A Finance Ontology for Global City Indicators (ISO 37120)

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1. Introduction

As Lord Kelvin supposedly said[1]: "If you can not measure it, you can not improve it." If we want to make cities smarter, we have to improve what currently exists, hence we have to measure them. Measuring a city's performance is a challenge given their breadth and complexity. The standardization of city indicators, as found in ISO 37120 (2014), is a first step towards making cities smarter. But it is only the first step. The second step is to understand why a city is underperforming. In order to understand why, we need to know 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 does the derivation of the indicator conform 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[2]. A drawback of the certification process is that the data used to derive indicator values remains closed; a recent study has shown that cities do not openly publish the data required by citizens to verify a city's indicators (Fox & Pettit, 2015). Consequently, without the underlying data, we cannot identify the root causes of a city's performance. Even if we had access to the data, it is too large and complex for an ordinary citizen to analyse.

The goal of the PolisGnosis Project is to automate the analysis of city performance in order to identify their root causes (Fox, 2015). In particular, we wish is to automate 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. We care creating an intelligent agent that is able to take as input: an indicator definition, and the data cities use to derive their indicator values, then analyse it to determine the root causes of their performance. However before we can focus on analysis,

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[1] http://zapatopi.net/kelvin/quotes/
[2] http://www.dataforcities.org/global-cities-registry/

we have to solve the indicator representation problem. The representation problem can be divided into five parts:

1. How do we represent the meta data associated with a published indicator value? For example, its units, 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 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 change 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 "primary school", "grades", "teachers", etc. differently. Differences in indicator values may be due to differences in the interpretation of these terms between cities.

This paper defines the GCI Finance Ontology 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 Indicator.

2. Indicators and Their Competency Requirements

Based on the ontology engineering methodology of Grüninger & Fox (1995), 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 answering of if it is to represent the indicator definition. They are derived from the definition of the indicators. Competency questions fall into the following categories (Fox, 2013):

- Factual (F): Questions that ask what the value of some property is.
- Consistency - Definitional (CD): Determine whether the instantiation of an indicator by a city is consistent with the ISO 37120 definition.
- Consistency - Internal (CI): Determine whether different parts of the instantiation are consistent with each other.
- Deduced (D): A value or relationship that can be deduced form the instantiation.

In each of the following subsections, we provide the ISO 37120 definition of each indicator and specify a set of CQs that are entailed by the definition.

2.1. 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. (F) What city is the indicator for?
2. (CI) 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. (F) What are the municipality's total expenditure and debt for the fiscal year?
4. (D) What percentage of the total debt is repaid?
5. (F) What types of debt are included in the municipality's debt expenditure?
6. (D) For each debt expenditure type X, what percentage does it contribute to the total debt expenditure?
7. (F) 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. (D) What percentage of each debt type X is repaid?
9. (F) What is the total revenue for the fiscal period?
10. (F) What is the total transfers revenue for the fiscal period?
11. (F) What is a municipality's own-source revenue?
12. (D) For each revenue type Y, what percentage does it contribute to the total own-source revenue?
13. (F) From which sources do transfer revenues originate?
14. (F) What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?

2.2. Capital spending as a percentage of total expenditures (supporting indicator) (ISO 37120: 9.2)

Reproduced from ISO 37120:

"The capital spending as a percentage of total expenditures shall be calculated as the total expenditure on fixed assets in the preceding year (numerator) divided by the total expenditure (operating and capital) (denominator) by the city in that same period. The result shall then be multiplied by 100 and expressed as a percentage of capital spending as a percent of total expenditures."

"NOTE   Fixed assets are not expected to be consumed or converted into cash in the normal source of business. They are long-term, more permanent or "fixed" items, such as land, building, equipment, fixtures, furniture, and leasehold improvements."

Competency Questions
1. (CI) For what time period is the capital spending of a municipality measured? For what time period are a municipality's total expenditures measured?
2. (F) Which fixed assets are included when calculating the capital spending?
3. (D) What percentage of the capital spending does fixed asset X contribute to?
4. (F) For a fixed asset X, is it rented, leased or purchased?
5. (F) For what period of time is the municipality in possession of fixed asset X? What are the terms on obtaining asset X?
6. (F) What sources contribute to the total operating expenditure?
7. (D) What percentage of the operating expenditure does expense item Y contribute to?

2.3. Own-source revenue as a percentage of total revenues (supporting indicator) (ISO 37120: 9.3)

Reproduced from ISO 37120:

"Own-source revenue as a percentage of total revenues shall be calculated as the total amount of funds obtained through permit fees, user charges for city services, and taxes collected for city purposes only (numerator), divided by all operating or re-occurring revenues including those provided by other levels of government transferred to the city (denominator). The result shall then be multiplied by 100 and expressed as a percentage.

Own-source revenue as a percentage of total revenues represent the percentage of local government revenues originating from fees, charges and taxes as permitted by law or legislation in relation to all revenues including those provided by other levels of government, (which includes operating or reoccurring revenues determined through methods such as formula driven payments or repatriation of income tax, grant donations from higher government levels including national or state governments and other types of financial transfers that may be tied to the delivery of specific services."

Competency questions:
1. (CI) For what time period is the own-source revenue of a municipality measured? For what time period are a municipality's total revenues measured?
2. (F) What is the budget for own-source revenue and total revenues for the fiscal year measured?
3. (F) What revenue sources does a municipality's own-source revenue comprise?
4. (F) What revenue sources do the total revenues include?
5. (D) What percentage of own-source revenue does revenue X contribute to? What percentage of the total revenues does X contribute to?
6. (F) Is revenue X an operating or recurring revenue?

2.4. Tax collected as a percentage of tax billed (supporting indicator) (ISO 37120: 9.4)

Reproduced from ISO 37120:

> "The tax collected as a percentage of tax billed measures the ratio of the actual tax collected to the mandated tax. It shall be calculated as the total revenues generated by tax collection (numerator) divided by the amount of taxes bills (denominator). The result shall then be multiplied by 100 and expressed as a percentage."

Competency questions:

1. (CI) For what time period is the tax collected and tax billed measured?
2. (F) Are the individual taxpayers residents of the city? Are the legal entity taxpayers based in the city?
3. (F) What is the age and employment status of individual taxpayer X?
4. (F) What is the ownership type of legal entity taxpayer X?
5. (F) What types of taxes do tax collected and tax billed comprise?
6. (D) What percentage of tax collected and tax billed does tax Y contribute to?
7. (F) What are the threshold, rate and imposing agent for tax Y? What is the penalty for failure to pay tax Y on time?

3. Background

The GCI Finance ontology is built on the Global City Indicator Foundation Ontology (Fox, 2013; 2015)[3], which integrates the following ontologies:

- Time (Hobbs & Pan, 2006),
- Measurement (Rijgersberg et al., 2011),
- Statistics (Pattuelli, 2009),
- Validity (Fox & Huang, 2005),
- Trust (Huang & Fox, 2006), and
- Placenames (www.geonames.org),

and extends them with city indicator specific concepts of populations, measurements, etc.

In this section we review existing Finance ontologies that we may re-use in or inspire our ontology design. Most of the ontologies we reviewed lack CQs, nor did they have documentation, which made their evaluation more difficult. The majority of the financial ontologies focus on financial instruments and industries, and we could not find any ontologies that focused on public finance.

3.1. Resources and ontologies that provide information directly relevant to municipal finance

OpenCYC (Matuszek et al., 2006) contained the largest number of classes and properties pertinent to our competency questions[4]. The classes are comparatively well defined. The concepts we re-used from OpenCYC include 'asset', 'monetary value', 'expense figure' and 'revenue'.

