Expenditure, Revenue and Taxes – Towards a Standard for Representing City Finance Open Data

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Abstract— In order to compare and analyse open data across cities, standard representations or ontologies have to be created. This paper describes the Global City Indicators Finance Ontology developed as part of the PolisGnosis Project. It defines the concepts and properties necessary to represent the definitions of ISO 37120 Finance Theme indicators, and to openly publish the indicators and the supporting data used to derive them, on the Semantic Web.

Keywords—Open Data, Ontology, City Indicators, Finance, Semantic Web

I. INTRODUCTION

Measuring a city's performance is a challenge given their breadth and complexity. The standardization of city indicators, as found in ISO 37120 (2014) [7], is a first step towards making cities smarter. The second step is to understand why a city is underperforming. In order to evaluate the underlying cause, we need to understand two things:

- 1. How a city is being measured. In other words the definition of the indicator, and
- 2. How the measurement (i.e., indicator value) was derived. In other words whether the derivation of the indicator conforms to its definition.

The current approach to validating a city's reported indicators is for the city to submit to a certification process. The World Council on City Data provides a certification process for ISO 37120. However, the data required to verify a city's indicators are generally difficult to access and too large and complex analyse for an ordinary citizen [5].

The goal of the PolisGnosis Project is to automate the analysis of city performance in order to identify their root causes [1], particularly longitudinal analysis, i.e., how and why a city's performance changes over time, and transversal analysis, i.e., how and why cities' performance differ from each other at the same time. However before we can focus on the automation, we have to solve the indicator representation problem that can be divided into five parts [14]:

1. How do we represent the meta data associated with a published indicator value? For example, its units and scale, it's provenance (when it was created, who created it, what process was used to create it), the degree of certainty in the value, and

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the degree to which we trust the organization that created it and/or the process they used?

2. How do we represent the definition of an indicator? In order for the analysis of indicators to be automated, the PolisGnosis system must be able to read and understand the definition of each indicator, which may alter over time.

3. How do we represent the data used to derive an indicator value? An indicator is the apex of a tree of supporting data that is aggregated across place, time, organizations, etc. How is this represented?

4. How do we represent indicator theme specific knowledge? Each theme, such as Education, Health, Shelter, etc., has a core set of knowledge that has to be represented in both the definition of an indicator and in publishing an instance of an indicator and its supporting data.

5. How do we represent a city's theme specific knowledge? Each city may define concepts such as "fixed asset", "tax billed", etc. differently. Differences in indicator values may be due to differences in the interpretation of these terms between cities.

This paper defines the Global City Indicators (GCI) Finance Ontology¹ composed of classes covering: Debt, Asset and Liability, Revenue, Expenditure, Tax and Monetary measures. The design of the GCI Finance ontology is guided by the requirement to represent the definition of ISO 37120 Finance Theme indicators, and provide a standard ontology for cities that wish to openly publish the data used to derive their Finance indicators. Secondly, we use the GCI Finance Ontology to represent each ISO 37120 Finance Indicator².

II. GCI FINANCE INDICATORS AND THEIR COMPETENCY REQUIREMENTS

Based on the ontology engineering methodology of Grüninger & Fox [5], the requirements for the GCI Finance ontology are defined by a set of Competency Questions (CQs). CQs are questions that the ontology must be able to support the

¹ The GCI Finance ontology can be found at

http://ontology.eil.utoronto.ca/GCI/Finance/GCI-Finance.owl.

² The internationalized resource identifier (IRI) for each ISO 37120 indicator is contained in the ISO 37120 module at the highest level. For example, the IRI for the Debt Service Ratio indicator is:

[&]quot;http://ontology.eil.utoronto.ca/ISO37120.owl#9.1"

answering of if it is to represent the indicator definition. In this paper, we provide the ISO 37120 definition of the core Finance indicator and specify a set of CQs that are entailed by the definition. The CQs for the supporting indicators can be found in the GCI Finance Ontology [14].

