dataset described in Table 1

As we can see, a data structure definition of a dataset represented using DCV consists of specifications of its components: dimensions, measures, and attributes. We introduce these components in the following section. However, you can see that we introduce dimensions `ex-dimension:refPeriod` and `ex-dimension:refArea` to represent the year, and reference area dimensions, respectively. The measure `ex-measure:total-general-government-expenditure` is introduced to represent the measured phenomenon in our example dataset. In Table 1, the total general government expenditure is expressed as percentage of GDP. Attribute `sdmx-attribute:unitMeasure` is used to denote the unit of measurement and declared as required component, i.e. the unit of measurement needs to be provided for every observation. Just for the purposes of this example we stick to the default attachment level of the unit of measurement attribute. However, the DCV allows to use different attachment levels. See (Cyganiak & Reynolds, 2014) for details.

In Example 2, we provide a sample of the instance data representation of the dataset in Table 1 - the dataset and observations for the EU28 region covering years 2012-2014.

```

@prefix dcterms:          <http://purl.org/dc/terms/>.
@prefix qb:              <http://purl.org/linked-data/cube#> .
@prefix rdfs:            <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute:  <http://purl.org/linked-data/sdmx/2009/attribute#> .

@prefix ex-dataset:     <http://data.example.org/resource/dataset/> .
@prefix ex-dimension:   <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:         <http://data.example.org/resource/dsd/> .
@prefix ex-measure:     <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Dataset
ex-dataset:total-general-government-expenditure a qb:DataSet ;
  rdfs:label "Total general government expenditure"@en ;
  rdfs:comment "Total general government expenditure expressed as % of GDP."@en ;
  dcterms:publisher <http://openbudgets.eu> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=-tec00023> ;
  qb:structure ex-dsd:total-general-government-expenditure .

# Example observations
<http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28> a qb:Ob-
servation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
  ex-measure:total-general-government-expenditure 49 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28> a qb:Ob-
servation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2013> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
  ex-measure:total-general-government-expenditure 48.6 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2014/EU28> a qb:Ob-
servation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2014> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
  ex-measure:total-general-government-expenditure 48.2 .

```

Example 2: Example instance data for the dataset described in Table 1

DIMENSIONS, MEASURES AND ATTRIBUTES

Data structure definition of a dataset represented using DCV is made of specifications of its components (qb:ComponentSpecification). There are 3 types of components: measures, dimensions, and attributes. The DCV provides specific classes to represent these components: qb:MeasureProperty, qb:DimensionProperty, qb:AttributeProperty. Component specification thus links data structure definition with instances of these classes that can be shared among multiple data structure definitions.

Measures (qb:MeasureProperty) represent types of the measured phenomenon, such as population of a given area or the total general government expenditure expressed as percentage of GDP, as illustrated in Table 1. As we have already mentioned, the measured values in the data cube model are indexed by one or more dimen-

sions. Dimensions provide additional information to the observations such as its reference period or reference area. Dimensions that are part of the structure of the given dataset are represented as instances of the class `qb:DimensionProperty`.

Sometimes it might be needed to provide additional information about observations that does not form dimensions of the multidimensional space, i.e. it does not index observation, such as unit of measurement, units of currency, precision or confidentiality level of a given measurement. In DCV such additional information is called an attribute. Instances of the class `qb:AttributeProperty` are used to represent attributes in data structure definitions.

The DCV specification (see Cyganiak & Reynolds, 2014) sets an important integrity constraint related to measures and dimensions: values for all measures and dimensions specified in the given data structure definition need to be present in every observation of a dataset. Attributes can be either required or optional depending on the data structure definition.

In the previous section we introduced an example data structure definition for the dataset described in Table 1. Component specifications of this data structure definition reference dimension properties and a measure property that represent the total general government expenditure (measure), the reference area (dimension), and the reference year (dimension). In the following example, we provide RDF representation of these properties.

```

@prefix interval:      <http://reference.data.gov.uk/def/intervals/> .
@prefix qb:           <http://purl.org/linked-data/cube#> .
@prefix rdf:          <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:         <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-concept: <http://purl.org/linked-data/sdmx/2009/concept#> .
@prefix sdmx-dimension: <http://purl.org/linked-data/sdmx/2009/dimension#> .
@prefix sdmx-measure: <http://purl.org/linked-data/sdmx/2009/measure#> .
@prefix xsd:          <http://www.w3.org/2001/XMLSchema#> .

@prefix ex:           <http://data.example.org/ontology/> .
@prefix ex-codelist: <http://data.example.org/resource/codelist/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-measure:  <http://data.example.org/ontology/dsd/measure/> .

# Dimension properties
ex-dimension:refPeriod a rdf:Property, qb:DimensionProperty ;
  rdfs:label "reference period"@en ;
  rdfs:subPropertyOf sdmx-dimension:refPeriod ;
  rdfs:range interval:Interval ;
  qb:concept sdmx-concept:refPeriod .

ex-dimension:refArea a rdf:Property, qb:DimensionProperty ;
  rdfs:label "reference area"@en ;
  rdfs:subPropertyOf sdmx-dimension:refArea ;
  rdfs:range ex:GeopoliticalEntity ;
  qb:codeList ex-codelist:geo ;
  qb:concept sdmx-concept:refArea .

# Measure properties
ex-measure:total-general-government-expenditure a rdf:Property, qb:MeasureProperty ;
  rdfs:label „total general government expenditure"@en ;
  rdfs:subPropertyOf sdmx-measure:obsValue ;
  rdfs:range xsd:decimal .

```

Example 3: Vocabulary for the data structure definition of the dataset described in Table 1

We use `interval:Interval` from the Interval ontology as the range for the reference period dimension property and

ex:GeopoliticalEntity as the range for the reference area dimension property. There needs to be a code list for every dimension property. Definition of the geopolitical entity is provided in the code lists section. See <http://reference.data.gov.uk/def/intervals> for intervals.

All the dimensions and the measure are modelled as subproperties of more generic concepts specified by the SDMX standard. The reason for taking this approach is that we define specific ranges and associated code lists for these dimensions.

It is possible to have more than one measure per observation. See Table 2 for an example.³

Year	2013	2013	2014	2014
Reference area/ measure	GDP at market prices (Current prices, euro per capita)	Real GDP growth rate - volume (Percentage change on previous year)	GDP at market prices (Current prices, euro per capita)	Real GDP growth rate - volume (Percentage change on previous year)
EU (28 countries)	26600	0,2	27400	1,4
EU (27 countries)	:	:	:	:
Euro area (changing composition)	29600	-0,3	30000	0,9
Euro area (19 countries)	29400	-0,3	29800	0,9
Euro area (18 countries)	29500	-0,3	30000	0,9
Euro area (17 countries)	:	:	:	:

Table 2: GDP at market prices and real GDP growth rate, source: excerpt from (Eurostat, 2015a; Eurostat, 2015c)

There are 2 measures present in Table 2: GDP at current market prices expressed as euro per capita and volume of the real GDP growth expressed as percentage change on previous year. Both measures are indexed by the same dimensions: reference area and year. Because the dimensions are the same for both of the measures, it would be possible to represent them both as measures of the same observation.

In the DCV there are two alternative approaches to observations with multiple measures (Cyganiak & Reynolds, 2014):

Multi-measure observations – if the multi-measure observations approach is used, all specified measures are attached to a single observation.

Measure dimension – in case of the measure dimension approach a single measure is always attached to an observation and an additional dimension qb:measureType is used to denote which particular measure is being conveyed by the observation. Note that DCV still requires all measures to be present in the dataset for a given combination of the original dimensions. For example, if we had 3 measures per observation using the Multi-measure approach, we need to have 3 observations using the measure dimension approach and we cannot omit any of them.

In the following example we provide data structure definition of the dataset in Table 2 that applies the multi-measure observations approach.

³ - Two datasets used: (Eurostat, 2015a; Eurostat, 2015c). Only data for EU28, EU27 and Euro areas and for years 2013 and 2014 presented, rest of the data omitted for the purposes of this example. Unavailable values are marked with ":". See the Eurostat website for detailed metadata.

```

@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd:         <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:       <http://data.example.org/resource/dsd/> .
@prefix ex-measure:   <http://data.example.org/ontology/dsd/measure/> .

ex-dsd:GDP-at-market-prices-and-real-GDP-growth-rate a qb:DataStructureDefinition ;
  rdfs:label „GDP at market prices and real GDP growth rate"@en ;
  # Dimensions
  qb:component [
    qb:dimension ex-dimension:refPeriod ;
    qb:order 1 ;
    rdfs:label „Dimension representing a year for which GDP at market prices and real GDP growth rate
are reported"@en
  ] ;
  qb:component [
    qb:dimension ex-dimension:refArea ;
    qb:order 2 ;
    rdfs:label „Dimension representing a state or group of states for which GDP at market prices and
real GDP growth rate are reported"@en
  ] ;
  # Measures
  qb:component [
    qb:measure ex-measure:GDP-at-market-prices ;
    qb:order 3 ;
    rdfs:label „Measure representing the GDP at market prices"@en
  ] ;
  qb:component [
    qb:measure ex-measure:real-GDP-growth-rate ;
    qb:order 4 ;
    rdfs:label „Measure representing the real GDP growth rate"@en
  ] ;
  # Attributes
  qb:component [
    qb:attribute sdmx-attribute:unitMeasure ;
    qb:componentRequired true ;
    qb:componentAttachment qb:MeasureProperty ;
  ] .

```

Example 4: Data structure definition of the dataset described in Table 2 (multi-measure observations)

In the following example we provide the RDF representation of the dataset described in Table 2 and instance data for years 2013 and 2014 for the EU28 area. We use the data structure definition introduced above that applies the multiple measure approach.

```

@prefix dcterms:          <http://purl.org/dc/terms/> .
@prefix qb:               <http://purl.org/linked-data/cube#> .
@prefix rdfs:             <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute:  <http://purl.org/linked-data/sdmx/2009/attribute#> .

@prefix ex-dataset:      <http://data.example.org/resource/dataset/> .
@prefix ex-dsd:          <http://data.example.org/resource/dsd/> .
@prefix ex-dimension:    <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-measure:      <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Dataset
ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate a qb:DataSet ;
  rdfs:label "GDP at market prices and real GDP growth rate"@en ;
  rdfs:comment "GDP at market prices (current prices, euro per capita) and real GDP growth rate (percentage change on previous year)."@en ;
  dcterms:publisher <http://openbudgets.eu> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&code=tec00001&plugin=1> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&code=tec00115&plugin=1> ;
  qb:structure ex-dsd:GDP-at-market-prices-and-real-GDP-growth-rate .

# Unit of measure attachment
ex-measure:GDP-at-market-prices sdmx-attribute:unitMeasure ex-units-of-measure:euro-per-capita .

ex-measure:real-GDP-growth-rate sdmx-attribute:unitMeasure ex-units-of-measure:percentage-change-on-previous-year .

# Example observations
<http://data.example.org/resource/observation/GDP-at-market-prices-and-real-GDP-growth-rate/2013/EU28>
a qb:Observation ;
  qb:dataSet ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  ex-measure:GDP-at-market-prices 26600 ;
  ex-measure:real-GDP-growth-rate 0.2 .

<http://data.example.org/resource/observation/GDP-at-market-prices-and-real-GDP-growth-rate/2014/EU28>
a qb:Observation ;
  qb:dataSet ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2013> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  ex-measure:GDP-at-market-prices 27400 ;
  ex-measure:real-GDP-growth-rate 1.4 .

```

Example 5: Example of instance data of the dataset described in Table 2 (multi-measure observations)

The example above shows that both measures (GDP at market prices and real GDP growth rate) are part of one observation. It also demonstrates a known limitation of this approach that makes it impossible to attach attributes to a single measured value. That is why units of measurement are attached to the measure properties instead. Impact of this limitation is that the attachment of the unit of measure would apply to any dataset using that measure property.

To demonstrate both of the possible approaches to handling datasets with multiple measures, we provide the following example where the measure dimensions approach is applied.


```

@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd:         <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:       <http://data.example.org/resource/dsd/> .
@prefix ex-measure:   <http://data.example.org/ontology/dsd/measure/> .

ex-dsd:GDP-at-market-prices-and-real-GDP-growth-rate a qb:DataStructureDefinition ;
  rdfs:label „GDP at market prices and real GDP growth rate"@en ;
  # Dimensions
  qb:component [
    qb:dimension ex-dimension:refPeriod ;
    qb:order 1 ;
    rdfs:label „Dimension representing a year for which GDP at market prices and real GDP growth rate are reported"@en
  ] ;
  qb:component [
    qb:dimension ex-dimension:refArea ;
    qb:order 2 ;
    rdfs:label „Dimension representing a state or group of states for which GDP at market prices and real GDP growth rate are reported"@en
  ] ;
  qb:component [
    qb:dimension qb:measureType ;
    qb:order 3 ;
    rdfs:label „Measure type"@en
  ] ;
  # Measures
  qb:component [
    qb:measure ex-measure:GDP-at-market-prices ;
    qb:order 4 ;
    rdfs:label „Measure representing the GDP at market prices"@en
  ] ;
  qb:component [
    qb:measure ex-measure:real-GDP-growth-rate ;
    qb:order 5 ;
    rdfs:label „Measure representing the real GDP growth rate"@en
  ] ;
  # Attributes
  qb:component [
    qb:attribute sdmx-attribute:unitMeasure ;
    qb:componentRequired true
  ] .

```

Example 6: Data structure definition of the dataset described in Table 2 (measure dimension)

In the following example we provide the RDF representation of the dataset described in Table 2 and instance data for years 2013 and 2014 for the EU28 area. We use the data structure definition introduced above that applies the measure dimension approach.

```

@prefix dcterms:          <http://purl.org/dc/terms/> .
@prefix qb:               <http://purl.org/linked-data/cube#> .
@prefix rdfs:             <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute:  <http://purl.org/linked-data/sdmx/2009/attribute#> .

@prefix ex-dataset:      <http://data.example.org/resource/dataset/> .
@prefix ex-dimension:    <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:          <http://data.example.org/resource/dsd/> .
@prefix ex-measure:      <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Dataset

ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate a qb:DataSet ;
  rdfs:label "GDP at market prices and real GDP growth rate"@en ;
  rdfs:comment "GDP at market prices (current prices, euro per capita) and real GDP growth rate (percentage change on previous year)."@en ;
  dcterms:publisher <http://openbudgets.eu> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00001&plugin=1> , <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00115&plugin=1> ;
  qb:structure ex-dsd:GDP-at-market-prices-and-real-GDP-growth-rate .

# Example observations

<http://data.example.org/resource/observation/GDP-at-market-prices-and-real-GDP-growth-rate/GDP-at-market-prices/2013/EU28> a qb:Observation ;
  qb:dataSet ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  qb:measureType ex-measure:GDP-at-market-prices;
  sdmx-attribute:unitMeasure ex-units-of-measure:euro-per-capita ;
  ex-measure:GDP-at-market-prices 26600 .

<http://data.example.org/resource/observation/GDP-at-market-prices-and-real-GDP-growth-rate/real-GDP-growth-rate/2013/EU28> a qb:Observation ;
  qb:dataSet ex-dataset:GDP-at-market-prices-and-real-GDP-growth-rate ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  qb:measureType ex-measure:real-GDP-growth-rate ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percentage-change-on-previous-year ;
  ex-measure:real-GDP-growth-rate 0.2 .

<http://data.example.org/resource/observation/GDP-at-market-prices-and-real-GDP-growth-rate/GDP-at-market-prices/2014/EU28> a qb:Observation ;

```

Example 7: Example of instance data of the dataset described in Table 2 (measure dimension)

As indicated above, when the measure dimensions approach is applied, there is always only one measure per observation. Due to this feature it is possible to denote the unit of the measured value as an attribute at the observation level which allows measure properties to be reused across multiple datasets with different units of measurement for the same measure type. In our example, GDP in market prices is expressed in euros per capita. However it would be also possible to express the GDP in market prices in millions of euro.⁴

4 - See the dataset (Eurostat, 2015a).