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[3] The GCI Foundation ontology can be found at http://ontology.eil.utoronto.ca/GCI/GCI-Foundation.owl along with its documentation at http://ontology.eil.utoronto.ca/GCI/GCI-Foundation.html. We will use the prefix "gci" where needed.

The class 'cyc:asset' is a subclass of 'cyc:Possession', and is defined as a class of which "Each instance is an anything of material value or usefulness." In order to answer the competency questions raised for the second GCI Finance Indicator, we need classes to capture concepts about fixed assets, which is a type of assets. Although ISO37120 does not include a direct definition of fixed assets, it does list examples of fixed assets, all of which being of long-term or permanent material value or usefulness. This concept is consistent with the definition provided by OpenCYC. Similarly, we re-use cyc:'intangible asset' as a subclass of cyc:Asset. Although OpenCYC does not provide an explicit definition for 'intangible asset', it does specify that it is equivalent to this concept defined at Wikipedia[5].

ISO 37120 standards have listed building and fixture as examples of fixed assets. Cyc:building and cyc:fixture are subsumed by cyc:'architectural_structure' and cyc:'solid object', respectively, and are therefore relevant to the fixed asset categories mentioned above.

In order to measure the sizes of monetary quantities for all four indicators, we need a concept to capture monetary values. OpenCYC has a class 'monetary value' which is defined as a collection of which each instance is "a value by means of which payments, wealth, capital, assets, etc., are measured". It also indicates that "each instance of this collection is an abstract object, not to be confused with the physical objects used as legal tender". This concept is consistent with what we need in order to answer the competency questions. Cyc:'monetary value' is accompanied with comments "Since instances of MonetaryValue are not pure numbers but quantities of some particular currency, they are denoted by means of the collection UnitOfMoney". The concept "UnitOfMoney" is what we need to capture the units of monetary quantities, and consistent with gci:'Monetary Unit', which will be used in our ontology.

OpenCYC defines numerous subtypes of 'monetary value', such as 'closing price' and 'gross income'. We use two of these subclasses to help answer the competency questions: 'expense figure' and 'revenue'. Although OpenCYC doesn't provide direct definition for these terms, it does specify that 'expense figure' has English aliases 'expense', and that 'revenue' has English aliases 'monetary values that is revenue of a social agent' and 'value of which some particular social agent has revenue'. Since both classes are subsumed by cyc:'monetary value', these aliases indicate that they capture concepts that measure monetary quantities for expense and revenue, and can be used to construct answers to the competency questions.

SUMO (Niles & Pierce, 2001) is an upper level ontology that contains a broad span of concepts[6], and also contains classes pertinent to our competency questions. A number of competency questions are directly related to the debt of the municipality. To refine the definition of debt, we need to introduce concepts such as debtor and creditor. The nature of the ISO 37120 standards implies that when speaking of debt, we mean the debt of the municipality, which is therefore the debtor. Sumo:Creditor

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[4] The OpenCYC ontology can be found at http://sw.opencyc.org/. We will use the prefix "cyc" where needed.
[5] The definition for 'intangible asset' can be found at https://en.wikipedia.org/wiki/Intangible_asset.
[6] The SUMO ontology can be found at http://ontologyportal.org/sumo.owl. We will use the prefix "sumo" where needed.

is defined as "a person to whom money is owed by a debtor; someone to whom an obligation exists", which is consistent with our understanding for the concept creditor.

The last Finance indicator explicitly concerns tax. In SUMO Ontology, the concept 'Tax' has the definition of "charge against a citizen's person or property or activity for the support of government". We therefore use this class as a type of own-source revenue, as defined in ISO 37120 standards.

SUMO also contains classes 'Equipment' and 'Furniture', which are consistent with the definition from ISO Finance indicators for these terms.

3.2. Resources and ontologies indirectly related to municipal finance

Schema.org contains a wide range of concepts and properties[7]. However, it does not include schemas directly related to financial matters. Instead, it provides definitions, properties and axioms for concepts such as Organization and Person. In our ontology, we will utilize its Person class. The class Organization has already been defined and included in the GCI Foundation ontology, which will be used in our computational representation of the Finance indicators.

When searching for classes and properties related to Finance or Public Finance, we came across the term FinancialService in schema.org. However, this class describes the financial services business, and is classified under Place and Organization. In our study regarding government finance and financial services, we focus on the branch of economics that assesses the government revenue and government expenditure of the public authorities and the adjustment of one or the other to achieve desirable effects and avoid undesirable ones[8]. Sc:FinancialService is thus irrelevant and does not overlap with the terms in our ontologies.

Sc:AccountingService is a subclass of sc:FinancialService, and therefore inherits all the properties from FinancialService. It is also a subclass of Place and Organization, and we cannot use it for our purposes.

3.3. Other ontologies reviewed

FIBO (Financial Industry Business Ontology, Bennett, 2013) by Object Management Group is one of the most important efforts in the Finance industry to standardize knowledge representation. It has included proper documentation to explain the contents and applications of FIBO, but mainly contains concepts regarding investment and business reporting. FIBO contains classes such as Equities, Derivatives and Loans, and they are all subclass of Financial Instruments. Although public finance is influenced by the financial markets, financial instruments such as bonds and securities are not needed in order to answer the competency questions. FIBO also defines 'monetary amount' as 'the measure which is an amount of money specified in monetary units'[9], which is consistent with OpenCYC's definition for 'monetary value'.

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[7] This ontology can be found under http://schema.org/. We will use the prefix "sc" where needed.
[8] The definition of public finance can be found at https://en.wikipedia.org/wiki/Public_finance.
[9] http://www.omg.org/spec/EDMC-FIBO/FND/Accounting/CurrencyAmount.rdf.

Other seemingly useful ontologies that we have discovered include the LSDIS Finance ontology[10], which contains important financial concepts such as equity and liability. However, these are simply empty classes, and do not include definitions or properties to help identify whether they represent the correct concepts and can be reused.

4. Architecture of the ISO 37120 Ontology

As explained in the Introduction of this paper, ISO 37120 defines 100 global city indicators. The following diagram (Fox, 2013) depicts the modules that are used to define the ISO 37120 indicators. 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: "http://ontology.eil.utoronto.ca/ISO37120.owl#9.1".

An ISO 37120 theme's indicators are defined in a separate file. A complete OWL definition for all four of the GCI Finance indicators can be found in ISO37120-Finance.owl.

The GCI Ontology level provides specific ontologies required to define each theme's indicators. The Finance indicators are defined with concepts such as revenue, expenditure, debt, creditor, etc. These concepts are captured in GCI-Finance.owl, and are used in ISO37120-Finance.owl.

All of the ontologies specific to individual themes are built on base on GCI Foundation ontology, which defines generic concepts such as monetary units and ratios, meta-information, etc.

The Enterprise Ontology level contains the TOVE Enterprise Modeling ontologies (Fox & Gruninger, 1998). Here only Organization.owl (Fox et al., 1998) is shown[11].

Lastly, the Foundation Ontology level contains the very basic ontologies which serve as the foundation for everything above.