A. Debt service ratio (debt service expenditure as a percentage of a municipality's own-source revenue) (core indicator) (ISO 37120: 9.1)

Reproduced from ISO 37120:

"Debt service ratio is the ratio of debt service expenditures as a per cent of a municipality's own source revenue. Debt service ratio shall be calculated as the total long-term debt servicing costs including lease payments, temporary financing and other debt charges (numerator) divided by total own source revenue (denominator). The result shall then be multiplied by 100 and expressed as a percentage of debt service expenditure as a percent of a municipality's own-source revenue.

Total own source revenue shall be calculated as the total revenue less transfers."

Competency Questions

- 1. What city is the indicator for?
- 2. For what time period is the debt service expenditure of a municipality measured? For what time period is a municipality's own-source revenue measured?
- 3. What are the municipality's total expenditure and debt for the fiscal year?
- 4. What percentage of the total debt is repaid?
- 5. What types of debt are included in the municipality's debt expenditure?
- 6. For each debt expenditure type X, what percentage does it contribute to the total debt expenditure?
- 7. For each debt type X: Who is the creditor? What is the interest rate? What is the payment period and what are the payment terms?
- 8. What percentage of each debt type X is repaid?
- 9. What is the total revenue for the fiscal period?
- 10. What is the total transfers revenue for the fiscal period?
- 11. What is a municipality's own-source revenue?
- 12. For each revenue type Y, what percentage does it contribute to the total own-source revenue?
- 13. From which sources do transfer revenues originate?
- 14. What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?

The remaining supporting indicators are:

- Capital spending as a percentage of total expenditures (supporting indicator) (ISO 37120: 9.2)
- Own-source revenue as a percentage of total revenues (supporting indicator) (ISO 37120: 9.3)
- Tax collected as a percentage of tax billed (supporting indicator) (ISO 37120: 9.4)

III. GCI FINANCE ONTOLOGY

The GCI Finance ontology is built on the Global City Indicator Foundation Ontology $[2]^3$ in OWL format⁴, which integrates the Time (Hobbs & Pan, 2006), Measurement (Rijgersberg et al., 2011), Statistics (Pattuelli, 2009), Validity (Fox & Huang, 2005), Trust (Huang & Fox, 2006) and Placenames (<u>www.geonames.org</u>) ontologies, and extends them with city indicator specific concepts of populations, measurements, etc.

There are existing ontologies that define or introduce certain concepts and properties pertinent to public finance. However, most of them lack competency questions and documentation, and only include general classes such as revenue and expenditure without essential properties to define the concepts. Therefore, while some of the existing ontologies are reusable, such as SUMO⁵, OpenCYC⁶, Schema.org⁷ and TOVE Organization Ontology⁸, most of the concepts need to be extended or created.

In order to answer the competency questions, additional classes, properties and axioms are required to cover the following aspects:

- 1. The types of debt and assets a municipality has, and the properties and terms of the debt,
- 2. The sources that contribute to revenue, and what type of revenue each source contributes to,
- 3. The types of expenditures, and the purpose of each expenditure, and
- 4. The types of taxes and taxpayers for tax collected and tax billed.

In this section we provide description of the classes and properties defined in the GCI Finance Ontology. Only key classes and properties are depicted in this paper. Complete ontological representation of the indicators can be found in [14].

A. Debt, Asset and Liability Classes

The taxonomy of Debt, as depicted in Fig. 1, is derived from the definitions in ISO 37120 for core indicator – debt service ratio: "Debt service ratio shall be calculated as the total long-term debt servicing costs including lease payments, temporary financing and other debt charges ..." Therefore, the Debt class subsumes LeasePayments, TemporaryFinancing and OtherDebt, as shown in the following diagram. Each of the debt items has a creditor, which will be defined in the following sections. As part of the definition for temporary financing, it summarizes negotiated current liabilities and temporary spontaneous liabilities, which leads to its property 'has_Liability'.

⁷ The Schema.org ontology can be found at <u>http://schema.org/</u>.

http://ontology.eil.utoronto.ca/organization.owl#.

³ The GCI Foundation ontology can be found at

<u>http://ontology.eil.utoronto.ca/GCI/GCI-Foundation.owl</u> along with its documentation at <u>http://ontology.eil.utoronto.ca/GCI/GCI-Foundation.html</u>.

⁴ https://en.wikipedia.org/wiki/Web_Ontology_Language

⁵ The SUMO ontology can be found at <u>http://ontologyportal.org/sumo.owl</u>.