CODE LISTS

Possible values of dimensions are limited to items of the used code lists. Code list can be defined as “a predefined list from which some statistical coded concepts take their values.”⁵ It is recommended to represent code lists as SKOS concept schemes,⁶ however, the DCV provides an alternative approach to definition of code lists via qb:HierarchicalCodeList – see (Cyganiak & Reynolds, 2014) for details. Existing code lists that might be used in budgetary and spending datasets are analysed in Deliverable D1.6 (Ioannidis et al., 2015).

In the above examples reference area is one of the dimensions. Various groups of European countries represent values of this dimension. We provide an excerpt of the code list of geopolitical entities as an example of a code list.

```
@prefix nuts:      <http://ec.europa.eu/eurostat/ramon/rdfdata/nuts2008/> .
@prefix rdfs:      <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema:    <http://schema.org/> .
@prefix skos:      <http://www.w3.org/2004/02/skos/core#> .

@prefix ex:        <http://data.example.org/ontology/> .
@prefix ex-codelist: <http://data.example.org/resource/codelist/> .
@prefix ex-geo:    <http://data.example.org/resource/codelist/geo/> .

# Geopolitical entity
ex:GeopoliticalEntity a rdfs:Class, s:Place ;
  rdfs:label "Geopolitical entity"@en ;
  rdfs:isDefinedBy <http://data.example.org/ontology> .

ex-codelist:geo a skos:ConceptScheme ;
  rdfs:label "Code list of geopolitical entities"@en .

ex-geo:EU28 a skos:Concept, ex:GeopoliticalEntity, schema:Place ;
  skos:prefLabel "European Union (28 countries)"@en ;
  skos:definition "This aggregate covers following countries: BE, BG, CZ, DK, DE, EE, IE, EL, ES, FR, HR, IT, CY, LV, LT, LU, HU, MT, NL, AT, PL, PT, RO, SI, SK, FI, SE, UK"@en ;
  skos:notation "EU28" ;
  skos:inScheme ex-codelist:geo ;
  skos:narrower nuts:AT, nuts:BE, nuts:BG, nuts:CY, nuts:CZ, nuts:DE, nuts:DK, nuts:EE, nuts:ES, nuts:FI, nuts:FR, nuts:GR, nuts:HR, nuts:HU, nuts:IE, nuts:IT, nuts:LT, nuts:LU, nuts:LV, nuts:MT, nuts:NL, nuts:PL, nuts:PT, nuts:RO, nuts:SE, nuts:SI, nuts:SK, nuts:UK ;
  rdfs:seeAlso <http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=DSP_NOM_DTL_VIE-W&StrNom=CL_GEO&StrLanguageCode=EN&IntPcKey=34617515&IntKey=34617522&StrLayoutCode=HIERARCHIC&IntCurrentPage=1> .

ex-geo:EA19 a skos:Concept, ex:GeopoliticalEntity, s:Place ;
  skos:prefLabel „Euro area (19 countries)"@en ;
  skos:definition „This aggregate covers following countries since 2015: BE, DE, EE, IE, EL, ES, FR, IT, CY, LV, LT, LU, MT, NL, AT, PT, SI, SK, FI"@en ;
  skos:notation „EA19" ;
  skos:inScheme ex-codelist:geo ;
  skos:narrower nuts:AT, nuts:BE, nuts:CY, nuts:DE, nuts:EE, nuts:ES, nuts:FI, nuts:FR, nuts:GR, nuts:IE, nuts:IT, nuts:LT, nuts:LU, nuts:LV, nuts:MT, nuts:NL, nuts:PT, nuts:SK, nuts:SI ;
  rdfs:seeAlso <http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=DSP_NOM_DTL_VIE-W&StrNom=CL_GEO&StrLanguageCode=EN&IntPcKey=34617515&IntKey=34617613&StrLayoutCode=HIERARCHIC&IntCurrentPage=1> .
```

Example 8: Geopolitical entity code list

See (Miles & Bechhofer, 2009) for more detailed reference of the Simple Knowledge Organization System (SKOS).

5 - <https://stats.oecd.org/glossary/detail.asp?ID=3371>

6 - See <http://www.w3.org/TR/skos-reference/>

SLICES AND SLICEKEYS

The DCV allows a set of observations with one or more dimensions fixed to be grouped into a slice and associated with a slice key. This allows the group of observations to be referenced and provided with additional metadata. Using the data in Table 1 as an example, it is possible to fix the area dimension and group all observations for EU (28 countries), forming a time-series slice for this reference area (the only free dimension is the time dimension). In order to be able to use slices, it is necessary to define data structure of the required slices and associate them with the respective slice keys. We illustrate this step with the following example that builds upon the dataset described in Table 1.

```
@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd:         <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dsd:      <http://data.example.org/resource/dsd/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-measure:  <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-slicekey: <http://data.example.org/resource/slicekey/> .

# Slice key definition
ex-slicekey:slice-by-ref-period a qb:SliceKey ;
  rdfs:label "slice by reference period"@en ;
  rdfs:comment "Slice by reference period, fixes the reference area forming a time series."@en ;
  qb:componentProperty ex-dimension:refArea .

# Data structure definition
ex-dsd:total-general-government-expenditure a qb:DataStructureDefinition ;
  rdfs:label „Total general government expenditure"@en ;
  # Dimensions
  qb:component [
    qb:dimension ex-dimension:refPeriod ;
    qb:order 1 ;
    rdfs:label „Dimension representing a year for which total general government expenditure is reported"@en
  ] ;
  qb:component [
    qb:dimension ex-dimension:refArea ;
    qb:order 2 ;
    rdfs:label „Dimension representing a state or group of states for which total general government expenditure is reported"@en
  ] ;
  # Measure
  qb:component [
    qb:measure ex-measure:total-general-government-expenditure ;
    rdfs:label „Measure representing the total general government expenditure"@en
  ] ;
  # Attributes
  qb:component [
    qb:attribute sdmx-attribute:unitMeasure ;
    qb:componentRequired true
  ] ;
  qb:sliceKey ex-slicekey:slice-by-ref-period .
```

Example 9: Slice key and updated data structure definition of the dataset described in Table 1

We use the same data structure definition as in Example 1, we only update it with a link to the defined slice key using the qb:sliceKey property. Slice in the example above groups together observations with the same referen-

ce area. Based on the data described in Table 1, the second dimension in this example is the reference period which remains a free dimension, i.e. it does not have a value fixed per slice and instead the slice should contain all yearly observations for a specific area. Example of the RDF representation of the instance data is provided below - slice for the EU28 area (we provide examples of only three observations to keep the the example to a reasonable length).

```

@prefix dcterms:      <http://purl.org/dc/terms/> .
@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .

@prefix ex-dataset:  <http://data.example.org/resource/dataset/> .
@prefix ex-dsd:      <http://data.example.org/resource/dsd/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-measure:  <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-slice:    <http://data.example.org/resource/slice/> .
@prefix ex-slicekey: <http://data.example.org/resource/slicekey/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Dataset
ex-dataset:total-general-government-expenditure a qb:DataSet ;
  rdfs:label "Total general government expenditure"@en ;
  rdfs:comment "Total general government expenditure expressed as % of GDP."@en ;
  dcterms:publisher <http://openbudgets.eu> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=-tec00023> ;
  qb:structure ex-dsd:total-general-government-expenditure ;
  qb:slice ex-slice:EU28 .

# Slice
ex-slice:EU28 a qb:Slice ;
  rdfs:label "Time series slice for the EU28 area"@en ;
  qb:sliceStructure ex-slicekey:slice-by-ref-period ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  qb:observation <http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28>,
    <http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28>,
    <http://data.example.org/resource/observation/total-general-government-expenditure/2014/EU28> .

# Example observations
<http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28> a qb:Observation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
  ex-measure:total-general-government-expenditure 49 .

```

Example 10: Example of instance data using a defined slice over the dataset described in Table 1

In Example 10, data about the reference area is provided at both the observation level as well as at the slice level. This allows working with the observations independently on the defined slice. However, slices can also be used to reduce verbosity of a dataset, as the values of the fixed components (dimensions, attributes) can be specified

only once at the slice level (in combination with the qb:componentAttachment qb:Slice property and value). This can save a number of triples. On the other hand, usage of components attached to slices complicates the data usage, as some of the dimensions for a given observation can be attached to the observation directly and some of them can be attached to the slice itself. We illustrate this with the following examples.

The following example shows a modified data structure definition used in Example 9, where the attachment level for the reference area dimension is changed to the slice level.

```

@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd:         <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:       <http://data.example.org/resource/dsd/> .
@prefix ex-measure:   <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-slicekey:  <http://data.example.org/resource/slicekey/> .

# Slice key definition
ex-slicekey:slice-by-ref-period a qb:SliceKey ;
  rdfs:label "slice by reference period"@en ;
  rdfs:comment "Slice grouping observations of the same region forming a time series."@en ;
  qb:componentProperty ex-dimension:refArea .

# Data structure definition
ex-dsd:total-general-government-expenditure a qb:DataStructureDefinition ;
  rdfs:label „Total general government expenditure"@en ;
  # Dimensions
  qb:component [
    qb:dimension ex-dimension:refPeriod ;
    qb:order 1 ;
    rdfs:label „Dimension representing a year for which total general government expenditure is reported"@en
  ] ;
  qb:component [
    qb:componentAttachment qb:Slice ;
    qb:dimension ex-dimension:refArea ;
    qb:order 2 ;
    rdfs:label „Dimension representing a state or group of states for which total general government expenditure is reported"@en
  ] ;
  # Measure
  qb:component [
    qb:measure ex-measure:total-general-government-expenditure ;
    rdfs:label „Measure representing the total general government expenditure"@en
  ] ;
  # Attributes
  qb:component [
    qb:attribute sdmx-attribute:unitMeasure ;
    qb:componentRequired true
  ] ;
  qb:sliceKey ex-slicekey:slice-by-ref-period .

```

Example 11: Slice key and data structure definition of the dataset described in Table 1 with changed reference area dimension attachment level

Changing the attachment level of the reference area dimension would allow to provide this dimension only at the slice level, as shown in the following example.

```

@prefix dcterms:      <http://purl.org/dc/terms/> .
@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:        <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .

@prefix ex-dataset:  <http://data.example.org/resource/dataset/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd:      <http://data.example.org/resource/dsd/> .
@prefix ex-measure:  <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-slice:    <http://data.example.org/resource/slice/> .
@prefix ex-slicekey: <http://data.example.org/resource/slicekey/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Dataset
ex-dataset:total-general-government-expenditure a qb:DataSet ;
  rdfs:label "Total general government expenditure"@en ;
  rdfs:comment "Total general government expenditure expressed as % of GDP."@en ;
  dcterms:publisher <http://openbudgets.eu> ;
  dcterms:source <http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tec00023> ;
  qb:structure ex-dsd:total-general-government-expenditure ;
  qb:slice ex-slice:EU28 .

# Slice
ex-slice:EU28 a qb:Slice ;
  rdfs:label "Time series slice for the EU28 area"@en ;
  qb:sliceStructure ex-slicekey:slice-by-ref-period ;
  ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
  qb:observation <http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28>,
  <http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28>,
  <http://data.example.org/resource/observation/total-general-government-expenditure/2014/EU28> .

# Example observations
<http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28> a qb:Observation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
  sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
  ex-measure:total-general-government-expenditure 49 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28> a qb:Observation ;
  qb:dataSet ex-dataset:total-general-government-expenditure ;
  ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2013> ;

```

Example 12: Example of instance data using a defined slice over the dataset described in Table 1 with slice level attachment of the reference period dimension

OpenBudgets.eu RDF prefixes

For OpenBudgets.eu we will use the following RDF prefixes based on a similar approach for the RDF version of SDMX:⁷

obeu: <<http://data.openbudgets.eu/ontology/>>

obeu-dsd: <<http://data.openbudgets.eu/resource/dsd/>>

obeu-dimension: <<http://data.openbudgets.eu/ontology/dsd/dimension/>>

obeu-measure: <<http://data.openbudgets.eu/ontology/dsd/measure/>>

obeu-attribute: <<http://data.openbudgets.eu/ontology/dsd/attribute/>>

obeu-codelist: <<http://data.openbudgets.eu/resource/codelist/>>

obeu-metadata: <<http://data.openbudgets.eu/ontology/metadata/>>

obeu-currency: <<http://publications.europa.eu/resource/authority/currency/>>

⁷ - <https://github.com/UKGovLD/publishing-statistical-data/tree/master/specs/src/main/vocab>

IRI patterns

Internationalized Resource Identifiers (IRIs) (Duerst & Suignard, 2004) should be treated as opaque,⁸ but following consistent IRI patterns improves human understanding of data, which is especially important for application developers and data analysts. Moreover, when source data identifiers are used in IRI patterns, IRIs can be programmatically constructed by simple string concatenation. In this way, it is straightforward to create links to external datasets. However, nothing should be inferred from the IRI's constituent parts and IRIs should be treated as meaningless identifiers. Note that we use IRIs instead of URIs, so that international character sets are supported as valid parts of identifiers.

When designing IRI patterns, start by choosing a base namespace on a domain you own. Consider using a dedicated subdomain for the namespace of IRIs in order to separate them from the rest of your domain. In the following example, we will use `http://data.openbudgets.eu/` as our base namespace. All your IRIs will start with this namespace. The IRIs in this namespace can be partitioned into a logical space by the types of resources they identify. First, we propose to distinguish the IRIs of the terminological entities from the data structure definition by appending `ontology/` to the base namespace and append `resource/` for the resources instantiating the terminological entities. Subsequently, we recommend to append a label of the type of the identified resource, such as `codelist/`. You can structure the types of the resource further, such as first adding `dsd/` for a data structure definition followed by `measure/` for an IRI identifying measure property. The last part of an IRI must uniquely identify the resource within its namespace. We recommend to reuse identifiers from the source data, such as codes of code list concepts. Make sure the characters of these identifiers are allowed in IRIs by converting them into URI slugs (see the chapter on identifier patterns in Dodds, Davis, 2012). If such identifiers are unavailable, use a randomly generated UUID that guarantees uniqueness. Using this approach has a downside that each time a dataset is transformed into RDF, different UUID-based IRIs are generated for the same resources. We recommend avoiding auto-incremented integer identifiers, since they are too brittle and in RDF they do not provide the usual benefit of fast index access.