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[10] http://lsdis.cs.uga.edu/projects/meteor-s/wsdl-s/ontologies/LSDIS_FInance.owl

[11] The Organization ontology can be found at http://ontology.eil.utoronto.ca/organization.owl along with its documentation at http://ontology.eil.utoronto.ca/organization.html. We will use the prefix "org" where needed.
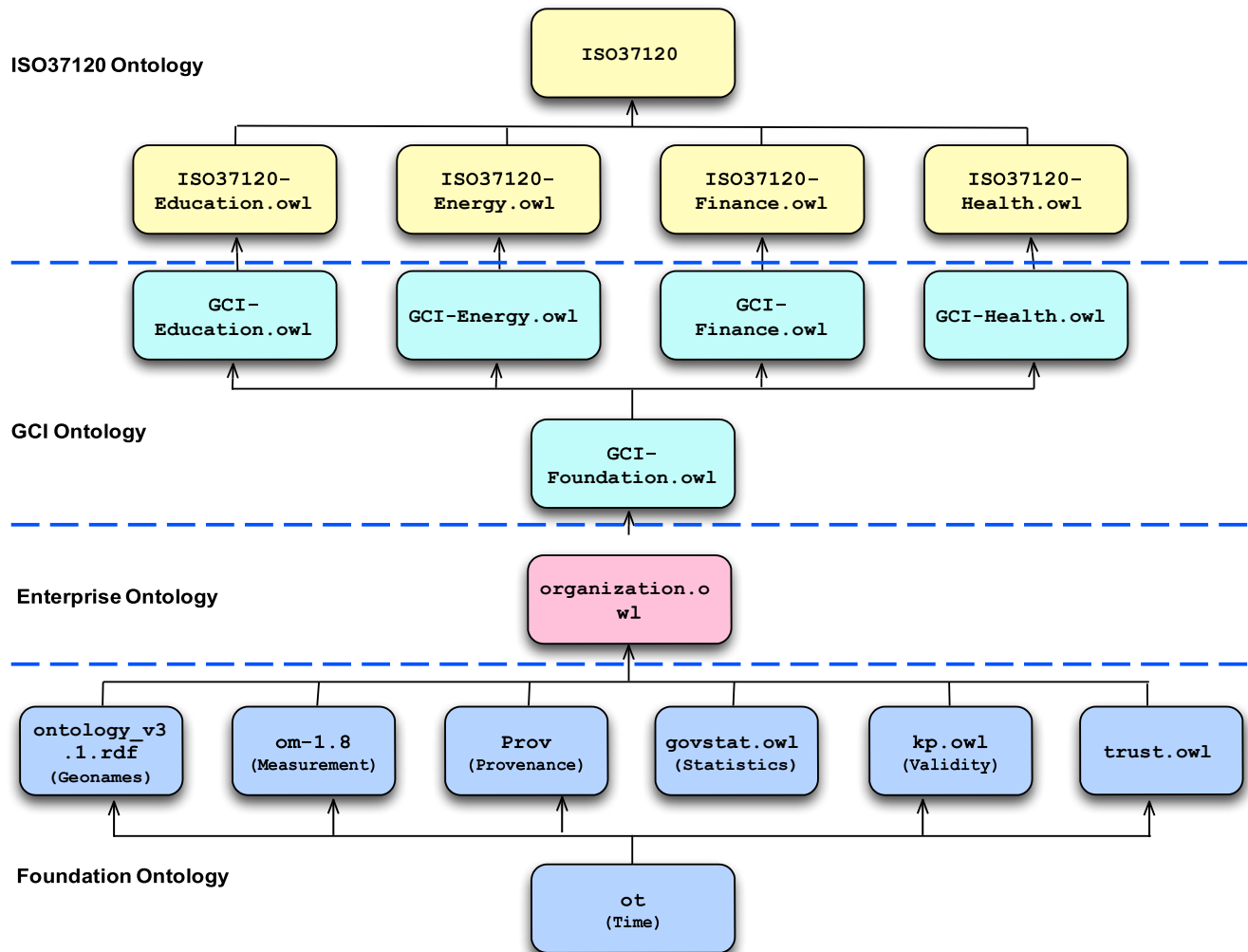
Figure 1: ISO 37120 Ontology Modules (Fox, 2013)

5. GCI Finance Ontology

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

- The types of debt and assets a municipality has, and the properties and terms of the debt,
- The sources that contribute to revenue, and what type of revenue each source contributes to,
- The types of expenditures, and the purpose of each expenditure, and
- 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. The GCI Finance ontology can be found at http://ontology.eil.utoronto.ca/GCI/Finance/GCI-Finance.owl.

5.1. Debt, Asset and Liability Classes

Some of the competency questions are directly related to debt, assets and liability:

1. (F) What are the municipality's total expenditure and debt?
2. (D) What percentage of the total debt is repaid?

3. (F) What types of debt are paid for by a municipality's debt expenditure?
4. (D) For each debt expenditure type X, what percentage does it contribute to the total debt expenditure?
5. (F) 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?
6. (D) What percentage of each debt type X is repaid?
7. (F) Which fixed assets are included when calculating the capital spending?
8. (D) What percentage of the capital spending does fixed asset X contribute to?
9. (F) For a fixed asset X, is it rented, leased or purchased?
10. (F) For what period of time is the municipality in possession of fixed asset X? What are the terms on obtaining asset X?
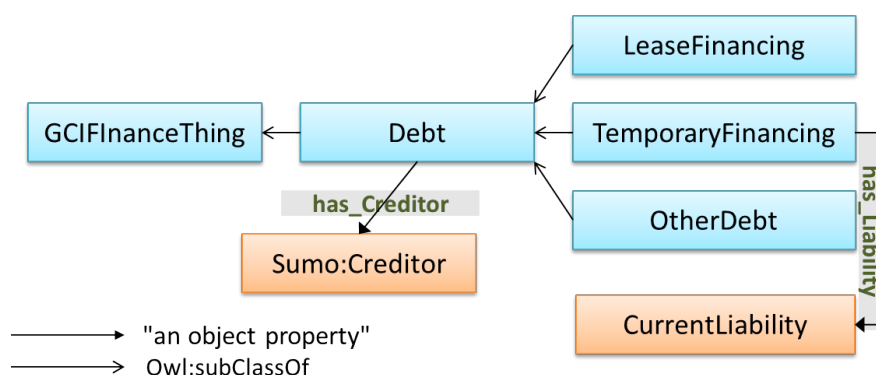
Figure 2: Debt Taxonomy

The taxonomy of Debt 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.

The following table describes the properties and axioms of the class Debt. Each debt items may have one code (ID), exactly one due date, one interest rate, one payment terms, and some creditor. All the subclasses of Debt also inherit these properties and axioms.

Class	Property	Value Restriction
Debt	owl: subClassOf	GCIFinanceThing
	due_Date	exactly 1 xsd:dateTime
	has_Amount	exactly 1 cyc:'monetary value'
	has_Code	max 1 xsd:string
	has_Creditor	min 1 Creditor
	interestRate	exactly 1 xsd:double
	paymentTerms	exactly 1 xsd:string
LeaseFinancing	owl: subClassOf	Debt
	lease_Property	min 1 Asset

TemporaryFinancing	owl: subClassOf	Debt
	has_Liability	some CurrentLiability
OtherDebt	owl: subClassOf	Debt

In the above table, a creditor is an individual or organization that the municipality owes money to. The class Creditor has two subclasses: CreditorIndividual and CreditorOrganization, which are under Person and Organization classes, respectively. They will be explained in detail in section 5.4. Each debt item has an amount that is a monetary value. A monetary value is a type of quantity, as explained in section 5.6.