⁶ The OpenCYC ontology can be found at <u>http://sw.opencyc.org/</u>.

⁸ The Organization ontology can be found at

Fig. 1. Debt Taxonomy



The following diagram describes the taxonomy of Asset classes. Two major subclasses of asset are tangible assets and intangible assets. ISO 37120 and our competency questions mainly focus on FixedAsset directly, which is a subclass of TangibleAsset, because fixed assets are directly tied to capital spending, which is the numerator of the second GCI Finance indicator. ISO 37120:9.2 defines fixed assets as "long-term, more permanent or 'fixed' items, such as land, building, equipment, fixtures, furniture, and leasehold improvements". These categories, such as land, building and equipment, are the subclasses of FixedAsset. Each asset instance is attributed to a creditor that can be a person or organization.

Fig. 2. Asset Taxonomy



Liability concepts are not directly mentioned in ISO standards, but they are inseparable from Debt concepts. Current liability describes all liabilities of the business that are to be settled in cash within the fiscal year or the operating cycle of a given firm, whichever period is longer. The property 'has_Liability' with a range of 'CurrentLiability' distinguishes temporary financing from lease financing. These classes are shown in Fig. 3.

All the subclasses of Liability inherit its properties.

Fig. 3. Liability Taxonomy



B. Revenue Classes

Two of the Finance indicators (ISO 37120:9.1 and ISO 37120:9.3) directly involve revenue of the city government, and ISO37120:9.4 concerns tax, a subclass of public revenue. This section explains the taxonomy of the Revenue class, as well as its properties and axioms.

ISO 37120:9.1 (debt service ratio) defines total own source revenue as total revenue less transfers, whereas ISO 37120:9.3 (own-source revenue as a percentage of total revenues) defines own source revenue as the total amount of funds obtained through permit fees, user charges for city services, and taxes collected for city purposes only.

Therefore, two types of definitions are made possible through the Revenue classes – total revenue is the sum of total own source revenue and total transfers, and total own source revenue consists of fees, charges and taxes.

Fig. 4. Revenue Taxonomy



Tax is the subclass of revenue that we will focus on for the fourth Finance indicator (Tax collected as a percentage of tax billed). Each tax item has a taxpayer, which can be an individual or an organization, and a rate and threshold of tax collection. The taxonomy of tax will be further explained in the following sections.

All the subclasses of Revenue inherit its properties.

C. Expenditure Classes

Figure 5 depicts the taxonomy for public expenditure in the GCI Finance ontology. Since the counterpart of capital expenditure is operational expenditure, any one of a municipality's expense items should be either capital spending or operating expenditure. By definition of operating expense, DebtExpenditure is a type of OperatingExpenditure.

ISO 37120:9.1 specifies that "total long-term debt servicing costs include lease payments, temporary financing and other debt charges", which is what we base on to create subclasses of DebtExpenditure. The sum of the monetary value (the definition of which to be explained later on) of these three types debt expense represent TotalDebtExpenditure.

Each debt expenditure item is an expense for a debt activity. A capital spending instance is an expenditure item on fixed asset, according to the definition in ISO 37120 standards.

All the subclasses of Expenditure inherit its properties.

Fig. 5. Expenditure Taxonomy



TABLE I. demonstrates the properties of Expenditure and its subclasses.

Each expenditure activity is carried out for a purpose, which can be represented as a financial object or outlined with a string. For example, CapitalSpending, according to its definition in ISO37120:9.2, is the type of expenditure on FixedAsset, and DebtExpenditure is the expense for debt items. As subclasses of Debt, LeasePayments is the expense on TemporaryFinancingPayments LeaseFinance, are for TemporarFinancing, and OtherDebtCharges are expenditure for OtherDebt, all three of which subsumed by Debt. The above definitions are captures with the property 'expense For'. Other expenditure subclasses do not have explicit financial objects as the purpose or reason of expense that are pertinent to the ISO 37120 Finance indicators, in which case the purpose of expenditure is captured with the property 'expensePurpose' whose value is a string.

As subclasses of DebtExpenditure, LeasePayments, TemporaryFinancingPayments and OtherDebtCharges are disjoint with each other.