For example, if data describing the budget of the EU for the year 2014 was published directly by its maintainers using the data model of OpenBudgets.eu, the base namespace can be defined as `http://open-data.europa.eu`, which is the URL of the European Union Open Data Portal. In order to distinguish elements of the data model and data described with the model, we can append `ontology/` or `resource/` respectively to the base namespace. Regarding word case, the path parts of IRIs use kebab-case. Kebab case lowercases all words and separates them by hyphens. The IRI's local name⁹ (ID) should use camelCase for properties or classes and kebab-case for instances (instances). In addition, local names of properties start with a lowercase letter and local names of classes start with an uppercase letter. Local names of instances start with a lowercase letter. An exception to this rule should be applied when an identifier from the source dataset is used as a local name. For example, suppose we create IRI for code list concepts using their codes as local names. In that case we recommend using the identifier literally, subjected only to IRI-encoding. For example, currency code "EUR" should be kept in uppercase. This way you can avoid potential IRI collisions caused by identifier normalization.

Examples of property and entity IRIs:

Core	OpenBudgets.eu	dimension	property	(fiscalPeriod):
<code>http://data.openbudgets.eu/ontology/dsd/dimension/fiscalPeriod</code>				
Core	OpenBudgets.eu	measure	property	(amount):
<code>http://data.openbudgets.eu/ontology/dsd/measure/amount</code>				
Core	OpenBudgets.eu	attribute	property	(taxesIncluded):
<code>http://data.openbudgets.eu/ontology/dsd/attribute/taxesIncluded</code>				
Core	OpenBudgets.eu	codelist	(operationCharacter):	
<code>http://data.openbudgets.eu/resource/codelist/operation-character</code>				
Core	OpenBudgets.eu	codelist	item	(Expenditure from operationCharacter codelist):
<code>http://data.openbudgets.eu/resource/codelist/operation-character/expenditure</code>				
Non	OpenBudgets.eu	dimension	property	(catpol from the EU Budget dataset):
<code>http://example.com/ontology/dsd/eu-budget-2014/dimension/catpol</code>				
Non	OpenBudgets.eu	attribute	property	(reserve from EU Budget dataset):

8 - <http://www.w3.org/DesignIssues/Axioms.html#opaque>

9 - Local name is the last part of an IRI that follows after the first "#" character or the last "/" character.

```

http://example.com/ontology/dsd/attribute/reserve
Non   OpenBudgets.eu   codelist   (EU   Budget   dataset   operation   character   codelist):
http://example.com/resource/eu-budget-2014/codelist/operation-character
Non   OpenBudgets.eu   codelist   item   (Commitment   from   EU   Budget   dataset   operation   character   codelist):
http://example.com/resource/eu-budget-2014/codelist/operation-character/commitment

```

As already illustrated, there is a special IRI pattern for observations of a data cube. The IRI starts with the domain as usual, followed by /resource and /observation and a URI slug of the name of the data cube. The data cube's name can be derived from the dataset's name or its abbreviation. The only requirement on the name is that it must be unique. Observations of a data cube are distinguished by values of dimensions. These values are taken from code lists where each code list item (usually skos:Concept) should also have a machine readable code (skos:notation). These codes can be then used in the observation IRI, as they should guarantee uniqueness of the IRI and provide some insight to the nature of the observation. An example is:

```

<http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28> a qb:Observation ;

qb:dataSet ex-dataset:total-general-government-expenditure ;
ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2013> ;
ex-dimension:refArea <http://data.example.org/resource/codelist/geo/EU28> ;
sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
ex-measure:total-general-government-expenditure 48.6 .

```

Here, total-general-government-expenditure is the name of the data cube and 2013 and EU28 are the dimension values (codes of codelist items) identifying the observation.

If you need a new property or class outside of the DCV model to describe a concrete dataset, you can create it either in a dataset-specific namespace (<http://data.openbudgets.eu/ontology/{dataset ID}/{local name}>) or the OpenBudgets.eu namespace directly (<http://data.openbudgets.eu/ontology/{local name}>) if you deem the new term to be reusable across multiple datasets.

Another area of IRI patterns are related to datasets, codelists, vocabularies and metadata in the context of RDF named graphs. In OpenBudgets.eu the IRI of an RDF named graph is the same as the IRI of the dataset (qb:DataSet) it contains. It consists of a common prefix and the identifier of the dataset: <http://data.openbudgets.eu/resource/dataset/{dataset ID}>. IRI of the RDF named graph that contains metadata about a dataset is created by appending /metadata to the dataset IRI, i.e.: <http://data.openbudgets.eu/resource/dataset/{dataset ID}/metadata>. IRI patterns for of named graphs that contain code lists or vocabularies depend on whether the code list or vocabulary is specific to a dataset, and therefore not expected to be used anywhere else, or it is global and expected to be reused. For specific code lists we use <http://data.openbudgets.eu/resource/dataset/{dataset ID}/codelist/{codelist ID}> as both the RDF named graph IRI and code list IRI. For specific vocabularies we use <http://data.openbudgets.eu/resource/dataset/{dataset ID}/vocabulary> as the RDF named graph IRI. For global code lists we use <http://data.openbudgets.eu/resource/codelist/{codelist ID}> as both the RDF named graph IRI and code list IRI. For global vocabularies we use <http://data.openbudgets.eu/resource/vocabulary/{vocabulary ID}> as the RDF named graph IRI.

Budget data modelling guide

Having introduced the core underpinnings of the DCV we will move on to a concrete application of the vocabulary into the domain of public finance. Data model of the OpenBudgets.eu is a specific application of the DCV designed to represent the core concepts of this domain. The RDF representation of the data model is available at <https://github.com/openbudgets/data-model>. We will walk through a sequence of steps in modelling fiscal datasets using the proposed data model.

DATA IDENTIFICATION

The first step in modelling budget data is to identify what kind of dataset you have. The OpenBudgets.eu data model recognizes 2 principal kinds of datasets: budget and spending. It may be difficult to tell them apart, in part because budget data may contain aggregated expenditure for previous fiscal periods. This is why we provide several checkpoints to help distinguish the nature of fiscal datasets.

Budget datasets:

Budget data is a plan for a future fiscal period, which is aggregated by classifications, i.e. rarely include individual transactions

Budget data does not contain specific partners who receive or pay the expenditures.

Spending datasets:

Spending data contains records of realized financial transactions, i.e. really collected revenue and paid expenditure are shown.

Spending data may contain specific partners who received or paid the reported expenditures.

Alternatively, source datasets can be combined for presentation purposes. For example, budgeted appropriations may be shown along with disbursed subsidies. In this case, it is advised to split the source dataset into multiple logical datasets. If needed, joins can be made over the datasets in queries to get at the same view as is provided by the source dataset.

DATA INTERPRETATION

Prior to formalizing the data model, we need to understand the data we have. Unlike RDF, most data formats are not self-descriptive, so that the data itself is often insufficient for deriving a correct interpretation. Therefore, it is necessary to have access to out-of-band information explaining the data. This information is typically embedded in schemata, documentation or metadata. For example, there can be a document explaining what column names in a dataset refer to. Alternatively, one can have a structured metadata descriptor of a dataset, such as the JSON descriptor format used by Fiscal Data Package.¹⁰ Without documentation, basing the interpretation of data on the column labels only should be used only when you have a strong confidence that you are able to interpret them correctly.

Understanding schemata is tied to the understanding of the language they are written in. This is often a natural language, since the schema is embodied only in column names. In other cases, a formal schema language is used, such as XML Schema. Understanding the language of data is the minimum prerequisite for understanding the data. First, users need to understand the natural language used in the descriptions of data. In case of fiscal data this aim often entails understanding the domain-specific jargon and terminology. If terminological confusion arises, we recommend to consult domain experts to help clarify the intended meaning of the employed terms. The second step is to understand the schema of the dataset at hand. Dataset schema can be explicitly formalized using a schema language or be left implicit, such as implied relations between columns in a table. This understanding is subsequently projected into the data structure definition of the dataset.

¹⁰ - <http://specs.frictionlessdata.io/fiscal-data-package>

MAPPING SOURCE DATA STRUCTURE TO THE TARGET (DCV) DATA MODEL STRUCTURE

Let us demonstrate the process of mapping the source data structure to the target OpenBudgets.eu DCV data structure definition using an example of a CSV file. A CSV file is composed of columns, some of which will become dimensions and others will become measures. Generally speaking, dimensions are usually columns representing classifications, time, area, etc., while measures are usually the numeric values like monetary amounts, numbers of persons etc. In addition, there are attributes like currency, which are often not specified in the source data, or which are specified only in documentation of the source data and need to be added during data transformation. Some CSVs can be more complicated, especially when they represent a direct transcript of a table originally formatted for visualizations, such as Table 1, where a more natural way of representing the same data would use 3 columns: reference area, time period (dimensions), and observed value (measure), instead of encoding the values of the time dimension in column names.

Not every column from the source data needs to be mapped to a component property. Some columns specify attributes of entities, which are already related to the described observation by another component property. For example, the source dataset may contain project names. Projects are already related to the described observations via `obeu-dimension:project`, so that their names can be represented as values of `foaf:name` property of the linked entities.

Reusing OpenBudgets.eu core component properties

When the dimension, measure and attribute roles are identified in the source dataset, we should look in the list of OpenBudgets.eu core component properties for corresponding ones to reuse. See the reference section below for a comprehensive overview of the component properties defined in the data model of OpenBudgets.eu. Typically, for datasets that OpenBudgets.eu is mainly focused on, there will be a monetary amount measure, for which we have the `obeu-measure:amount` measure property and also often there will be measurements in different time periods, for which we can reuse the `obeu-dimension:fiscalPeriod` property in our new data structure definition. The remaining parts of data structure definitions typically vary among datasets and may require dataset-specific extensions of the OpenBudgets.eu data model.

Extending the core data model

If the core data model of OpenBudgets.eu does not suffice for your modelling needs, you can extend it. You typically extend the core data model if you need a specific measure subproperty or if you require a dimension with custom code list. The primary way of extending the data model is to derive a more specific component property from a more generic core component property. With a specific component property the representation of your dataset can be more descriptive. For example, the core data model contains the component property `obeu-dimension:fiscalPeriod` to represent time intervals associated with fiscal data:

```
obeu-dimension:fiscalPeriod a rdf:Property, qb:DimensionProperty, qb:CodedProperty ;
  rdfs:label "fiscal period"@en ;
  rdfs:comment "The period of time reflected in financial statements."@en ;
  rdfs:subPropertyOf sdmx-dimension:refPeriod ;
  rdfs:range time:Interval ;
  qb:concept sdmx-concept:refPeriod .
```

In order to derive a more specific component properties use the `rdfs:subPropertyOf` property from RDF Schema (Brickley, Guha, 2014) to link the specific property to its parent and more generic property. In this way, tools that understand the core data model can treat data using the specific property as if it used the core property, from which the specific one is derived. Each derived component property should be described well enough to be able to distinguish it clearly from its parent component property. Property's description should include a label and a definition at least. Additionally, each property can link to a concept it represents via the `qb:concept` property. For example, a subproperty can link a narrower concept of the concept linked by its parent property.

The time intervals used in budget data often last for a year, which is why the core data model also includes the `obeu-dimension:fiscalYear` component property as a sub-property of `obeu-dimension:fiscalPeriod`:

```

obeu-dimension:fiscalYear a rdf:Property, qb:DimensionProperty, qb:CodedProperty ;
  rdfs:label "fiscal year"@en ;
  rdfs:comment "The year reflected in financial statements."@en ;
  rdfs:subPropertyOf obeu-dimension:fiscalPeriod ;
  rdfs:range interval:Year ;
  qb:concept sdmx-concept:refPeriod .

```

Similarly, component properties for other sub-intervals may be created, such as for a quarter of a year. An important part of defining a component property is specifying its code list. Code lists enumerate the values that are allowed to be used with a given component property. All dimension properties are coded, that is, there is a code list restricting the range of their values. Code lists can be optionally defined for attribute properties as well. In the DCV you associate a code list with a component property using the `qb:codeList` property that links the IRI of the code list. If you derive a coded component property, it would typically define a different code list to its parent property. However, this code list may include concepts from the parent property's code list. You can include external concepts into your code list by linking them to the code list IRI via the `skos:inScheme` property. This way, you can directly reuse code list concepts instead of duplicating them. Code lists can be extended in a similar fashion as component properties. You can create a mode specific code list concept and link it to its parent concept using the `skos:broader` property. Other semantic relations defined by SKOS¹¹, such as `skos:related`, can be used as well. If you want to use a code list not included in the core data model of OpenBudgets.eu, create a new component property for use with this code list.

An example use of the described code list extension can be seen in Appendix A. For the purpose of modelling the European Union budget dataset we extended the `obeu-codelist:operation-character` code list enumerating the characters of operations for which budget is allocated. For the same purpose we created the `eu-dimension:operationCharacter` subproperty. The extended code list directly reuses the top concepts of the `obeu-codelist:operation-character` code list: `obeu-operation:expenditure` and `obeu-operation:revenue`. It defines 2 additional concepts that are narrower to the concept of `obeu-operation:expenditure`: `eu-operation:commitment` and `eu-operation:payment`. These concepts are specific for the budget of the European Union.

Composing a data structure definition

Now that we are familiar with our source data and we have the necessary dimension, measure and attribute properties ready (either reused from OpenBudgets.eu core properties or newly defined), it is time to compose the data structure definition (DSD).¹² DSD specifies mainly the logical structure (e.g., what dimensions are used) of a dataset, but can also contain usage hints and optimisations (e.g., component ordering and component attachment). Understanding of the dataset's structure should be captured in a DSD. Let us demonstrate the composition of a DSD out of component properties on an example of the budget of the European Union:

```

<http://example.openbudgets.eu/resource/dsd/eu-budget-2014> a qb:DataStructureDefinition ;
  rdfs:label "Data structure definition for the budget of the European Union of the year 2014"@en ;
  qb:component [ qb:dimension obeu-dimension:organization ;
    qb:componentAttachment qb:DataSet ],
  [ qb:dimension obeu-dimension:budgetPhase ],
  [ qb:dimension eu-dimension:operationCharacter ],
  [ qb:dimension obeu-dimension:fiscalYear ],
  [ qb:dimension eu-dimension:budgetNomenclature ],
  [ qb:dimension eu-dimension:catpol ],

  [ qb:attribute obeu-attribute:currency ;
    qb:componentRequired true ;
    qb:componentAttachment qb:DataSet ],
  [ qb:attribute eu-attribute:reserve ;
    qb:componentRequired false ],

  [ qb:measure obeu-measure:amount ] .