The following diagram describes the taxonomy of Asset classes. Two major asset classes are tangible assets and intangible assets[12]. ISO 37120 and our competency questions only concern FixedAsset directly, which is a subclass of TangibleAsset, because fixed assets are directly tied to capital spending as 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.
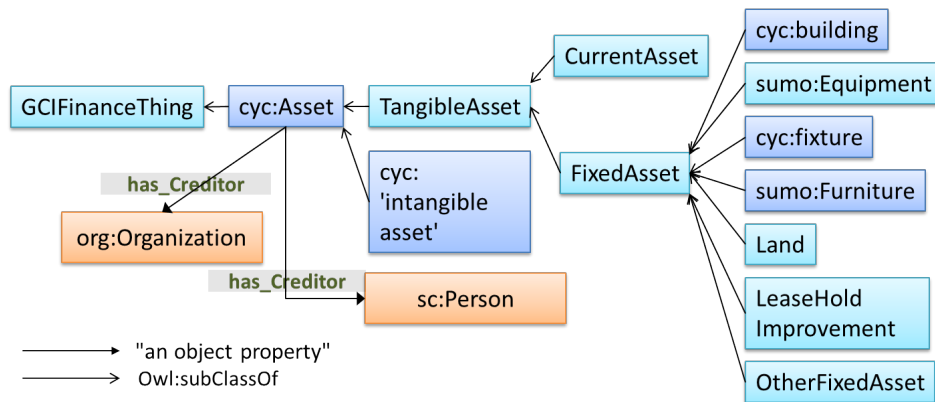

Figure 3: Asset Taxonomy

Class	Property	Value Restriction
cyc:Asset	owl: subClassOf	GCIFinanceThing
	ending_Month	exactly 1 xsd:int
	ending_Year	exactly 1 xsd:int
	has_Owner	some Organization
	has_Owner	some Person
	starting_Month	exactly 1 xsd:int
	starting_Year	exactly 1 xsd:int
cyc:'intangible asset'	owl: subClassOf	Asset
	disjointWith	TangibleAsset

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[12] This classification comes from Wikipedia: https://en.wikipedia.org/wiki/Asset.

TangibleAsset	owl: subClassOf	Asset
	disjointWith	cyc:'intangible asset'
FixedAsset	owl: subClassOf	TangibleAsset
CurrentAsset	owl: subClassOf	TangibleAsset
cyc:building	owl: subClassOf	FixedAsset
sumo:Equipment	owl: subClassOf	FixedAsset
cyc:fixture	owl: subClassOf	FixedAsset
sumo:Furniture	owl: subClassOf	FixedAsset
Land	owl: subClassOf	FixedAsset
LeaseholdImprovement	owl: subClassOf	FixedAsset
OtherFixedAsset	owl: subClassOf	FixedAsset

Liability classes 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[13]. The property has_Liability having a range of CurrentLiability distinguishes temporary financing from lease financing. Payables over a term exceeding one year would be fixed liabilities or long-term liabilities.
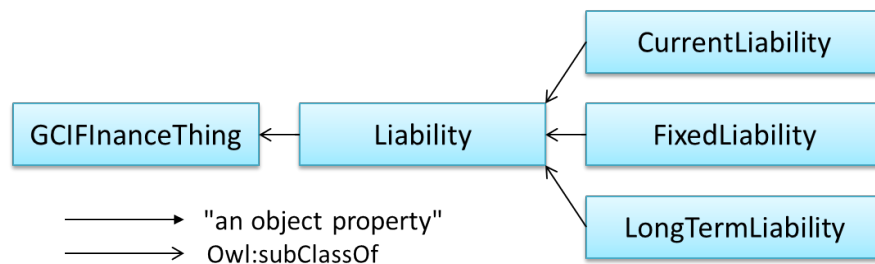

Figure 4: Liability Taxonomy

Class	Property	Value Restriction
Liability	owl: subClassOf	GCIFinanceThing
	ending_Month	exactly 1 xsd:gMonth
	ending_Year	exactly 1 xsd:gYear
	starting_Month	exactly 1 xsd:gMonth
	starting_Year	exactly 1 xsd:gYear
CurrentLiability	owl: subClassOf	Liability
	disjointWith	{FixedLiability, LongTermLiability}
FixedLiability	owl: subClassOf	Liability
	disjointWith	{CurrentLiability, LongTermLiability}
LongTermLiability	owl: subClassOf	Liability
	disjointWith	{FixedLiability, CurrentLiability}

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[13] https://en.wikipedia.org/wiki/Current_liability

5.2. Revenue Classes

Some of the competency questions are directly related to public revenue:

1. (CI) For what time period is a municipality's own-source revenue measured?
2. (F) What is the total revenue for the fiscal period?
3. (F) What is the total transfers revenue for the fiscal period?
4. (F) What is a municipality's own-source revenue?
5. (D) For each revenue type Y, what percentage does it contribute to the total own-source revenue?
6. (F) From which sources do transfer revenues originate?
7. (F) What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?
8. (CI) For what time period is the own-source revenue of a municipality measured? For what time period are a municipality's total revenues measured?
9. (F) What is the budget for own-source revenue and total revenues for the fiscal year measured?
10. (F) What revenue sources do the total revenues include?
11. (D) What percentage of own-source revenue does revenue X contribute to? What percentage of the total revenues does X contribute to?
12. (F) Is revenue X an operating or recurring revenue?

Two of the indicators (ISO 37120:9.1 and ISO 37120:9.3) directly involve revenue of the city government, and ISO37120:9.4 concerns tax, which is 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.
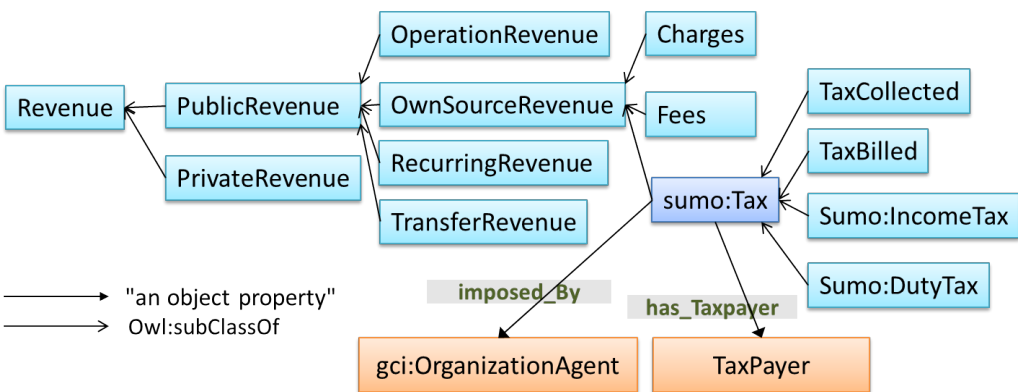

Figure 5: Revenue Taxonomy

Class	Property	Value Restriction
Revenue	owl: subClassOf	GCIFinanceThing
	has_amount	exactly 1 cyc:'monetary value'

	revenueSource	min 1 xsd:string
	hasCode	max 1 xsd:string
PrivateRevenue	owl: subClassOf	Revenue
	disjointWith	PublicRevenue
PublicRevenue	owl: subClassOf	Revenue
	disjointWith	PrivateRevenue
OwnSourceRevenue	owl: subClassOf	PublicRevenue
TransfersRevenue	owl: subClassOf	PublicRevenue
sumo:Tax	has_Taxpayer	only TaxPayer
	imposed_By	min 1 OrganizationAgent
	tax_Rate	min 1 xsd:double
	tax_Threshold	exactly 1 xsd:double
	owl: subClassOf	OwnSourceRevenue
Fees	owl: subClassOf	OwnSourceRevenue
Charges	owl: subClassOf	OwnSourceRevenue
RecurringRevenue	owl: subClassOf	PublicRevenue
OperatingRevenue	owl: subClassOf	PublicRevenue

Each revenue item may have an ID or code associated to it, depending on the format of reporting. OwnSourceRevenue can be classified into tax, fees and charges, as explained in Introduction to Public Finance (Plehn, 1902), as well as in the definition for own source revenue in ISO 37120:9.3. Public revenue can take form of operating revenue or re-occurring revenue, also as indicated in ISO 37120:9.3. Additionally, public revenue can be expressed as own source revenue plus transfers, based on ISO 37120:9.1.