Class	Property	Value Restriction
Expenditure	expensePurpose	min 1 String
	has_Code	max 1 String
	owl: subClassOf	GCIFinanceThing
Capital	expense_For	only FixedAsset
Spending	owl: subClassOf	PublicExpenditure
	disjointWith	OperatingExpenditure
Debt	expense_For	only Debt
Expenditure	owl: subClassOf	OperatingExpenditure
Public Expenditure	owl: subClassOf	Expenditure
Private Expenditure	owl: subClassOf	Expenditure
Operating	owl: subClassOf	PublicExpenditure
Expenditure	disjointWith	CapitalSpending
Lease	owl: subClassOf	DebtExpenditure
Payments	expense_For	only LeaseFinancing
	disjointWith	{TemporaryFinancingPayment, OtherDebtCharges}
Temporary	owl: subClassOf	DebtExpenditure
Financing	expense_For	only TemporaryFinancing
Payments	disjointWith	{LeasePayments, OtherDebtCharges}
OtherDebt	owl: subClassOf	DebtExpenditure
Charges	expense_For	some OtherDebt
	disjointWith	{TemporaryFinancingPayment, LeasePayments }

D. Person and Organization Classes

The information regarding debt service expenditure and tax cannot be coherently represented without concepts regarding person and organization. This section introduces Creditor and TaxPayer classes, which appear in the form of either an individual or an organization.

The Person class is imported from schema.org, as it is consistent with our definition for person individuals. For each Person, our ontology has included properties such as birthdate, residency and employment status. The Organization class is inherited from the TOVE Organization ontology, together with its properties, such as name, legal name and ownership.

Fig. 6. Person and Organization Taxonomy



E. Tax Classes

The fourth GCI Finance indicator (ISO 37120:9.4) regards tax collected and tax billed. Classes to define taxpayers, whether in the form of individuals or organizations, have been explained in section D in this paper.

Fig. 7 depicts the classes and properties corresponding to tax. According to the definition of tax, each tax item has its taxpayer, threshold, tax rate and imposing agent. Tax billed and tax collected are both subclasses of Tax.

All the subclasses of Tax inherit its properties.

Fig. 7. Tax Taxonomy



F. Monetary Measurement Classes

All four Finance indicators are defined through monetary measures. The monetary measure directly needed is the ratio between two monetary values. In order to measure monetary quantities, we also need monetary units, including compound unit to describe monetary ratio, and singular units to define the unit of monetary values. Competency questions regarding currency and exchange ratio introduce a representational requirement not seen in other themes. The Finance indicators are different in that none of their measures are represented in the form of countable amounts. Instead, they exist as continuous quantities. Additionally, all the numerators and denominators in the Finance indicators may incur different currencies and exchange rates, and the exchange ratio between monetary units changes over time, increasing the potential of inconsistency internally.

Fig. 8 depicts the monetary quantities defined in GCI Finance Ontology regarding Expense, Revenue, Tax and Debt. They are represented as the sum of monetary values or the difference between two monetary values, depending on the definition in [7].

Fig. 8. Monetary Value Taxonomy



Fig. 9 illustrates the relationship between compound monetary ratio unit and singular monetary unit. GCI Foundational Ontology [2] defines the numerator and denominator of a monetary ratio as a monetary value.

Fig. 9. Monetary Unit Taxonomy



IV. ISO37120 FINANCE INDICATORS DEFINITIONS

In this section, the GCI Finance Ontology is applied to the core finance indicator -9.1 debt service ratio, in order to represent the indicator's definition. The definitions of all four of the ISO 37120 Finance Theme indicators can be found in [14].

The first ISO 37120 Finance indicator is the core indicator, and is defined as the ratio of debt service expenditure as a per cent of own source revenue.

Figure 10 depicts the class properties of each class defined in ISO Finance ontology for ISO37120:9.1. The monetary values of the numerator and denominator are represented as the TotalDebtExpenditure and TotalOwnSourceRevenue, which of DebtExpenditure and are the monetary values OwnSourceRevenue, respectively. 9.1 TotalDebtExpenditure is the debt service expense for this indicator, and is the expense for 9.1 TotalDebt. GCI Finance ontology defines TotalDebtExpenditure as the sum of LeasePayments, TemporaryFinancingPayments and OtherDebtCharges. An example of the data properties are provided for expenditure classes. The complete data properties and complete definition of classes and axioms can be found in [14].