```

11 - <http://www.w3.org/TR/skos-reference/#semantic-relations>

12 - <http://www.w3.org/TR/vocab-data-cube/#dsd>

Here, the DSD is composed of 3 reused dimensions (obeu-dimension:organization, obeu-dimension:budgetPhase, obeu-dimension:fiscalYear), 3 newly defined dimensions (eu-dimension:operationCharacter, eu-dimension:budgetNomenclature, eu-dimension:catpol), 1 reused attribute (obeu-attribute:currency), 1 newly defined attribute (eu-attribute:reserve), and 1 reused measure (obeu-measure:amount). The obeu-dimension:organization dimension has the qb:componentAttachment property set to qb:DataSet. This is because its value will be the European Union for each observation in the dataset and therefore it is not necessary to specify it for each observation separately. The same goes for the obeu-attribute:currency attribute which, in addition, has the qb:componentRequired property set to true, because every dataset in OpenBudgets.eu should have the currency specified. Not every observation in the EU budget dataset has to have a eu-attribute:reserve specified though, and therefore this attribute is not required to be specified for each observation.

Once the DSD is set, the thing left to do is the actual transformation of the source data to the observations in RDF which form the target data cube. Note that a single source dataset may be split into multiple qb:DataSets that may be structured according to different DSDs. Doing this allows to simplify complex datasets and maintain high fidelity of their representation in RDF.

Modelling patterns

Having described the core mechanisms of building DSDs, we continue with a description of more high-level data modelling patterns. Following these patterns influences design of DSDs.

LOSSLESS MAPPING

We recommend to attempt a lossless data conversion when mapping source data to RDF. Even when the source dataset contains measures that can be derived from other measures, it is better to preserve them in the RDF mirror of this dataset. Recomputing measures may be complicated in case several data points need to be used as input or the result of computation may be skewed by rounding error. By preserving the source data you preserve the authoritative values present in it.

MULTI-CURRENCY DATASETS

For datasets that capture financial amounts in multiple currencies we recommend using both the `obeu-dimension:currency` dimension and the `obeu-attribute:currency` attribute. The currency dimension distinguishes between observations in different currencies such as the amount in euros (EUR) and the amount in Czech crowns (CZK), while the attribute specifies the currency for each observation consistent with single currency datasets, which improves consistency across datasets.

As examples of observations of a multi-currency dataset we picked the EU fishing subsidies fund 2007-2013 for the Czech Republic which indicates amounts both in EUR and CZK. Note that the measure property and the `qb:measureType` dimensions are the same and the only thing distinguishing between the two observations is the value of the currency dimension. The measure `eu-measure:amountCZ` indicates an amount paid by the Czech Republic, i.e. "CZ" in the identifier of the measure does not denote the currency. The currency attribute is then provided to interpret the value in the same way as that in the single currency case:

```
<http://data.openbudgets.eu/resource/observation/eu-fishing-subsidies-CS-2007-2013/expenditure/Ministry_of_Agriculture_(Czech_Republic)/2.1a/CZ25170538/EUR/amountCZ> a qb:Observation ;
    obeu-dimension:currency obeu-currency:EUR ;
    obeu-attribute:currency obeu-currency:EUR ;
    qb:measureType eu-measure:amountCZ ;
    eu-measure:amountCZ 13829.87 ;
    qb:dataSet <http://data.openbudgets.eu/resource/dataset/eu-fishing-subsidies-CS-2007-2013> .
<http://data.openbudgets.eu/resource/observation/eu-fishing-subsidies-CS-2007-2013/expenditure/Ministry_of_Agriculture_(Czech_Republic)/2.1a/CZ25170538/CZK/amountCZ> a qb:Observation ;
    obeu-dimension:currency obeu-currency:CZK ;
    obeu-attribute:currency obeu-currency:CZK ;
    qb:measureType eu-measure:amountCZ ;
    eu-measure:amountCZ 345000.0 ;
    qb:dataSet <http://data.openbudgets.eu/resource/dataset/eu-fishing-subsidies-CS-2007-2013> .
```

DATA NORMALIZATION

There are 2 key ways to normalize DCV data cubes.

According to DCV, a data cube is called normalized, if all its components are attached at the level of `qb:Observation`.¹³ This is not always the case as DCV also supports other types of component attachment, i.e. observations, slices, measure properties or the dataset entity. One normalization way is therefore to reattach values of all components that do not have `qb:componentAttachment` set to observations (`qb:Observation`), which simplifies querying the data, while increasing data redundancy. We illustrate data normalization via component attachment in examples 9 to 11. As each implementation of RDF store leads to specific querying behaviors for different ways of component attachment, the choice of the component attachment matters especially for larger datasets. Different ways of attachments represent the same meaning. What changes are only the number of triples and the complexity of queries.

¹³ - http://www.w3.org/TR/vocab-data-cube/#h2_normalize

The second normalization way is to reattach data about linked entities. Linked data can be structured using the star schema (see Appendix B for example) or the fully denormalized schema (see Appendix C for example). In this sense, the representation that is favoured by DCV and linked data principles is the normalized star or snowflake schema. However, as with component attachment the choice of normalization schema can affect queries both in terms of complexity and performance. For instance, (Jakobsen et al., 2015) found that data following the snowflake pattern is around 6 times slower to query using Openlink Virtuoso¹⁴ RDF store than the same data denormalized. However, the contrary holds for the Apache Jena¹⁵ RDF store, in which the snowflake pattern is generally faster. Data denormalization is thus recommended for Openlink Virtuoso, while it should be avoided in Jena that does not cope that well with the increased data size. The denormalized pattern is better for static data. If data changes frequently, then the cost of updates may surpass the benefits gained from denormalization. However, in the context of fiscal data we suggest using immutable snapshots of data, so that data does not change in place.

SLICES AS VIEWS

If you want to model a subset of a dataset, you can describe it as a dataset's slice (instance of qb:Slice). Data publishers may decide to split a dataset into multiple slices to ease consumption. For example, all dimensions except a temporal one can be grouped into the temporal slice to produce time series. Similarly, publishers may decide to reduce dimensionality of their datasets in order to make them fit the tabular format (e.g., an Excel file). If datasets views are published as slices of a single dataset, it simplifies integration of this dataset. Since the structure of the dataset is explicitly described in a DSD and the structure of its slices is described using instances of qb:SliceKey, slices can be automatically merged to form a unified dataset. Data publishers may also use slices to explicitly convey that only a particular subset of data is disclosed, while the remaining data is kept withheld. Consumers can infer this by comparing components included in the dataset's DSD and the components included in the slice's slice key.

Conversely, when data consumer recognizes that some published non-RDF data belongs to a single dataset, they can represent it in RDF using slices to maintain the identity and separation of the published data, while integrating the data in a single dataset.

VERSIONING VIA SNAPSHOTS

In the course of budget formulation several versions of budget are created. We recommend using immutable snapshots of DCV datasets to represent versions of the same data. Newer snapshots of a dataset should link the qb:DataSet instance by dcterms:replaces to the qb:DataSet instance in the previous snapshot.

Snapshots should be used for versions of budget during its life cycle. For example, there can be a snapshot for a proposed budget and an approved budget. This technique of versioning should not be used for correction of minor errors. If each fix required a new snapshot of data to be produced, the volume of data would quickly become unwieldy. Instead, data corrections change data in place. Since this way of changing data is not explicit and cannot be observed, dataset metadata should document what changes were made using provenance information (e.g., using the PROV-O Ontology¹⁶).

OPTIONAL PROPERTIES

Many budget datasets are sparse and contains properties that have values only for a fraction of observations in the dataset. Sparsity may be caused by missing data, but there are other legitimate reasons why a property is missing a value. For instance, some spending may be associated with a concrete geographical location, such as for road construction, while other spending may lack such association; typically for services. However, Data Cube Vocabulary is strict when it comes to cardinality of dimensions. According to the Data Cube Vocabulary all dimensions must have exactly one value. Optional use of component properties is allowed only for attributes. Nevertheless, attributes are intended to be used to qualify measures, which does not fit the above-mentioned cases. Hence we decided to extend the Data Cube Vocabulary and derive obeu:OptionalProperty as a subclass from qb:ComponentProperty.

@prefix obeu: <http://data.openbudgets.eu/ontology/> .

14 - <https://github.com/openlink/virtuoso-opensource>

15 - <https://jena.apache.org/>

16 - <http://www.w3.org/TR/prov-o>


```
@prefix qb:          <http://purl.org/linked-data/cube#> .
@prefix rdfs:       <http://www.w3.org/2000/01/rdf-schema#> .
obeu:OptionalProperty a rdfs:Class ;
  rdfs:label "Optional property"@en ;
  rdfs:comment "A property that may not be present for some observations."@en ;
  rdfs:subClassOf qb:ComponentProperty ;
  rdfs:isDefinedBy <http://data.openbudgets.eu/ontology> .
```

You can use `obeu:OptionalProperty` for component properties that may be missing for some observations. Note that observations still need to be uniquely identified by the values of their dimensions. Values of `obeu:OptionalProperty` do not identify observations.

Missing values of dimensions may indicate either errors in data or that the component property is in fact not a dimension. Optional properties should not be used to legitimize missing data. Using placeholders for missing dimension values also legitimizes errors in data and makes them harder to discover. Nor does deleting observations that miss dimension values solve this problem. If missing dimension values indicate errors in data, then using a dimension makes the errors explicit, because a missing value constitutes a clear violation of the integrity condition 11 from the Data Cube Vocabulary.¹⁷ Using optional properties, placeholder values, or deleting observations hides this violation. Instead of using these provisions data publishers should keep the error explicit. These provisions can be then adopted by data consumers when a need for a valid data cube arises.

VERSIONED CODE LISTS

In some datasets,¹⁸ especially the budget ones, each year a slightly different version of a code list may be used. From the modelling point of view, these versions are treated as different code lists. Depending on the documentation of the input data and its code lists, information on changes made to the code lists and their items may be attached to ease data processing across years; i.e. creation of time series. However, there is typically no documentation of the changes which occurred, which makes creating such time series difficult. In order to be able to connect observations into a time series, data described by versioned code lists must be first consolidated and their concepts linked.

Code lists can be linked using SKOS mapping properties,¹⁹ such as `skos:exactMatch`. Linking versions of code lists can be done as needed prior to data consumption as part of data pre-processing using ETL tools.

¹⁷ - <https://www.w3.org/TR/vocab-data-cube/#ic-11>

¹⁸ - For example, in the budget of Aragón (<https://github.com/openbudgets/datasets/tree/master/Aragon>).

¹⁹ - <https://www.w3.org/TR/skos-reference/#mapping>

Validation

When you have an RDF dataset following the proposed data model, there are several ways to test whether it is valid. Besides manual scrutiny, there are few automated tests that can help you to ascertain that the dataset is well-formed. The tests check either syntax or semantics of the dataset.

First, you should verify that the syntax of your dataset is correct. In order to do so, you can use any of the RDF validators available. Most RDF parsers offer syntax validation. For example, Riot from Apache Jena²⁰ can be invoked with the `--validate` parameter to test syntactical validity (e.g., `riot --validate path/to/file.ttl`).

Semantic validity with respect to the integrity constraints defined by DCV can be checked by the Data Cube Validator.²¹ However, note that this tool is intended to be used for small datasets. If you have a larger dataset you can test the integrity constraints using any SPARQL endpoint that exposes the dataset thanks to the constraints being expressed as SPARQL ASK queries.²² If your datasets passes all the constraints, it is considered to be well-formed. Alternatively, you can employ more sophisticated tools such as RDFUnit²³ to perform the validation.

20 - <https://jena.apache.org/documentation/io/>

21 - <http://www.w3.org/2011/gld/validator/qb/qb-validator>

22 - http://www.w3.org/TR/vocab-data-cube/#h3_wf-rules

23 - <http://aksw.org/Projects/RDFUnit.html>

Recommended metadata

We recommend the budget and spending datasets to be described by the metadata proposed in the DCV specification²⁴ and in the DCAT-AP v1.1.²⁵ While we aim for the data to be as self-descriptive as possible, some information required for correct interpretation of data is beyond what can be explicitly formalized. This is why fiscal datasets should link to a textual documentation explaining how the data was created and how it can be used.

An important prerequisite for data reuse is an explicitly specified open licence. We adopt the Open Definition²⁶ to define what an open licence must conform to. When choosing which licence to use, we recommend following the Publisher's Guide to Open Data Licensing.²⁷

In this section, the following prefixes are used:

```
dcat: <http://www.w3.org/ns/dcat#>
dcterms: <http://purl.org/dc/terms/>
foaf: <http://xmlns.com/foaf/0.1/>
schema: <http://schema.org/>
vcard: <http://www.w3.org/2006/vcard/ns#>
```

MANDATORY DATASET METADATA ITEMS

In correspondence with the DCAT-AP v1.1 specification, the following metadata items are recommended for each Dataset:

Dataset IRI (entity of type `dcat:Dataset`)

Dataset name (`dcterms:title`)

Dataset description (`dcterms:description`)

Dataset modified date (`dcterms:modified`)

Publisher IRI (entity of type `foaf:Agent` connected to the dataset via the `dcterms:publisher` property)

Publisher name (`foaf:name`)

Publisher type (`dcterms:type`), from <http://purl.org/adms/publishertype/1.0>

Author of the dataset (entity of type `dcat:contactPoint`)

Name of the author of the dataset (`vcard:fn`)

Email of the author of the dataset (`vcard:hasEmail`)

Temporal coverage of the dataset (`schema:startDate` and `schema:endDate`)

For each Distribution of the Dataset, these items are recommended:

Distribution IRI (entity of type `dcat:Distribution` connected to the dataset via the `dcat:distribution` property)

Distribution modified date (`dcterms:modified`)

Access URL (`dcat:accessURL`)

Download URL (`dcat:downloadURL`)

Media type (`dcat:mediaType`), e.g., <http://www.iana.org/assignments/media-types/application/trig>

File format (`dcterms:format`), from <http://publications.europa.eu/mdr/authority/file-type/index.html>

License (entity of type `dcterms:LicenseDocument` connected to the Distribution via the `dcterms:license` property)

License type (`dcterms:type`), from <http://purl.org/adms/licencetype/1.1>

OPENBUDGETS.EU METADATA IMPLEMENTATION GUIDELINES

Within the OpenBudgets.eu project we work with data modelled according to the Data Cube Vocabulary (DCV). To comply with DCAT-AP v1.1 and to structure the data and metadata in a uniform way, we follow the following guidelines:

The `qb:DataSet` instance complies with the IRI pattern <http://data.openbudgets.eu/resource/dataset/DATASETID>

The named graph containing the data complies with the same IRI pattern <http://data.openbudgets.eu/resource/dataset/DATASETID>

The `dcat:Dataset` instance complies with the IRI pattern

²⁴ - <http://www.w3.org/TR/vocab-data-cube/#metadata>

²⁵ - https://joinup.ec.europa.eu/asset/dcat_application_profile/description

²⁶ - <http://opendefinition.org/>

²⁷ - <https://theodi.org/guides/publishers-guide-open-data-licensing>

<http://data.openbudgets.eu/resource/dataset/DATASETID/metadata>

There is a `dcterms:subject` property linking the `dcat:Dataset` to the `qb:DataSet` instance that it describes.

The named graph containing the metadata complies with the same IRI pattern <http://data.openbudgets.eu/resource/dataset/DATASETID/metadata>

The `dcat:Distribution` instance complies with the IRI pattern <http://data.openbudgets.eu/resource/dataset/DATASETID/metadata/DISTRIBUTIONID>

Where `DISTRIBUTIONID` is different for every distribution of this Dataset (i.e. `rdf-trig`, `csv`, `sparql`, etc.)