Tax is the subclass of revenue that we will focus on for the fourth Finance indicator. 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.

5.3. Expenditure Classes
Some of the competency questions are pertinent to public spending:
1. (CI) For what time period is the debt service expenditure of a municipality measured?
2. (F) What are the municipality's total expenditure and debt?
3. (D) What percentage of the total debt is repaid?
4. (F) What types of debt are paid for by a municipality's debt expenditure?
5. (D) For each debt expenditure type X, what percentage does it contribute to the total debt expenditure?
6. (F) What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?
7. (CI) For what time period is the capital spending of a municipality measured? For what time period are a municipality's total expenditures measured?
8. (D) What percentage of the capital spending does fixed asset X contribute to?

9. (F) What sources contribute to the total operating expenditure?
10. (D) What percentage of the operating expenditure does expense item Y contribute to?

Figure 6 depicts the taxonomy for public expenditure in the GCI Finance ontology. Since the counterpart of capital expenditure is operational expenditure[14], any one of a municipality's expense items should be either capital spending or operating expenditure. By definition of operating expense[15], DebtExpenditure is a subclass 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 these three types represent TotalDebtExpenditure.
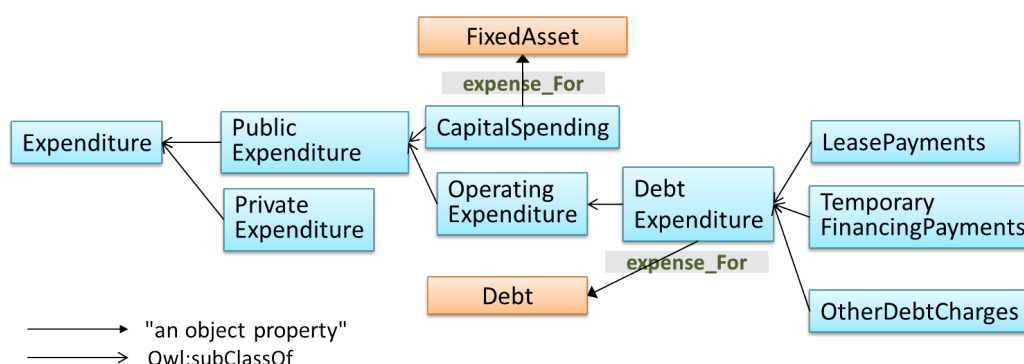

Figure 6: Expenditure Taxonomy

The following table shows the properties of Expenditure and its subclasses.

Class	Property	Value Restriction
Expenditure	expensePurpose	min 1 String
	has_Code	max 1 String
	has_amount	exactly 1 'monetary value'
	om:unit_of_measure	gct:'Monetary Unit'
	owl: subClassOf	GCIFinanceThing
CapitalSpending	expense_For	Some FixedAsset
	owl: subClassOf	PublicExpenditure
	disjointWith	OperatingExpenditure
DebtExpenditure	expense_For	Some Debt
	owl: subClassOf	OperatingExpenditure
PublicExpenditure	owl: subClassOf	Expenditure
	disjointWith	PrivateExpenditure
PrivateExpenditure	owl: subClassOf	Expenditure
	disjointWith	PublicExpenditure

[14] Detailed explanation can be found on Wikipedia: https://en.wikipedia.org/wiki/Capital_expenditure.
[15] https://en.wikipedia.org/wiki/Operating_expense.

OperatingExpenditure	owl: subClassOf	PublicExpenditure
	disjointWith	CapitalSpending
TotalPublicExpenditure	owl: subClassOf	PublicExpenditure
	sum_Term	only (CapitalSpending or OperatingExpenditure)
LeasePayments	owl: subClassOf	DebtExpenditure
	expense_For	some LeaseFinancing
	disjointWith	{ TemporaryFinancingPayment, OtherDebtCharges}
TemporaryFinancingPayment	owl: subClassOf	DebtExpenditure
	expense_For	some TemporaryFinancing
	disjointWith	{ LeasePayments, OtherDebtCharges}
OtherDebtCharges	owl: subClassOf	DebtExpenditure
	expense_For	some OtherDebt
	disjointWith	{ TemporaryFinancingPayment, LeasePayments }

Like revenue, each expenditure item might have its code or ID depending on the format of reporting. At the same time, each expenditure item has a purpose, or reason of expense. CapitalSpending, according to its definition in ISO37120:9.2, is the type of expenditure on fixed assets, and DebtExpenditure is the type of expense for debt items. Both relationships are captures with the property gcif[16]:expense_For. All other expenditure subclasses without explicit expense subjects that are pertinent to our indicators have the property gcif:expensePurpose, whose value is a String. Each subclass of Expenditure inherits its properties.

5.4. Person and Organization Classes

In order to collect information regarding debt service expenditure and tax, we introduce the classes Creditor and TaxPayer, which appear in the form of either individuals or organizations. Following are the competency questions related to Person and Organization:
1. (F) For each debt type X: Who is the creditor
2. (F) Are the individual taxpayers residents of the city? Are the legal entity taxpayers based in the city?
3. (F) What is the age and employment status of individual taxpayer X?
4. (F) What is the ownership type of legal entity taxpayer X?

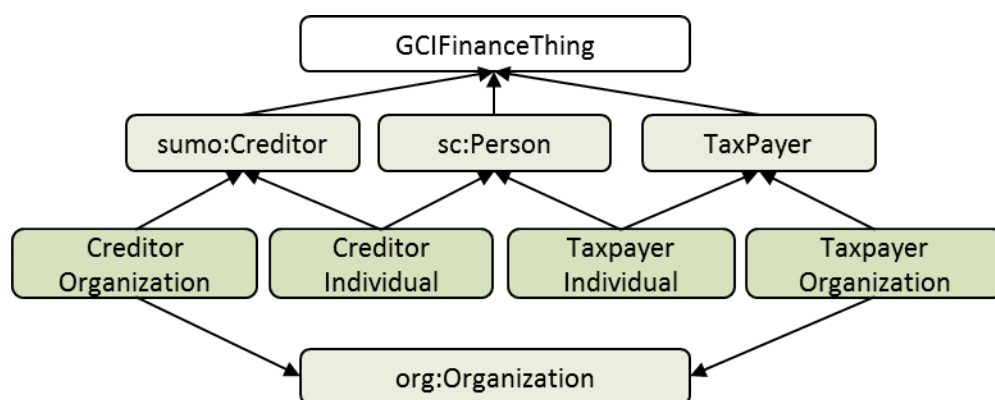[16] gcif is the prefix for GCI Finance ontology.

Figure 7: Person and Organization Taxonomy

The Person class is imported from Asset Description Metadata Schema[17], 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.

As explained earlier in this chapter, each debt item has one or more Creditor. The fourth indicator has a numerator and a denominator as tax collected and tax billed, both of which have corresponding taxpayers. Creditor and TaxPayer can be individuals or organizations.