The first indicator specifies that own source revenue is total revenue less transfers, and therefore 9.1_TotalRevenue is the sum of only 9.1_TotalOwnSourceRevenue and 9.1_TransferRevenue.

In order to answer the competency questions related to total revenue and total expenditure, the ISO Finance ontology also includes 9.1_TotalRevenue and 9.1_TotalExpenditure and their monetary values.

Additionally, we need other basic information for indicator ISO 37121:9.1 such as which fiscal year and which city it is reported for.

In Figure 10, iso37120:9.1 is equivalent to class 'Debt service ratio (debt service expenditure as a percentage of a municipality's own-source revenue) (core indicator)' in Finance.owl. It defines the ratio for the first Finance indicator as well as its numerator and denominator, and is imported from GCI Foundation ontology.

Fig. 10. ISO 37120 Finance Indicator 9.1 Definition



Additional axioms are needed to complete the above definitions:

- 1. Debt types 'LeaseFinancing' 'TemporaryFinancing' and 'OtherDebt' all have some 'Creditor'.
- 'LeasePayments' is the expense for 'LeaseFinancing', 'TemporaryFinancingPayments' is the expense for 'TemporaryFinancing', and 'OtherDebtCharges' is the expense for 'OtherDebt'.

- 3. 'TotalDebt' is the sum of terms 'LeaseFinancing', 'TemporaryFinancing' and 'OtherDebt'.
- 4. 'TotalOwnSourceRevenue' is a term of the sum quantity 'TotalPublicRevenue'.

V. EVALUATION

The competency questions stated in section II are used to verify our ontology. The implementation of three selected competency questions for indicator '9.1 debt service ratio' are demonstrated as follows. The implementation of the rest of 9.1 competency questions can be found in [14].

1. What types of debt are paid for by a municipality's debt expenditure?

```
SELECT ?debt WHERE
{9.1_ex gci:numerator ?debtexpamt .
?debtexpamt gcif:amount_Of ?debtexp .
?debtexp gcif:defined_by ?debtexp .
?debtexp gcif:sum_term ?determ .
?determ gcif:expense For ?debt }
```

2. For each revenue type Y, what percentage does it contribute to the total own-source revenue?

```
SELECT (?revxvalue / ?revvalue)
as ?revxcontribution WHERE
 {?revxamt om:value ?revxvalue .
 ?revxamt gcif:amount_Of ?revx .
 ?revx org:memberOf ?revclass .
 9.1_totalrev gcif:sum_Term ?revclass .
 ?revamt gcif:amout_Of 9.1_totalrev .
 ?revamt om:value ?revvalue }
```

3. What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?

SELECT ?decurr ?deexch ?osrcurr ?osrexch WHERE
 {9.1_ex gci:numerator ?deamt .
 ?deamt om:value ?devalue .
 ?devalue gcif:originalCurrency ?decurr .
 ?devalue gcif:exchangeRatio ?deexch .
 9.1_ex gci:denominator ?osramt .
 ?osramt om:value ?osrvalue .
 ?osrvalue gcif:originalCurrency ?osrcurr .
 ?osrvalue gcif:exchangeRatio ?osrexch }

VI. CONCLUSION

The goal of this research is to standardize the representation of city financial information. A Finance ontology was defined to represent financial concepts that were used in the definitions of ISO 37120 Finance theme indicators which is applied to city of Toronto, Canada. Each indicator's definition was then represented using the GCI Finance ontology, GCI Foundation ontology and other ontologies as described above. Key to the design of this ontology were the compentency questions derived from the indicator definitions. This allowed us to discern what needs to be represented and what should not. In summary, this research makes four contributions:

- 1. Defines a general Finance ontology;
- 2. Represents each ISO37120 shelter indicator definition using the GCI Foundation and Finance ontologies;
- 3. Enables the publishing of the ISO37120 Finance theme indicator definitions using Semantic Web standards; and
- 4. Enables the publishing of a city's ISO37120 Finance theme indicators' values along with the supporting data used to derive them using Semantic Web standards.

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