The dataset publisher is the project partner responsible for that dataset.

The author of the dataset is the person responsible for that dataset.

Access URL and Download URL for file distributions must both point to the data dump.

For the SPARQL endpoint distribution, the Access URL points to the endpoint. The additional metadata items are not to be used for this type of distribution.

Note that DCAT-AP v1.1 is supported in LinkedPipes ETL - the tool used to produce RDF datasets in OpenBudgets.eu - by two specific components: DCAT-AP Dataset²⁸ and DCAT-AP Distribution²⁹. Nevertheless, this is an open specification and compliant metadata can be also produced in other ways.

28 - <http://etl.linkedpipes.com/components/e-dcatap11dataset>

29 - <http://etl.linkedpipes.com/components/e-dcatap11distribution>

Use cases

To illustrate the data model with complete examples we describe two cases in which the data model was used to describe fiscal data: 2016 budget of Aragón and Czech projects funded from the EU structural funds during the funding period 2007-2013.

ARAGÓN 2016 BUDGET

The budget of the Spanish region of Aragón is split into two datasets: one containing the planned expenditure, and the other containing the planned revenue. The data structure definitions of these datasets are the same except that functional classification is missing in the revenue dataset. Functional classification does not apply to revenue. The dimensions of both datasets contain the dataset-attached obeu-dimension:budgetaryUnit, obeu-dimension:operationCharacter, and obeu-dimension:fiscalYear, plus classification dimensions attached to individual observations, namely aragon-dimension:administrativeClassification, aragon-dimension:economicClassification, and aragon-dimension:fundingClassification. The currency attribute is attached to the dataset and marks all measures to be provided in euro. The core property obeu-measure:amount is reused as the single measure in the datasets. Data structure definitions for both expenditure and revenue can be found in Appendix E. The classification dimensions are derived as subproperties of the respective core classification properties. For instance, aragon-dimension:administrativeClassification is derived from obeu-dimension:administrativeClassification. Each of the classification dimensions is provided with a custom code list. Expenditure and revenue datasets use distinct code lists. The code lists are versioned using snapshots for each year the data is available. The versioning is required by the changes introduced to the code lists over time, which makes it difficult to classify the budgets of Aragón with a single code list per dimension and thus create time series.

However, a cursory analysis revealed that the changes in code list labels are frequently caused by trimming characters from labels. For example, if we compare the 2006 and 2007 versions of the Estructura económica code list, then we can find that the concept 760012 was originally labelled as “Documentos de Planeamiento y apoyo a Técnicos e instrumentos de Planeamiento”, but the next year its label was trimmed to “Documentos de Planeamiento y apoyo a Técnicos e in”. These errors may be caused by capping the maximum length of code list labels. If we decide to reconcile the versions of code list, we may start by replacing the trimmed labels by their complete forms.

EJERCICIO	CENTRO GESTOR	FUNCIONAL	ECONOMICA	FINANCIACION	DESCRIPCION	IMPORTE
2016	1010	1111	100000	91002	Retribuciones básicas de Altos Cargos	2684202,85
2016	1010	1111	100001	91002	Otras remuneraciones de Altos Cargos	297969
2016	1010	1111	110000	91002	Retribuciones básicas Pers. Eventual de Gabinete	117622,12
2016	1010	1111	110001	91002	Otras remuneraciones de Pers. Eventual de Gabinete	132449,24
2016	1010	1111	120000	91002	Sueldos de Personal Funcionario	1463114,04
2016	1010	1111	120005	91002	Trienios de Personal Funcionario	632347,74
2016	1010	1111	120006	91002	Pagas extraordinarias de Personal Funcionario	548205,18
2016	1010	1111	121000	91002	Complemento de destino de Personal Funcionario	662460,48
2016	1010	1111	121001	91002	Complemento específico de Personal Funcionario	594051,96
2016	1010	1111	122002	91002	Otras retribuciones en especie	110000
2016	1010	1111	130000	91002	Salario base de Personal Laboral Fijo	96070,8
2016	1010	1111	130001	91002	Antigüedad de Personal Laboral Fijo	22774,68
2016	1010	1111	130002	91002	Pagas extraordinarias de Personal Laboral Fijo	28788,18
2016	1010	1111	130003	91002	Otras remuneraciones de Personal Laboral Fijo	56025,6

Figure 2: CSV file with expenditure budget of Aragón for 2016

The budget data is published in CSV files by the Government of Aragón in its open data catalogue,³⁰ covering the years from 2006 to 2016. Besides the consolidated form, the budgets are also available in raw, unconsolidated form since 2015. We converted only the consolidated form to RDF. An example of the consolidated spreadsheet for the 2016 expenditure budget can be seen in Figure 2.

Examples of observations in these datasets can be found in Appendix G.

30 - <http://opendata.aragon.es/catalogo/presupuesto-gobierno-aragon-2016>

EU STRUCTURAL FUNDS 2007-2013 IN THE CZECH REPUBLIC

The Ministry of Regional Development of the Czech Republic publishes data on the Czech projects funded from the EU structural funds in the 2007-2013 programming period. There are two views of the data. One is about beneficiaries and the other is about their projects. Both are published as Excel spreadsheets at <http://www.strukturalni-fondy.cz/cs/Informace-o-cerpani/Seznamy-prijemcu>. A fragment of one of these spreadsheets is shown in Figure 3. They overlap in terms of their content, however, each view also contains data that is not available in the other view. The list of beneficiaries contains more data about beneficiaries and data on cancelled projects. The list of projects contains more measures of funding, so that co-financing rate can be computed. It also features short descriptions of projects, their priority axes, reference numbers, and locations where the projects were realized represented as NUTS5/LAU2 codes. We transformed both datasets to RDF described using the OpenBudgets.eu data model.³¹ However, in this use case description we focus on the dataset of projects because of its richer coverage.

Rozhodnutí/Smlouva o poskytnutí dotace (celkové zdroje)	Rozhodnutí/Smlouva o poskytnutí dotace (veřejné prostředky rálkem)	Rozhodnutí/Smlouva o poskytnutí dotace (FI) zřídla	Proplacené prostředky příjemcům - uvolňovaná	Proplacené prostředky příjemcům - uvolňovaná (FI)	Certifikované prostředky (veřejné prostředky)	Certifikované prostředky (EU zdroje)	Kód NUTS	Název NUTS
4041118446,39	3706234999,71	2600257413	3715323035,9	2606427441,6	3658862575,7	2566814782,94	CZ0201529303	Benešov
1282060534	1181842444	841525002	1181842443,61	873972486,63	1181842443,61	873972486,63	CZ0311544256	České Budějovice
90854520,85	90854520,85	73365025,58	80386873,96	64912400,7	80386873,96	64912400,7	CZ0631568414	Havlíčkův Brod
93669567,18	93669567,18	66083879,65	93182020,09	65739915,17	93182020,09	65739915,17	CZ0643584002	Tišnov
189129000	184260435	155055156,05	179099825,25	150712502,76	179099825,25	150712502,76	CZ0321553549	Česká Kubice
3027608584,08	2603025892,05	1826256935	2606819203,3	1828918774,08	2556812734	1793834235,46	CZ0317552046	Tábor
1608083910	1458643115	1187773089	1458643115	1187773089	1457382098,32	1187773089	CZ0534580538	Letohrad
5755121611,1	4910718620,51	3879001191	4981083617,02	3922957011,98	5308266428,54	3884090718,77	CZ0802511633	Bocanovice
2544265162	2259974470	1617271630	2259974469,83	1788317797,55	2259974469,83	1788317797,55	CZ0644584291	Břeclav
1482683625	1355466971	969185993	1340625608,92	958547310,38	1340625608,92	958547310,38	CZ0100500089	Praha 2
4053468974,28	3661166838,26	2675690559	3707965700,37	2709781333,63	3633692116,1	2655502198,45	CZ0411554481	Čheb
4487653701	3529289858	2579310907	3487443950,11	2548624038,73	3396159137,83	2548624038,73	CZ0327541559	Kočov
783635575,74	703122246,83	586298485	693282389,15	591913432,5	676425411,4	476989312,97	CZ0313546089	České Velenice
4642493519,11	4212506784,08	3246199852	4233472132,01	3262313624,41	3804997926,27	3176425702,99	CZ0202531057	Beroun
6101053636,03	5473694297,67	3897516656	5461681179,91	3888716999,42	4876559098,12	3737255670,37	CZ0201529303	Benešov
2792347142,56	2455803201,27	1939851227	2489248629,33	1945798528,49	2264371241,68	1870656255,19	CZ0802598062	Bystrice
4375524991,62	3751783632,16	2891161984	3751320770,27	2890767784,87	3447592606,34	2890767784,87	CZ0326541150	Kamenný Újezd
341360062,22	312057318,93	256389413	330206192,7	271532506,93	301578007,31	247535228,17	CZ0723542725	Horní Lideč

Figure 3: Excel spreadsheet with data on the EU structural funds 2007-2013 in the Czech Republic

We split the projects dataset into two DCV data cubes; one representing the projects and the other representing the project statuses over time. The data structure definition of the part about projects consists of seven dimensions, one optional property, one attribute (obeu-attribute:currency), and one measure (obeu-measure:amount). Six of the seven component properties are reused from the core OpenBudgets.eu data model: obeu-dimension:operationCharacter, obeu-dimension:organization, obeu-dimension:partner, obeu-dimension:project, obeu-dimension:date, and obeu-dimension:paymentPhase. The dimension esf-dimension:operationalProgramme was derived as a subproperty of obeu-dimension:programmeClassification. It represents the operational programme under which the projects were funded. The optional property obeu-optional:location is used to describe the locations where the projects were realized. The payments contained in this dataset go through a sequence of phases. Funding is first allocated, then paid, and finally certified, in which the certification authority verifies the beneficiary adhered to the funding rules. For each phase the dataset features the amounts funded by the EU and the co-financing from the budget of the Czech Republic. Both data structure definitions can be found in Appendix D.

The data structure of the part that describes project statuses contains two dimensions and one measure. The dimensions include obeu-dimension:project to reference the project and obeu-dimension:date that indicates the time at which the status was reported. Unlike typical measures, the measure esf-measure:projectStatus is not numeric. Instead, its values are constrained by a code list. The measure identifies the project's status. For example, the valid values of this measure include an undergoing or cancelled project. Examples of observations in this dataset can be found in Appendix E.

31 - <https://github.com/openbudgets/datasets/tree/master/ESF-CZ/2007-2013>

Analysis of the reuse of the data model

We analysed 195 DSDs in the repository of the OpenBudgets.eu datasets (<https://github.com/openbudgets/datasets>). These DSDs contains 309 distinct component properties. The analysis was done with the datasets available on August 4, 2016.

CORE COMPONENT PROPERTIES

The most commonly reused core component properties correspond to the properties that are designated as mandatory: obeu-attribute:currency, obeu-dimension:fiscalPeriod, obeu-dimension:operationCharacter, obeu-dimension:organization, and obeu-measure:amount. If the mandatory property is missing in a DSD, it is substituted with its subproperty.

Component property	Frequency
obeu-attribute:currency	193
obeu-measure:amount	191
obeu-dimension:operationCharacter	188
obeu-dimension:fiscalYear	186
obeu-dimension:organization	167
obeu-dimension:budgetaryUnit	25
obeu-dimension:project	6
obeu-dimension:date	5
obeu-dimension:partner	4
obeu-dimension:budgetPhase	3
obeu-dimension:administrativeClassification	1
obeu-dimension:fiscalPeriod	1
obeu-dimension:location	1

Table 3: Frequency of direct reuse of the core component properties

CORE COMPONENT SUPERPROPERTIES

The most common core properties from which subproperties are derived as the classifications ones. These properties are defined as abstract, so they should not be directly reused. They need to be provided with a custom code list, which warrants minting a specific subproperty.

Component property	Frequency
obeu-dimension:classification	191
obeu-dimension:administrativeClassification	185
obeu-dimension:economicClassification	185
obeu-dimension:functionalClassification	174
obeu-dimension:programmeClassification	4
obeu-dimension:budgetPhase	1
obeu-dimension:operationCharacter	1
obeu-measure:amount	1

Table 4: Frequency of reuse of the core component properties as superproperties

UNUSED CORE PROPERTIES

Six out of the 23 component properties defined by the OpenBudgets.eu data model were never used in the OpenBudgets.eu datasets. It reflects what is missing in the currently available datasets published by public bodies. However, the unused properties may find their use in applications for creating fiscal data from scratch. In this setting, the data model can have an instructive value suggesting what kinds of data should be published. While there is an option of deprecating the unused properties or removing them from the data model, the only downside of keeping them in the data model is a potential confusion of the data model's users leading to inconsistent application of these properties.

Component property
obeu-attribute:taxesIncluded
obeu-dimension:accountingRecord
obeu-dimension:budgetLine
obeu-dimension:currency
obeu-dimension:taxesIncluded
obeu-optional:contract

Table 5: Unused core component properties

CODE LISTS

What is perhaps alarming is the low reuse of code lists in the datasets. Only a handful of code lists were used more than once. These are listed below. We omitted the code lists that are specific to a single dataset. In total, there are 291 code lists used in OpenBudgets.eu datasets.

The low reuse of code lists indicates a potential problem for comparability of the OpenBudgets.eu datasets. In effect, in order to improve comparability, more effort will need to be spent on linking these code lists.

No core code lists are reused for dataset-specific component properties. Instead, the core code lists are reused indirectly via the core component properties that are defined to have values from the core code lists.

Code list	Frequency
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2006/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2007/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2008/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2009/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2010/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2011/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2012/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2013/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2014/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2015/	2
http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2016/	2
http://data.openbudgets.eu/resource/codelist/kae-ota-administration-2014	2
http://data.openbudgets.eu/resource/eu-budget-2014/codelist/budget-nomenclature-2014	2

Table 6: Frequency of reuse of code lists

Data model reference

In this section we present a comprehensive reference of the OpenBudgets.eu core data model. We list the core component properties defined for budget and spending data along with the core entities that are described using these properties. Additionally, we describe the linked entities that are modelled outside of the DCV model. These entities are linked via the component properties from DCV datasets.

CORE PROPERTIES

The core data model of OpenBudgets.eu defines 19 dimensions, 2 attributes, and 1 measure. Additionally, the model defines 2 extra properties not included in the data cube model.

Dimensions

accounting record

IRI: `obeu-dimension:accountingRecord`

Description: Link to an accounting record (e.g., invoice, credit note) associated with expenditure or revenue.

Allowed values: `foaf:Document`

Example value:

```
:document a foaf:Document;  
    dcterms:issued "2015-11-04"^^xsd:date .
```

administrative classification

IRI: `obeu-dimension:administrativeClassification`

Description: Identifies the entity responsible for managing the public funds concerned. For example, it can be used to specify a department of an organization. This is an abstract property that should not be used directly. Instead, a subproperty with a concrete code list should be created.