Class	Property	Value Restriction
org:Organization	org:hasName	only String
	org:hasLegalName	exactly 1 String
	org:has_Ownership	exactly 1 Ownership
sc:Person	has_Birthdate	exactly 1 xsd:dateTime
	hasEmploymentStatus	exactly 1 EmploymentStatus
	resident_Of	min 1 City
	gci:has_Primary_Residence	exactly 1 Address
	owl: subClassOf	GCIFinanceThing
sumo:Creditor	owl: subClassOf	GCIFinanceThing
TaxPayer	owl: subClassOf	GCIFinanceThing
TaxPayerOrganization	based_In	exactly 1 City
	owl: subClassOf	TaxPayer
	owl: subClassOf	org:Organization
TaxPayerIndividual	owl: subClassOf	adms:Person
	owl: subClassOf	TaxPayer
CreditorOrganization	owl: subClassOf	org:Organization
	owl: subClassOf	sumo:Creditor

CreditorIndividual	owl: subClassOf	adms:Person
	owl: subClassOf	sumo:Creditor

5.5. Tax Classes

The fourth GCI Finance indicator (ISO 37120:9.4) regards tax collected and tax billed. Therefore, all of its competency questions are related to tax classes:

1. (CI) For what time period is the tax collected and tax billed measured?
2. (F) Are the individual taxpayers residents of the city? Are the legal entity taxpayers based in the city?
3. (F) What is the age and employment status of individual taxpayer X?
4. (F) What is the ownership type of legal entity taxpayer X?
5. (F) What types of taxes do tax collected and tax billed comprise?
6. (D) What percentage of tax collected and tax billed does tax Y contribute to?
7. (F) What are the threshold, rate and imposing agent for tax Y? What is the penalty for failure to pay tax Y on time?

In our Finance ontology, sumo:Tax is a subclass of OwnSourceRevenue, and Sumo defines two subclasses of Tax – IncomeTax and DutyTax. The class OtherTax is defined to captured other tax categories not belonging to income or duty types. The classes TaxCollected and TaxBilled are defined because they are the nominator and denominator of the last Finance indicator, and they are disjoint with each other, because they represent tax at different stages.

Each tax item has a tax payer which can be either an individual or organization, and also imposed by an OrganizationAgent.

Figure 8: Tax Taxonomy
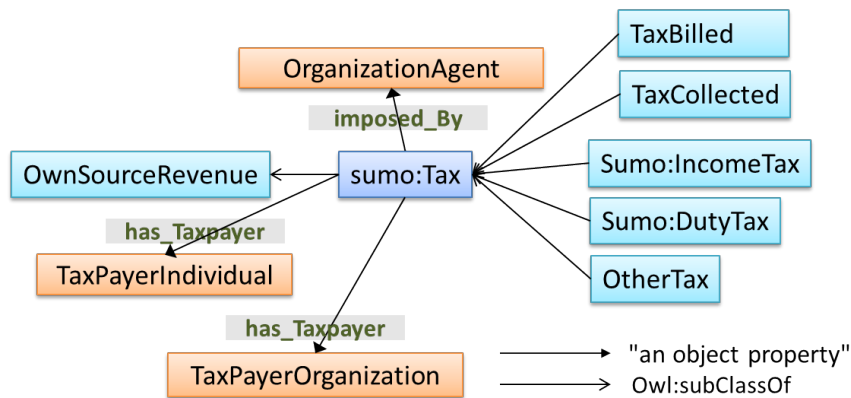
Class	Property	Value Restriction
sumo:Tax	owl: subClassOf	OwnSourceRevenue
	has_Taxpayer	some TaxPayerIndividual
	has_Taxpayer	some TaxPayerOrganization
	imposed_By	min 1 OrganizationAgent

	tax_Rate	min 1 Double
	tax_Threshold	exactly 1 Double
TaxBilled	owl: subClassOf	sumo:Tax
	disjointWith	TaxCollected
TaxCollected	owl: subClassOf	sumo:Tax
	disjointWith	TaxBilled
sumo:IncomeTax	owl: subClassOf	sumo:Tax
	disjointWith	sumo:DutyTax, OtherTax
sumo:DutyTax	owl: subClassOf	sumo:Tax
	disjointWith	sumo:IncomeTax, OtherTax
OtherTax	owl: subClassOf	sumo:Tax
	disjointWith	sumo:DutyTax, sumo:IncomeTax

Classes regarding taxpayer has been explained in 5.4 in this paper.

According to the definition of tax[18], each tax item has its taxpayer, threshold, tax rate and imposing agent. Tax billed and tax collected are both subclasses of Tax.

5.6. Monetary Measurement Classes

The following competency question:

1. (F) What currency and exchange ratio are used in reporting debt service expenditure and own-source revenue?

introduces a representational requirement not seen in other themes. The Finance indicators are different in that none of their measures are represented as population sizes. Instead, they exist as continuous quantities. Additionally, all the numerators and denominators in the Finance indicators may incur different currencies and exchange rates, increasing the potential of inconsistency internally.

In order to measure total financial quantities, we need a concept to capture 'monetary value', which is defined in OpenCYC. This class subsumes concepts representing monetary values for debt, tax, expense and revenue. Each of the monetary value subtypes contains total quantities for financial activities. For example, TaxMonetaryValue subsumes TotalTaxCollected and TotalTaxBilled, both of which of certain types of tax monetary value. The taxonomy for monetary value representation is shown in Figure 9.
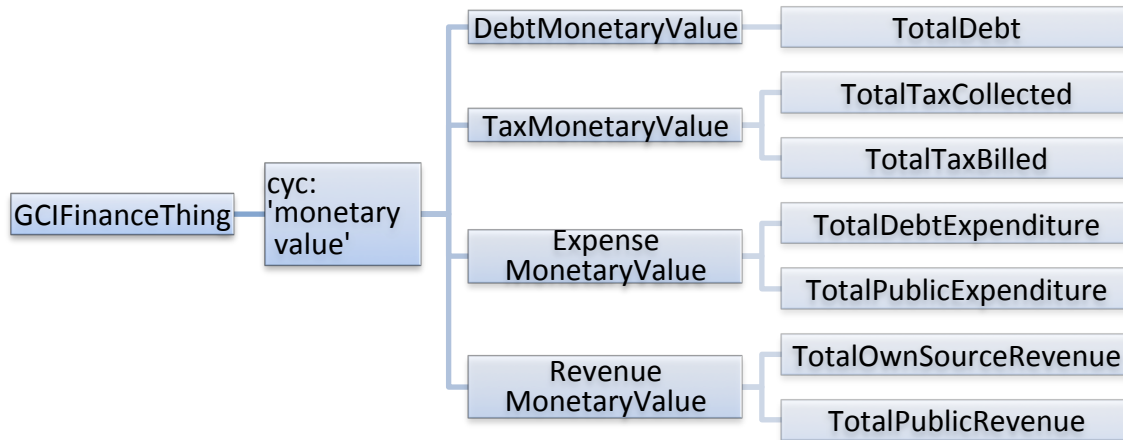
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[18] https://en.wikipedia.org/wiki/Tax.

Figure 9: Monetary Value Taxonomy

The monetary concepts related to measure and unit are inferred from OM Ontology[19]. Each of the indicators under GCI Finance is an om:Quantity, and has a MonetaryRatioUnit which is an om:UnitOfMeasure. Any MonetaryValue has a MonetaryUnit that is a currency. Each GCI Finance indicator has a numerator and a denominator, both of which are monetary values.
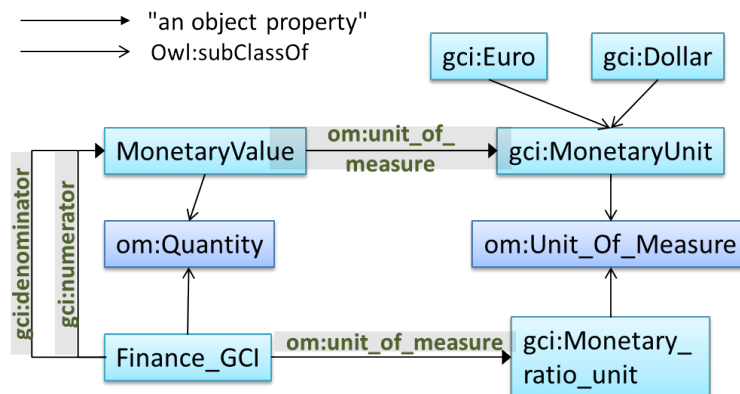
Figure 10: Monetary Unit Taxonomy

'Monetary Unit' has already been defined in GCI Foundation ontology, and here we import the corresponding classes into the Finance ontology.