Allowed values: `skos:Concept`

Super-property: `obeu-dimension:classification`

Example

	value:
<code><http://publications.europa.eu/resource/authority/corporate-body/ECHA></code>	a <code>skos:Concept</code> ;
	<code>skos:notation</code> "ECHA" ;
<code>skos:broader</code> <code><http://publications.europa.eu/resource/authority/corporate-body/EURAG></code>	; ;
	<code>skos:inScheme</code> <code>atold:corporate-body</code> ;
<code>skos:prefLabel</code>	"Европейска агенция по химикали"@bg, "Evropská agentura pro chemické látky"@cs, "Det Europæiske Kemikalieagentur"@da, "Europäische Chemikalienagentur"@de, "Ευρωπαϊκός Οργανισμός Χημικών Προϊόντων"@el, "European Chemicals Agency"@en, "Agencia Europea de Sustancias y Preparados Químicos"@es, "Euroopa Kemikaaliamet"@et, "Euroopan kemikaalivirasto"@fi, "Agence européenne des produits chimiques"@fr, "An Ghníomhaireacht Eorpach Ceimiceán"@ga, "Europska agencija za kemikalije"@hr, "Európai Vegyianyag-ügynökség"@hu, "Agenzia europea per le sostanze chimiche"@it, "Europos cheminių medžiagų agentūra"@lt, "Eiropas Ķīmisko vielu aģentūra"@lv, "L-Aġenzija Ewropea għas-Sustanzi Kimiċi"@mt, "Europees Agentschap voor chemische stoffen"@nl, "Europejska Agencja Chemikaliów"@pl, "Agência Europeia dos Produtos Químicos"@pt, "Agenția Europeană pentru Produse Chimice"@ro, "Európska chemická agentúra"@sk, "Evropska agencija za kemikalije"@sl,

budget line

IRI: obeu-dimension:budgetLine

Description: Budget line from which the payment draws its funds. See also the Budget line in the Core entities section.

Allowed values: qb:Observation

Example value: <<http://data.openbudgets.eu/resource/observation/eu-fishing-subsidies-CS-2007-2013/EUR/amountCZ>>

budget phase

IRI: obeu-dimension:budgetPhase

Description: Major event or stage in the budget cycle.

Allowed values: obeu:BudgetPhase

Code list: obeu-codelist:budget-phase

Example value: obeu-budgetphase:draft

budgetary unit

IRI: obeu-dimension:budgetaryUnit

Description: Deprecated. Use obeu-dimension:organization instead. This property was deprecated because it was not sufficiently distinct from the obeu-dimension:organization, which is more generic, hence applicable in more contexts.

Allowed values: org:Organization

Example value: <<http://reference.data.gov.uk/id/department/justice>>

classification

IRI: obeu-dimension:classification

Description: Category to which the observation belongs.

Allowed values: skos:Concept

Example value: This property is abstract, so it is not expected to be used directly. Either use a more specific property or create your own subproperty of this one.

currency

IRI: obeu-dimension:currency

Description: Currency of a financial amount.

Allowed values: obeu:Currency

Code list: Currencies Authority Table³²

Example value: <<http://publications.europa.eu/resource/authority/currency/EUR>>

date

IRI: obeu-dimension:date

Description: Date when expense was paid or revenue received.

Allowed values: time:Interval

Example value:

```
:2015-11-01 a time:Interval ;  
  time:hasBeginning :2015-11-01T00-00-00Z ;  
  time:hasEnd :2015-11-01T00-00-00Z .
```

```
:2015-11-01T00-00-00Z a time:Instant ;  
  time:inXSDDateTime "2015-11-01T00:00:00Z"^^xsd:dateTime .
```

economic classification

IRI: obeu-dimension:economicClassification

Description: Groups revenue according to its source and expenditure according to the type of the economic activity the government undertakes. For example, economic classification may include compensation of employees or subsidies for expenditure and tax revenue or property income for revenue. This is an abstract property that should not be used directly. Instead, a subproperty with a concrete code list should be created.

Allowed values: skos:Concept

Super-property: obeu-dimension:classification

³² - <http://publications.europa.eu/mdr/authority/currency/index.html>

Example value:

```
<http://data.openbudgets.eu/resource/codelist/esa2010-distributive-transactions/D.211> a skos:Concept ;
  skos:prefLabel "Value added type taxes (VAT)"@en ;
  skos:notation "D.211" ;
  skos:broader <http://data.openbudgets.eu/resource/codelist/esa-2010-classification-of-transactions-and-other-flows-
/D.21> ;
  skos:inScheme <http://data.openbudgets.eu/resource/codelist/esa-2010-classification-of-transactions-and-other-
flows> .
```

fiscal period

IRI: obeu-dimension:fiscalPeriod

Description: The period of time reflected in financial statements.

Allowed values: time:Interval

Example value:

```
<http://reference.data.gov.uk/id/quarter/2012-Q1> a interval:Quarter ;
  time:hasBeginning <http://reference.data.gov.uk/id/gregorian-instant/2012-01-01T00:00:00> ;
  time:hasEnd <http://reference.data.gov.uk/id/gregorian-instant/2012-04-01T00:00:00> .
```

fiscal year

IRI: obeu-dimension:fiscalYear

Description: The year reflected in financial statements.

Allowed values: interval:Year

Super-property: obeu-dimension:fiscalPeriod

Example value: <http://reference.data.gov.uk/id/year/2012>

functional classification

IRI: obeu-dimension:functionalClassification

Description: Classifies expenditure or revenue by general government sector and by its purpose. This is an abstract property that should not be used directly. Instead, a subproperty with a concrete code list should be created.

Allowed values: skos:Concept

Super-property: obeu-dimension:classification

Example value:

```
<http://unstats.un.org/unsd/cr/references/cofog/version1/09> a skos:Concept ;
  skos:notation "09" ;
  skos:prefLabel "Educación"@es, "Education"@en,
  "Enseignement"@fr, "Образование"@ru ;
  skos:inScheme <http://unstats.un.org/unsd/cr/references/cofog/version1/> .
```

operation character

IRI: obeu-dimension:operationCharacter

Description: Distinguishes among expenditure and revenue.

Allowed values: obeu:OperationCharacter

Code list: obeu-codelist:operation-character

Example value: obeu-operation:expenditure

organization

IRI: obeu-dimension:organization

Description: An economic entity that is capable, in its own right, of owning assets, incurring liabilities, and engaging in economic activities and in transactions with other entities. Organization figures as the "subject" in data. In case of expenditure, the organization pays the partner. In case of revenue, the organization is paid by the partner. In fiscal datasets, the organization is usually the same throughout the dataset and corresponds with the publisher of the dataset.

Allowed values: org:Organization

Example value:

```
<http://reference.data.gov.uk/id/department/dclg> a org:Organization ;
  rdfs:label "Department for Communities and Local Government" .
```

partner

IRI: obeu-dimension:partner

Description: The entity to which the payment was made or from which the revenue was collected. Partner figures as the "object" in data. In case of expenditure, the organization pays the partner, while in case of revenue the organization is paid by the partner.

Allowed values: org:Organization

Example value:

```
:organization a org:Organization;
  rdfs:label "ACME Corp." .
```

payment phase

IRI: obeu-dimension:paymentPhase

Description: Indicates the phase of payment.

Allowed values: obeu:PaymentPhase

Code list: obeu-codelist:payment-phase

Example value:

```
obeu-paymentphase:certified a skos:Concept, obeu:PaymentPhase ;
  skos:prefLabel "Certified"@en ;
  skos:topConceptOf obeu-codelist:payment-phase ;
  skos:inScheme obeu-codelist:payment-phase .
```

programme classification

IRI: obeu-dimension:programmeClassification

Description: Grouping of expenditure or revenue by common objective. This is an abstract property that should not be used directly. Instead, a subproperty with a concrete code list should be created.

Allowed values: skos:Concept

Super-property: obeu-dimension:classification

Example value:

```
eff:2 a skos:Concept ;
  skos:notation "2" ;
  skos:prefLabel "Aquaculture, processing and marketing of fishery and aquaculture products"@en ;
  skos:narrower eff:2.1 ;
  skos:topConceptOf <http://example.openbudgets.eu/resource/eu-fishing-subsidies-2007-2013/codelist/eu-fishing-subsidies-2007-2013> .
```

project

IRI: obeu-dimension:project

Description: Project associated with a payment.

Allowed values: foaf:Project

Example value:

```
:project a foaf:Project ;
  foaf:name "Renovation of playgrounds" .
```

taxes included

IRI: obeu-dimension:taxesIncluded

Description: Indicates whether the reported amount includes taxes.

Allowed values: xsd:boolean

Example value: false

Attributes

currency

IRI: obeu-attribute:currency

Description: Currency of a financial amount.

Allowed values: obeu:Currency

Code list: Currencies Authority Table

Example value: obeu-currency:CZK

taxes included

IRI: obeu-attribute:taxesIncluded

Description: Indicates whether the reported amount includes taxes.

Allowed values: xsd:boolean

Example value: true

Optional properties

contract

IRI: obeu-optional:contract

Description: Public contract for which the payment is made.

Compatible with: qb:Observation

Allowed values: pc:Contract

Example value:

```
:contract a pc:Contract ;
  pc:contractingAuthority :authority ;
  pc:awardedTender [
    pc:bidder :supplier ;
    pc:offeredPrice [
      a gr:PriceSpecification ;
      gr:hasCurrencyValue 1000000.0 ;
      gr:hasCurrency "EUR"
    ]
  ] .
```

location

IRI: obeu-optional:location

Description: Physical location affected by a payment.

Allowed values: schema:Place

Example

value:

```
:place a schema:Place ;
  schema:geo [
    a schema:GeoCoordinates ;
    schema:latitude 50.088382 ;
    schema:longitude 14.403665
  ] .
```

Measures

amount

IRI: obeu-measure:amount

Description: Monetary amount.

Allowed values: xsd:decimal

Example value: 3141.59

Extra properties

The extra properties do not fit the DCV model, so they are defined as regular RDF properties.

Methodology used

IRI: obeu-metadata:methodologyUsed

Description: A link to the document describing the methodology that was used a data structure definition.

Compatible with: qb:DataStructureDefinition

Allowed values: foaf:Document

Example value:

```
:document a foaf:Document;
  foaf:name "A budget methodology" ;
  foaf:homepage <http://example.org/budget/methodology/> .
```

CORE ENTITIES

The core entities of the OpenBudgets.eu data model are represented as instances of qb:Observation from DCV. The observations can form a part of either budget or spending data. The OpenBudgets.eu directly reuses qb:Observation instead of a specific subclass³³ to maintain compatibility with existing tools for processing DCV data.

Budget line (qb:Observation)

Budget line is an identified amount allocated for a specific purpose.³⁴

```
<http://data.openbudgets.eu/resource/dataset/eu-budget-2014/observation/Executed/Expenditure/2012/XX-01-01-01-02/5.2.3X> a qb:Observation ;
  qb:dataSet <http://data.openbudgets.eu/resource/dataset/eu-budget-2014> ;
  obeu-dimension:budgetPhase obeu-budgetphase:executed ;
  eu-dimension:operationCharacter obeu-operation:expenditure ;
  obeu-dimension:fiscalYear <http://reference.data.gov.uk/id/year/2012> ;
  eu-dimension:budgetNomenclature <http://data.openbudgets.eu/resource/codelist/eu-budget-nomenclature/XX-01-01-01-02> ;
  eu-dimension:catpol <http://data.openbudgets.eu/resource/codelist/catpol/5.2.3X> ;
  obeu-measure:amount 13301985.81 .
```

Expenditure line (qb:Observation)

An item of expenditure that can be classified or assigned to a cost centre.^{35,36}

```
<http://data.openbudgets.eu/resource/observation/eu-fishing-subsidies-CS-2007-2013/Expenditure/Ministry_of_Agriculture_(Czech_Republic)/2.1a/CZ25170538/1/EUR/amountCZ> a qb:Observation ;
  obeu-dimension:currency eu-currency:EUR ;
  obeu-attribute:currency eu-currency:EUR ;
  qb:measureType eu-measure:amountCZ ;
  eu-measure:amountCZ 13829.87 ;
  qb:dataSet <http://data.openbudgets.eu/resource/dataset/eu-fishing-subsidies-CS-2007-2013> .
```

LINKED ENTITIES

Code list concept (skos:Concept)

The core code list concepts are represented as SKOS concepts and the code lists themselves are SKOS Concept schemes. For each concept scheme a class is also defined and each concept of the concept scheme belongs to this class. We recommend to reuse code lists published by an authoritative body, such as the Publications Office of the European Union³⁷ or the interval URIs³⁸ maintained by Data.gov.uk.

Budget phase

Budget phase distinguishes among phases of the budget. We specify 4 core budget phases, Draft, Revised, Approved and Executed.

```
obeu:BudgetPhase a rdfs:Class ;
  rdfs:label "Budget phase"@en ;
  rdfs:isDefinedBy <http://data.openbudgets.eu/ontology> .

obeu-codelist:budget-phase a skos:ConceptScheme ;
  rdfs:label "Code list that distinguishes among phases of the budget."@en ;
  skos:hasTopConcept obeu-budgetphase:draft, obeu-budgetphase:revised, obeu-budgetphase:approved, obeu-budgetpha-
```

33 - For example, the Payments Ontology provides the class pay:Payment as a specific subclass of qb:Observation.

34 - "Budget line" is a widely disputed term (European Court of Auditors, 2013, p. 20). But, however flawed it may be, it is the most recognized term for the concept.

35 - Definition reused from the Payments Ontology (<https://data.gov.uk/resources/payments>).

36 - A cost centre is a part of an organization to which costs may be charged for accounting purposes.

37 - <http://publications.europa.eu/mdr/authority>

38 - <http://www.epimorphics.com/using-interval-set-uris-in-statistical-data>

```
se:executed .
```

```
obeu-budgetphase:draft a skos:Concept, obeu:BudgetPhase ;  
  skos:prefLabel "Draft"@en ;  
  skos:topConceptOf obeu-codelist:budget-phase ;  
  skos:inScheme obeu-codelist:budget-phase .
```

```
obeu-budgetphase:revised a skos:Concept, obeu:BudgetPhase ;  
  skos:prefLabel "Revised"@en ;  
  skos:topConceptOf obeu-codelist:budget-phase ;  
  skos:inScheme obeu-codelist:budget-phase .
```

```
obeu-budgetphase:approved a skos:Concept, obeu:BudgetPhase ;  
  skos:prefLabel "Approved"@en ;  
  skos:topConceptOf obeu-codelist:budget-phase ;  
  skos:inScheme obeu-codelist:budget-phase .
```

```
obeu-budgetphase:executed a skos:Concept, obeu:BudgetPhase ;  
  skos:prefLabel "Executed"@en ;  
  skos:topConceptOf obeu-codelist:budget-phase ;  
  skos:inScheme obeu-codelist:budget-phase .
```

Classification

Revenue and expenditure are grouped based on common characteristics. Several different criteria may be used for grouping revenue and expenditure via classifications. Classifications constitute a basic information system that enables an objective breakdown of the operations performed by the public sector.³⁹

There are 4 main types of budget and spending classifications: administrative, economic, functional, and programme. Usually, classifications are organized hierarchically, so that major categories break down into narrower categories. Several guiding principles can be used when you try to recognize what kind of classification is used in a fiscal dataset:

In case of administrative classification each category of the most detailed breakdown will be equal to a single organization or its units.

In case of economic classification the major categories for revenue are taxes and other revenues and for expenditure these categories include current (operational) and capital (investment) expenditure. The major categories of current expenditures are wages, purchases, and transfers.

The distinction between functional and programme classification is not always clear: functional classification organizes government activities according to their purpose and programme classification according to government policy objectives. While functional classification can be in place for years, programme classification should reflect current policy documents (Allen & Tommasi, 2001, p. 126).

Currency

Currency is specified by an entity and its label, it is connected to qb:Observations through the obeu-attribute:currency and obeu-dimension:currency component properties.

```
:observation obeu-attribute:currency obeu-currency:czk .
```

```
obeu-currency:czk skos:prefLabel "Czech koruna" ;  
  skos:notation "CZK" .
```

Operation character

Operation character distinguishes among characters of fiscal operation. We specify two core operation characters, Expenditure and Revenue.

```
obeu:OperationCharacter a rdfs:Class ;
```

³⁹ - <http://www.mecon.gov.ar/consulta/ingles/glosario.html>

```

rdfs:label "Operation character"@en ;
rdfs:isDefinedBy <http://data.openbudgets.eu/ontology> .

obeu-codelist:operation-character a skos:ConceptScheme ;
  rdfs:label "Code list that distinguishes among characters of fiscal operation."@en ;
  skos:hasTopConcept obeu-operation:expenditure, obeu-operation:revenue .

obeu-operation:expenditure a skos:Concept, obeu:OperationCharacter ;
  skos:prefLabel "Expenditure"@en ;
  skos:definition "Decrease in net worth resulting from a transaction and the net investment in nonfinancial assets"@en ;
  skos:topConceptOf obeu-codelist:operation-character ;
  skos:inScheme obeu-codelist:operation-character .

obeu-operation:revenue a skos:Concept, obeu:OperationCharacter ;
  skos:prefLabel "Revenue"@en ;
  skos:definition "An increase in net worth resulting from a transaction"@en ;
  skos:topConceptOf obeu-codelist:operation-character ;
  skos:inScheme obeu-codelist:operation-character .

```

Interval (time:Interval)

Temporal intervals are represented using the Time Ontology in OWL.⁴⁰ Intervals are delimited by 2 instants (time:Instant). Each instant is represented using the xsd:dateTime data type associated via the time:inXSDDateTi-me property. If source data contains only dates expressed by the xsd:date data type, you can coerce them into xsd:dateTime by appending T00:00:00.

In case a single point in time is associated with a fiscal data item, both instants delimiting the interval are the same. To prevent data duplication in such case, IRIs should be used to identify instances of time:Instant. This way the instant can be described once and reused many times.

For longer intervals representing fiscal periods, such as quarter or year, established IRIs from the http://reference.data.gov.uk/id/ namespace (e.g., http://reference.data.gov.uk/id/year/2014 for the year 2014) should be reused.

Organization (org:Organization)

Organizations, including budgetary units or project partners, are represented as instances of the org:Organization class from the Organization Ontology.⁴¹ You can use the means provided by this ontology to further describe the organizations.

Place (schema:Place)

Locations where money is spent are represented as instances of the schema:Place class from the Schema.org.⁴²

Accounting record (foaf:Document)

Accounting records are represented as instances of the foaf:Document class from the Friend of a Friend vocabulary.⁴³ They can be further described by the Dublin Core⁴⁴ vocabulary.

Project (foaf:Project)

Projects are represented as instances of the foaf:Project class from the Friend of a Friend vocabulary.

40 - <http://www.w3.org/TR/owl-time/>

41 - <http://www.w3.org/TR/vocab-org/>

42 - <http://schema.org>

43 - <http://xmlns.com/foaf/spec/>

44 - <http://dublincore.org/documents/dcmi-terms/>

Contract (pc:Contract)

Public contracts are represented as instances of the pc:Contract class from the Public Contracts Ontology.⁴⁵

45 - <https://github.com/opendatacz/public-contracts-ontology>

Conclusion

We described the OpenBudgets.eu data model that was designed to support the use cases dealing with fiscal data in the OpenBudgets.eu project. This deliverable presents a final version of the data model that incorporates feedback from a year of its use within the OpenBudgets.eu project. Since the scope of the project covers a large variety of datasets from the fiscal domain, the data model was consequently built to accommodate heterogeneous data structures. A fundamental element of its design is that of reusable component properties that can be composed on demand to form data structure definitions for multidimensional fiscal datasets. While there is a slight bias towards the EU context, the data model's design direction made it generic and fit to reuse beyond the scope of the OpenBudgets.eu project in other efforts that require modelling of fiscal data.

The data model will be maintained until the end of the OpenBudgets.eu project. Since the data model reached its final version, during this period we intend not to introduce any breaking changes that are not backwards compatible.

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Appendix A: Codelist extension example

```
# ----- DSD-specific namespaces -----

@prefix eu-attribute:    <http://example.openbudgets.eu/ontology/dsd/eu-budget-2014/attribute/> .
@prefix eu-dimension:   <http://example.openbudgets.eu/ontology/dsd/eu-budget-2014/dimension/> .
@prefix eu-measure:     <http://example.openbudgets.eu/ontology/dsd/eu-budget-2014/measure/> .
@prefix eu-codelist:    <http://example.openbudgets.eu/resource/eu-budget-2014/codelist/> .
@prefix eu-operation:   <http://example.openbudgets.eu/resource/eu-budget-2014/codelist/operation-character/> .

# ----- OpenBudgets.eu namespaces -----

@prefix obeu:           <http://data.openbudgets.eu/ontology/> .
@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
@prefix obeu-measure:   <http://data.openbudgets.eu/ontology/dsd/measure/> .
@prefix obeu-operation: <http://data.openbudgets.eu/resource/codelist/operation-character/> .

# ----- Generic namespaces -----

@prefix qb:             <http://purl.org/linked-data/cube#> .
@prefix rdf:           <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:          <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos:          <http://www.w3.org/2004/02/skos/core#> .
@prefix xsd:           <http://www.w3.org/2001/XMLSchema#> .

eu-dimension:operationCharacter a rdf:Property, qb:CodedProperty, qb:DimensionProperty ;
  rdfs:label "Operation character"@en ;
  rdfs:comment "EU budget's specific operation characters"@en ;
  rdfs:subPropertyOf obeu-dimension:operationCharacter ;
  qb:codeList eu-codelist:operation-character ;
  rdfs:range obeu:OperationCharacter ;
  rdfs:isDefinedBy <http://example.openbudgets.eu/resource/dsd/eu-budget-2014> .

eu-codelist:operation-character a skos:ConceptScheme ;
  rdfs:label "An extended code list of operation characters for the EU budget"@en ;
  skos:hasTopConcept obeu-operation:expenditure, obeu-operation:revenue .

eu-operation:commitment a skos:Concept, obeu:OperationCharacter ;
  skos:prefLabel "Commitment"@en ;
  skos:definition "Total cost of the legal commitments during the current fiscal year."@en ;
  skos:broader obeu-operation:expenditure ;
  skos:inScheme eu-codelist:operation-character .

eu-operation:payment a skos:Concept, obeu:OperationCharacter ;
  skos:prefLabel "Payment"@en ;
  skos:definition "Payments made to honour the legal commitments entered into in the current fiscal year and/or earlier fiscal years."@en ;
  skos:broader obeu-operation:expenditure ;
  skos:inScheme eu-codelist:operation-character .
```

Appendix B: Star schema

```

@prefix interval: <http://reference.data.gov.uk/def/intervals/> .
@prefix qb: <http://purl.org/linked-data/cube#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix scv: <http://purl.org/NET/scovo#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-codelist: <http://data.example.org/resource/codelist/> .
@prefix ex-dataset: <http://data.example.org/resource/dataset/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd: <http://data.example.org/resource/dsd/> .
@prefix ex-geo: <http://data.example.org/resource/codelist/geo/> .
@prefix ex-measure: <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

# Data structure definition
ex-dsd:total-general-government-expenditure a qb:DataStructureDefinition ;
    rdfs:label "Total general government expenditure"@en ;
    qb:component [
        qb:dimension ex-dimension:refPeriod ],
        [ qb:dimension ex-dimension:refArea ],
        [ qb:measure ex-measure:total-general-government-expenditure ],
        [ qb:attribute sdmx-attribute:unitMeasure ;
            qb:componentRequired true ] .

# Dataset
ex-dataset:total-general-government-expenditure a qb:DataSet ;
    rdfs:label "Total general government expenditure"@en ;
    qb:structure ex-dsd:total-general-government-expenditure .

<http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2012> ;
    ex-dimension:refArea ex-geo:EU28 ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 49 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2013> ;
    ex-dimension:refArea ex-geo:EU28 ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 48.6 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2014/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriod <http://reference.data.gov.uk/id/gregorian-year/2014> ;
    ex-dimension:refArea ex-geo:EU28 ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 48.2 .

<http://reference.data.gov.uk/id/gregorian-year/2014> a interval:Year ;
    scv:max "2014-12-31"^^xsd:date ;
    scv:min "2014-01-01"^^xsd:date .

```

```

<http://reference.data.gov.uk/id/gregorian-year/2013>          a          interval:Year          ;
    scv:max          "2013-12-31"^^xsd:date          ;
    scv:min          "2013-01-01"^^xsd:date          .

<http://reference.data.gov.uk/id/gregorian-year/2012>          a          interval:Year          ;
    scv:max          "2012-12-31"^^xsd:date          ;
    scv:min          "2012-01-01"^^xsd:date          .

ex-geo:EU28          a          skos:Concept          ;
    skos:prefLabel          "European Union (28 countries)"@en          ;
    skos:notation          "EU28"          ;
    skos:inScheme ex-codelist:geo .

```

Appendix C: Fully denormalized schema

```

@prefix qb: <http://purl.org/linked-data/cube#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sdmx-attribute: <http://purl.org/linked-data/sdmx/2009/attribute#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

@prefix ex-dataset: <http://data.example.org/resource/dataset/> .
@prefix ex-dimension: <http://data.example.org/ontology/dsd/dimension/> .
@prefix ex-dsd: <http://data.example.org/resource/dsd/> .
@prefix ex-measure: <http://data.example.org/ontology/dsd/measure/> .
@prefix ex-units-of-measure: <http://data.example.org/resource/codelist/units-of-measure/> .

#
# Data structure definition
#
ex-dsd:total-general-government-expenditure a qb:DataStructureDefinition ;
    rdfs:label "Total general government expenditure"@en ;
    qb:component [
        qb:dimension ex-dimension:refPeriodStart ],
        [ qb:dimension ex-dimension:refPeriodEnd ],
        [ qb:dimension ex-dimension:refAreaCode ],
        [ qb:dimension ex-dimension:refAreaLabel ],
        [ qb:measure ex-measure:total-general-government-expenditure ],
        [ qb:attribute sdmx-attribute:unitMeasure ;
            qb:componentRequired true ] .

#
# Dataset
#
ex-dataset:total-general-government-expenditure a qb:DataSet ;
    rdfs:label "Total general government expenditure"@en ;
    qb:structure ex-dsd:total-general-government-expenditure .

<http://data.example.org/resource/observation/total-general-government-expenditure/2012/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriodStart "2012-01-01"^^xsd:date ;
    ex-dimension:refPeriodEnd "2012-12-31"^^xsd:date ;
    ex-dimension:refAreaCode "EU28" ;
    ex-dimension:refAreaLabel "European Union (28 countries)"@en ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 49 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2013/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriodStart "2013-01-01"^^xsd:date ;
    ex-dimension:refPeriodEnd "2013-12-31"^^xsd:date ;
    ex-dimension:refAreaCode "EU28" ;
    ex-dimension:refAreaLabel "European Union (28 countries)"@en ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 48.6 .

<http://data.example.org/resource/observation/total-general-government-expenditure/2014/EU28> a qb:Observation ;
    qb:dataSet ex-dataset:total-general-government-expenditure ;
    ex-dimension:refPeriodStart "2014-01-01"^^xsd:date ;
    ex-dimension:refPeriodEnd "2014-12-31"^^xsd:date ;
    ex-dimension:refAreaCode "EU28" ;
    ex-dimension:refAreaLabel "European Union (28 countries)"@en ;
    sdmx-attribute:unitMeasure ex-units-of-measure:percent-of-GDP ;
    ex-measure:total-general-government-expenditure 48.2 .

```

Appendix D: data structure definitions of EU structural funds 2007-2013 in the Czech Republic

Projects data structure definition

```
# ----- DSD-specific namespaces -----

@prefix esf-class:      <http://data.openbudgets.eu/ontology/esf-czech-projects/class/> .
@prefix esf-codelist:  <http://data.openbudgets.eu/ontology/esf-czech-projects/code-list/> .
@prefix esf-dimension: <http://data.openbudgets.eu/ontology/esf-czech-projects/dimension/> .

# ----- OpenBudgets.eu namespaces -----

@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
@prefix obeu-measure:   <http://data.openbudgets.eu/ontology/dsd/measure/> .
@prefix obeu-optional:  <http://data.openbudgets.eu/ontology/dsd/optional/> .

# ----- Generic namespaces -----

@prefix owl:          <http://www.w3.org/2002/07/owl#> .
@prefix qb:             <http://purl.org/linked-data/cube#> .
@prefix rdf:           <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:          <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema:        <http://schema.org/> .
@prefix sdmx-concept:  <http://purl.org/linked-data/sdmx/2009/concept#> .
@prefix skos:          <http://www.w3.org/2004/02/skos/core#> .

# ----- DSD -----

<http://data.openbudgets.eu/resource/dsd/esf-czech-projects> a qb:DataStructureDefinition ;
  rdfs:label "DSD of Czech ESF projects"@en ;
  qb:component [ qb:dimension obeu-dimension:operationCharacter ;
                qb:componentAttachment qb:DataSet ],
  [ qb:dimension obeu-dimension:organization ],
  [ qb:dimension esf-dimension:operationalProgramme ],
  [ qb:dimension obeu-dimension:partner ],
  [ qb:dimension obeu-dimension:project ],
  [ qb:dimension obeu-dimension:date ],
  [ qb:dimension obeu-dimension:paymentPhase ],
  [ qb:componentProperty obeu-optional:location ],
  [ qb:attribute obeu-attribute:currency ;
    qb:componentRequired true ;
    qb:componentAttachment qb:DataSet ],
  [ qb:measure obeu-measure:amount ] .

# ----- Component properties -----

esf-dimension:operationalProgramme a rdf:Property, qb:DimensionProperty, owl:ObjectProperty ;
  rdfs:label "Operational programme"@en ;
  rdfs:subPropertyOf obeu-dimension:programmeClassification ;
  qb:codeList esf-codelist:operational-programme ;
  rdfs:range esf-class:OperationalProgramme ;
  rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/esf-czech-projects> .

# ----- Code lists -----
```



```

esf-codelist:operational-programme a skos:ConceptScheme ;
  rdfs:label "Code list of operational programmes"@en .

# ----- Classes -----

esf-class:OperationalProgramme a rdfs:Class ;
  rdfs:label "Operational programme"@en ;
  rdfs:subClassOf skos:Concept .
Project statuses data structure definition
# ----- DSD-specific namespaces -----

@prefix esf-class:      <http://data.openbudgets.eu/ontology/esf-czech-projects/class/> .
@prefix esf-codelist:  <http://data.openbudgets.eu/ontology/esf-czech-projects/code-list/> .
@prefix esf-measure:   <http://data.openbudgets.eu/ontology/esf-czech-projects/measure/> .

# ----- OpenBudgets.eu namespaces -----

@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .

# ----- Generic namespaces -----

@prefix owl:          <http://www.w3.org/2002/07/owl#> .
@prefix qb:            <http://purl.org/linked-data/cube#> .
@prefix rdf:           <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:          <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos:          <http://www.w3.org/2004/02/skos/core#> .

# ----- DSD -----

<http://data.openbudgets.eu/resource/dsd/esf-czech-project-statuses> a qb:DataStructureDefinition ;
  rdfs:label "DSD of statuses of Czech ESF projects"@en ;
  qb:component [ qb:dimension obeu-dimension:project ],
               [ qb:dimension obeu-dimension:date ],
               [ qb:measure esf-measure:projectStatus ] .

# ----- Component properties -----

esf-measure:projectStatus a rdf:Property, qb:MeasureProperty, owl:ObjectProperty ;
  rdfs:label "Project status"@en ;
  qb:codeList esf-codelist:project-statuses ;
  rdfs:range esf-class:ProjectStatus ;
  rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/esf-czech-project-statuses> .

# ----- Code lists -----

esf-codelist:project-statuses a skos:ConceptScheme ;
  rdfs:label "Code list of project statuses"@en .

# ----- Classes -----

esf-class:ProjectStatus a rdfs:Class ;
  rdfs:label "Project status"@en ;
  rdfs:subClassOf skos:Concept .