Properties of MonetaryValue 'originalCurrency' 'exchangeRatio' capture the exchange rate of MonetaryValue to a different currency.

When reviewing existing ontologies, we found that OpenCYC includes and defines some Finance terms, such as 'monetary value', 'expense figure' and 'revenue', which are equivalent to classes

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[19] The OM ontology can be found at http://www.wurvoc.org/vocabularies/om-1.6/. We will use the prefix "om" where needed.

MonetaryValue, ExpenseMonetaryValue and RevenueMonetaryValue in our Finance ontology, respectively.

The property sum_Term denotes all the terms whose values need to be added to calculate the sum. For example, TotalDebt has sum_Term of (LeaseFinancing and OtherDebt and TemporaryFinancing), meaning that TotalDebt is the sum of the monetary values of LeaseFinancing,TemporaryFinancing and OtherDebt. These terms need to be disjoint with each other.

Class	Property	Value Restriction
cyc:'monetary value'	owl:subClassOf	GCIFinanceThing
	owl:subClassOf	om:Quantity
	gci:unit_of_measure	exactly 1 gci:'Monetary Unit'
	exchangeRatio	exactly 1 Double
	originalCurrency	exactly 1 gci:'Monetary Unit'
DebtMonetaryValue	owl: subClassOf	cyc:'monetary value'
	amount_Of	exactly 1 Debt
TotalDebt	owl: subClassOf	DebtMonetaryValue
	sum_Term	only (LeaseFinancing and OtherDebt and TemporaryFinancing)
TaxMonetaryValue	owl: subClassOf	cyc:'monetary value'
	amount_Of	exactly 1 Tax
TotalTaxBilled	owl: subClassOf	TaxMonetaryValue
	sum_Term	only (sumo:IncomeTax and sumo:DutyTax and OtherTax)
TotalTaxCollected	owl: subClassOf	TaxMonetaryValue
	sum_Term	only (sumo:IncomeTax and sumo:DutyTax and OtherTax)
ExpenseMonetaryValue	owl:equivalentTo	cyc:'expense figure'
	owl: subClassOf	cyc:'monetary value'
TotalPublicExpenditure	owl: subClassOf	ExpenseMonetaryValue
	sum_Term	only (CapitalSpending and OperatingExpenditure)
TotalDebtExpenditure	owl: subClassOf	ExpenseMonetaryValue
	sum_Term	only (LeasePayments and OtherDebtCharges and TemporaryFinancingPayments)
RevenueMonetaryValue	owl:equivalentTo	cyc:revenue
	owl: subClassOf	MonetaryValue
TotalPublicRevenue	owl: subClassOf	RevenueMonetaryValue
	sum_Term	only ((OperatingRevenue and RecurringRevenue) or (OwnSourceRevenue

		and TransferRevenue))
TotalOwnSourceRevenue	owl: subClassOf	RevenueMonetaryValue

6. GCI Foundation Ontology Infrastructure

The GCI Foundation Ontology (Fox, 2013) defines the basic structure of a ratio indicator, which is the basis of the finance indicators ontology that we're going to discuss in the next section.

The GCI Foundation Ontology uses the OM measurement ontology (Rijgersberg et al., 2011) to provide the underlying semantics of a number, such as what is being measured and the unit of measurement. This ensures the comparability of the numbers, e.g., the monetary value of debt service expenditure and own source revenue, which comprise the debt service ratio, are of the same unit and use the same conversion standards.

Figure 11 depicts the basic classes of the OM ontology used to represent an indicator. There are three main classes in OM: a 'Quantity' that denotes what is being measured, e.g., diameter of a ball; a 'Unit of Measure' that denotes how the quantity is measured, e.g., centimeters; and a 'Measure' that denotes the value of the measurement which is linked to both 'Quantity' and 'Unit of Measure'. For example, Debt Service Ratio is a subclass of 'Quantity' that has a value that is a subclass of 'Measure' whose units are a 'Monetary ratio unit' that is a subclass of 'Unit of Measure'. The actual value measured is a property of the 'Measure' subclass 'Debt Service Ratio Measure'.
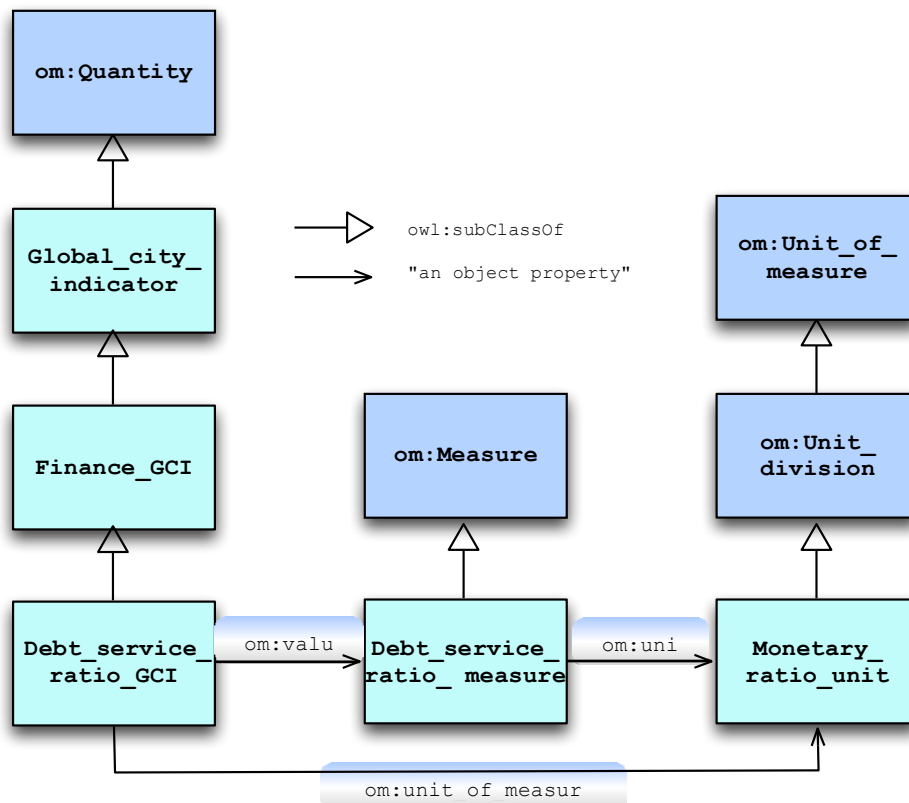
Figure 11. Measurement Ontology

The debt service ratio indicator is based on a measure of the monetary value of debt expenditure and own source revenue, which satisfy the indicators' definition of each, within a city's finances. Both can be viewed as a statistical measurement in the sense that there is a monetary value that we want to perform a measurement of, the measurement being a measure of the quantity of financial activity size that satisfy a description of the debt service expense and own source revenue, respectively. While the indicators require a measure of transactions of the financial activities, other measures may require statistics such as mean, standard deviation, etc.