```

Appendix E: example observations of EU structural funds 2007-2013 in the Czech Republic

```
@prefix esf-dimension: <http://data.openbudgets.eu/ontology/esf-czech-projects/dimension/> .
@prefix esf-measure: <http://data.openbudgets.eu/ontology/esf-czech-projects/measure/> .
@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
@prefix obeu-measure: <http://data.openbudgets.eu/ontology/dsd/measure/> .
@prefix obeu-operation: <http://data.openbudgets.eu/resource/codelist/operation-character/> .
@prefix obeu-optional: <http://data.openbudgets.eu/ontology/dsd/optional/> .
@prefix obeu-paymentphase: <http://data.openbudgets.eu/resource/codelist/payment-phase/> .
@prefix qb: <http://purl.org/linked-data/cube#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<http://data.openbudgets.eu/resource/dataset/esf-czech-projects> a qb:DataSet ;
    qb:structure <http://data.openbudgets.eu/ontology/dsd/esf-czech-projects> ;
    obeu-attribute:currency <http://data.openbudgets.eu/codelist/currency/CZK> ;
    obeu-dimension:operationCharacter obeu-operation:expenditure .

<http://data.openbudgets.eu/resource/datasets/esf-czech-projects/observation/expenditure/66002222/allocated/1.1.1/70994234/CZ.1.01/1.1.00/06.0019/2008-07-02/529303> a qb:Observation ;
    obeu-dimension:date "2008-07-02"^^xsd:date ;
    obeu-optional:location <http://linked.opendata.cz/resource/region/529303> ;
    esf-dimension:operationalProgramme <http://data.openbudgets.eu/codelist/cz-operational-programme/1-1-1> ;
    obeu-dimension:partner <http://linked.opendata.cz/resource/business-entity/CZ70994234> ;
    obeu-dimension:project <http://data.openbudgets.eu/resource/dataset/esf-czech-projects/project/CZ-1-01-1-1-00-06-0019> ;
    qb:dataSet <http://data.openbudgets.eu/resource/dataset/esf-czech-projects> ;
    obeu-dimension:organization <http://linked.opendata.cz/resource/domain/mfcr/monitor/ciselniky/UcetniJednotka/66002222/2009-12-31> ;
    obeu-dimension:paymentPhase obeu-paymentphase:allocated ;
    obeu-measure:amount 3706234999.71 .

<http://data.openbudgets.eu/resource/dataset/esf-czech-project-statuses> a qb:DataSet ;
    qb:structure <http://data.openbudgets.eu/ontology/dsd/esf-czech-project-statuses> .

<http://data.openbudgets.eu/resource/dataset/esf-czech-project-statuses/observation/7b5a2033bee688570179c06c7ad08e040232e408/CZ.1.01/3.1.00/08.0027/2008-06-27> a qb:Observation ;
    obeu-dimension:date "2008-06-27"^^xsd:date ;
    obeu-dimension:project <http://data.openbudgets.eu/resource/dataset/esf-czech-projects/project/CZ-1-01-3-1-00-08-0027> ;
    esf-measure:projectStatus <http://data.openbudgets.eu/resource/dataset/esf-czech-project-statuses/codelist/project-statuses/7b5a2033bee688570179c06c7ad08e040232e408> ;
    qb:dataSet <http://data.openbudgets.eu/resource/dataset/esf-czech-project-statuses> .
```

Appendix F: data structure definitions of Aragón 2016 budget

EXPENDITURE

```
@prefix aragon-attribute: <http://data.openbudgets.eu/ontology/dsd/aragon-budget/attribute/> .
@prefix aragon-dimension: <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016/dimension/> .
@prefix aragon: <http://data.openbudgets.eu/ontology/aragon-budget/> .
@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
@prefix obeu-measure: <http://data.openbudgets.eu/ontology/dsd/measure/> .
@prefix obeu: <http://data.openbudgets.eu/ontology/> .
@prefix org: <http://www.w3.org/ns/org#> .
@prefix qb: <http://purl.org/linked-data/cube#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<http://data.openbudgets.eu/resource/dsd/aragon-budget-exp-2016>
  qb:component [
    qb:componentAttachment qb:DataSet ;
    qb:dimension obeu-dimension:budgetaryUnit
  ], [
    qb:componentAttachment qb:DataSet ;
    qb:dimension obeu-dimension:operationCharacter
  ], [
    qb:componentAttachment qb:DataSet ;
    qb:dimension obeu-dimension:fiscalYear
  ], [
    qb:dimension aragon-dimension:administrativeClassification
  ], [
    qb:dimension aragon-dimension:functionalClassification
  ], [
    qb:dimension aragon-dimension:economicClassification
  ], [
    qb:dimension aragon-dimension:fundingClassification
  ], [
    qb:attribute obeu-attribute:currency ;
    qb:componentAttachment qb:DataSet ;
    qb:componentRequired true
  ], [
    qb:measure obeu-measure:amount
  ] ;
  a qb:DataStructureDefinition ;
  rdfs:label "Data structure definition for the expenditure part of the Aragonian budget (autonomous community in northeastern Spain)."@en .

aragon-dimension:administrativeClassification
  qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2016> ;
  a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
  rdfs:comment "The administrative classification is organized hierarchical in four levels."@en ;
  rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016> ;
  rdfs:label "Organization managing the planned budget"@en ;
  rdfs:range skos:Concept ;
```

```
    rdfs:subPropertyOf obeu-dimension:administrativeClassification .
```

```
aragon-dimension:economicClassification
```

```
    qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_economica_g_aragon_2016> ;
```

```
    a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
```

```
    rdfs:comment "Identifies the type of expenditure incurred or source of revenues. The economic classification is organized hierarchical into chapters, articles, concepts, and sub-concepts. This dimension is used for both, expenditure and revenue."@en ;
```

```
    rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016> ;
```

```
    rdfs:label "Economic Classification"@en ;
```

```
    rdfs:range skos:Concept ;
```

```
    rdfs:subPropertyOf obeu-dimension:economicClassification .
```

```
aragon-dimension:functionalClassification
```

```
    qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_funcional_aragon_2016> ;
```

```
    a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
```

```
    rdfs:comment "Classifies expenditures by general government sector and by the purpose of the expenditure. The functional classification is organized hierarchical into groups, functions, sub-functions and programs."@en ;
```

```
    rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016> ;
```

```
    rdfs:label "Functional Classification"@en ;
```

```
    rdfs:range skos:Concept ;
```

```
    rdfs:subPropertyOf obeu-dimension:functionalClassification .
```

```
aragon-dimension:fundingClassification
```

```
    qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_financiacion_g_aragon_2016> ;
```

```
    a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
```

```
    rdfs:comment "Describes the origin of the funding. The funding classification is organized hierarchical into origin, fund, and program. This dimension is used for both, expenditure and revenue."@en ;
```

```
    rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016> ;
```

```
    rdfs:label "Funding Classification"@en ;
```

```
    rdfs:range skos:Concept ;
```

```
    rdfs:subPropertyOf obeu-dimension:classification .
```

REVENUE

```
@prefix aragon-attribute: <http://data.openbudgets.eu/ontology/dsd/aragon-budget/attribute/> .
```

```
@prefix aragon-dimension: <http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016/dimension/> .
```

```
@prefix aragon: <http://data.openbudgets.eu/ontology/aragon-budget/> .
```

```
@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
```

```
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
```

```
@prefix obeu-measure: <http://data.openbudgets.eu/ontology/dsd/measure/> .
```

```
@prefix obeu: <http://data.openbudgets.eu/ontology/> .
```

```
@prefix org: <http://www.w3.org/ns/org#> .
```

```
@prefix qb: <http://purl.org/linked-data/cube#> .
```

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
```

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
```

```
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
```

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
```

```
<http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016>
```

```
    qb:component [
```

```
        qb:componentAttachment qb:DataSet ;
```

```
        qb:dimension obeu-dimension:budgetaryUnit
```

```
    ], [
```

```
        qb:componentAttachment qb:DataSet ;
```

```
        qb:dimension obeu-dimension:operationCharacter
```

```
    ], [
```

```
        qb:componentAttachment qb:DataSet ;
```

```

    qb:dimension obeu-dimension:fiscalYear
  ], [
    qb:dimension aragon-dimension:administrativeClassification
  ], [
    qb:dimension aragon-dimension:economicClassification
  ], [
    qb:dimension aragon-dimension:fundingClassification
  ], [
    qb:attribute obeu-attribute:currency ;
    qb:componentAttachment qb:DataSet ;
    qb:componentRequired true
  ], [
    qb:measure obeu-measure:amount
  ] ;
  a qb:DataStructureDefinition ;
  rdfs:label "Data structure definition for the expenditure part of the Aragonian budget (autonomous community in northeastern Spain)."@en .

```

aragon-dimension:administrativeClassification

```

qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2016> ;
a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
rdfs:comment "The administrative classification is organized hierarchical in four levels."@en ;
rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016> ;
rdfs:label "Organization managing the planned budget"@en ;
rdfs:range skos:Concept ;
rdfs:subPropertyOf obeu-dimension:administrativeClassification .

```

aragon-dimension:economicClassification

```

qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_economica_i_aragon_2016> ;
a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
rdfs:comment "Identifies the type of expenditure incurred or source of revenues. The economic classification is organized hierarchical into chapters, articles, concepts, and sub-concepts. This dimension is used for both, expenditure and revenue."@en ;
rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016> ;
rdfs:label "Economic Classification"@en ;
rdfs:range skos:Concept ;
rdfs:subPropertyOf obeu-dimension:economicClassification .

```

aragon-dimension:fundingClassification

```

qb:codeList <http://data.openbudgets.eu/resource/codelist/estructura_financiacion_i_aragon_2016> ;
a qb:CodedProperty, qb:DimensionProperty, rdf:Property ;
rdfs:comment "Describes the origin of the funding. The funding classification is organized hierarchical into origin, fund, and program. This dimension is used for both, expenditure and revenue."@en ;
rdfs:isDefinedBy <http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016> ;
rdfs:label "Funding Classification"@en ;
rdfs:range skos:Concept ;
rdfs:subPropertyOf obeu-dimension:classification .

```

Appendix G: example observations of Aragón 2016 budget

```
@prefix aragon-dimension: <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016/dimension/> .
@prefix obeu-attribute: <http://data.openbudgets.eu/ontology/dsd/attribute/> .
@prefix obeu-dimension: <http://data.openbudgets.eu/ontology/dsd/dimension/> .
@prefix obeu-measure: <http://data.openbudgets.eu/ontology/dsd/measure/> .
@prefix obeu-operation: <http://data.openbudgets.eu/resource/codelist/operation-character/> .
@prefix qb: <http://purl.org/linked-data/cube#> .

<http://data.openbudgets.eu/resource/dataset/aragon-2016-expenditure> a qb:DataSet ;
  obeu-attribute:currency <http://data.openbudgets.eu/codelist/currency/EUR> ;
  obeu-dimension:organization <http://dbpedia.org/resource/Aragon> ;
  obeu-dimension:fiscalYear <http://reference.data.gov.uk/id/year/2016> ;
  obeu-dimension:operationCharacter obeu-operation:Expenditure ;
  qb:structure <http://data.openbudgets.eu/ontology/dsd/aragon-budget-exp-2016> .

<http://data.openbudgets.eu/resource/dataset/aragon-2016-expenditure/observation/103> a qb:Observation ;
  obeu-measure:amount 45146.46 ;
  aragon-dimension:administrativeClassification <http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2016/01020> ;
  aragon-dimension:functionalClassification <http://data.openbudgets.eu/resource/codelist/estructura_funcional_aragon_2016/1112> ;
  aragon-dimension:economicClassification <http://data.openbudgets.eu/resource/codelist/estructura_economica_g_aragon_2016/120006> ;
  aragon-dimension:fundingClassification <http://data.openbudgets.eu/resource/codelist/estructura_financiacion_g_aragon_2016/91002> ;
  qb:dataSet <http://data.openbudgets.eu/resource/dataset/aragon-2016-expenditure> .

<http://data.openbudgets.eu/resource/dataset/aragon-2016-income> a qb:DataSet ;
  obeu-attribute:currency <http://data.openbudgets.eu/codelist/currency/EUR> ;
  obeu-dimension:organization <http://dbpedia.org/resource/Aragon> ;
  obeu-dimension:fiscalYear <http://reference.data.gov.uk/id/year/2016> ;
  obeu-dimension:operationCharacter obeu-operation:revenue ;
  qb:structure <http://data.openbudgets.eu/ontology/dsd/aragon-budget-inc-2016> .

<http://data.openbudgets.eu/resource/dataset/aragon-2016-income/observation/80> a qb:Observation ;
  aragon-dimension:administrativeClassification <http://data.openbudgets.eu/resource/codelist/estructura_organica_aragon_2016/12500> ;
  aragon-dimension:economicClassification <http://data.openbudgets.eu/resource/codelist/estructura_economica_i_aragon_2016/400051> ;
  aragon-dimension:fundingClassification <http://data.openbudgets.eu/resource/codelist/estructura_financiacion_i_aragon_2016/91003> ;
  obeu-measure:amount 145321950.0 ;
  qb:dataSet <http://data.openbudgets.eu/resource/dataset/aragon-2016-income> .
```