All of the finance indicators are ratios. A ratio indicator (Figure 12) has a unit of measure defined to be a 'Monetary Ratio Unit' that specifies that the indicator is the ratio of the financial quantity (monetary value). One monetary value is the numerator and the other the denominator. A 'monetary value' has a unit of measure which is a 'Monetary Unit'.
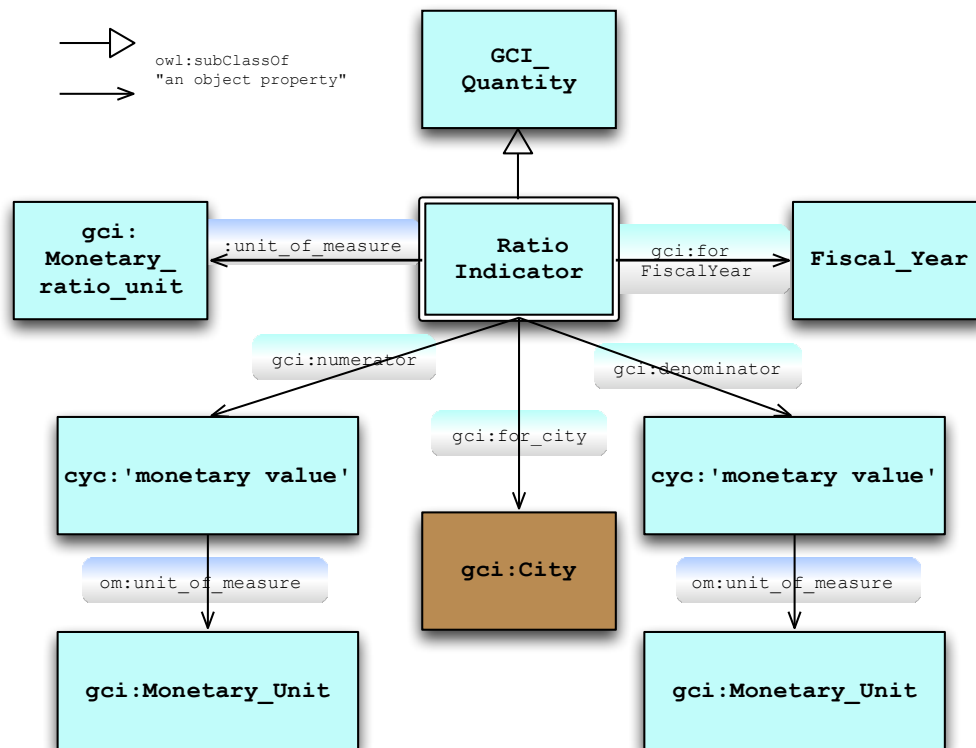
Figure 12. Foundation Ontology Monetary Ratio definition

7. ISO 37120 Finance Indicators Ontology

The GCI Finance ontology provides the classes and properties necessary to represent the definitions of the ISO 37120 Finance theme indicators. This section depicts the representation of the four ISO 37120 Finance indicators. The OWL representation of the finance indicator definitions can be found at http://ontology.eil.utoronto.ca/GCI/ISO37120/Finance.owl.

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

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

The following diagram depicts the definition of ISO37120:9.1. For the numerator and denominator, the monetary value is represented as the amount of DebtExpenditure and 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. Own source revenue is total revenue less transfers, and therefore 9.1_TotalRevenue is 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 value. Additionally, we depict the fiscal year and which city it is reported for.
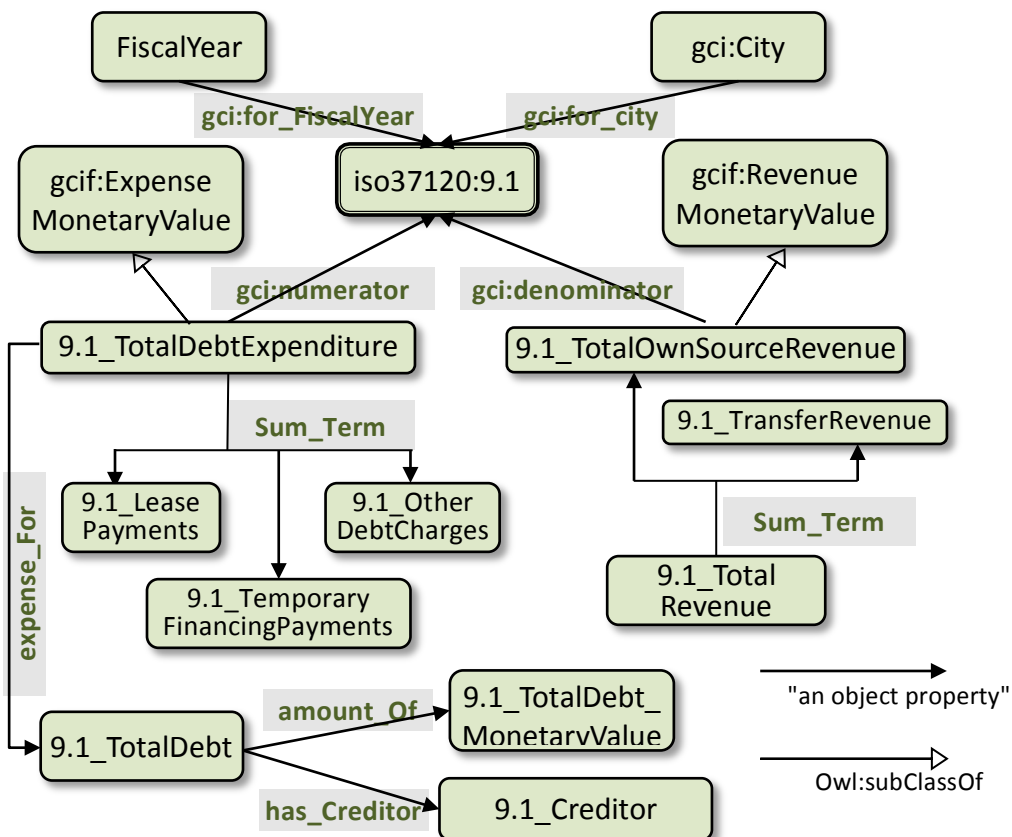

Figure 13: ISO 37120 finance Indicato - 9.1 Definition

In the above diagram and the following tables, 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.

Class	Property	Value Restriction
iso37120:9.1	owl: subClassOf	gci: 'Finance Indicators'
	gci: 'for city'	exactly 1 gci:City
	for_FiscalYear	exactly 1 FiscalYear
	gci: numerator	exactly 1 9.1_TotalDebtExpenditure
	gci: denominator	exactly 1 9.1_TotalOwnSourceRevenue

Debt service expenditure is defined as the sum of lease payments, temporary financing payment and other debt charges, whereas own source revenue is the difference between total revenue and transfers revenue. Although subtypes of own source revenue are specified in 9.3, they are not considered here due to the definition used in the first indicator. The way ISO Finance Ontology represents these relationships is demonstrated in the following table.

Class	Property	Value Restriction
9.1_TotalDebtExpenditure	owl: subClassOf	gcif:TotalDebtExpenditure
	gcif:for_FiscalYear	exactly 1 9.1_FiscalYear
	gcif:sum_Term	only (9.1_LeasePayments and 9.1_OtherDebtCharges and 9.1_TemporaryFinancingPayments)
	expense_For	only 9.1_TotalDebt
9.1_TotalOwnSourceRevenue	owl: subClassOf	gcif:TotalOwnSourceRevenue
9.1_TotalRevenue	owl: subClassOf	gcif:TotalPublicRevenue
	sum_Term	only (9.1_TotalOwnSourceRevenue and 9.1_TransferRevenue)

Additional axioms are needed to complete the above definitions:
1. Debt types 'LeaseFinancing' 'TemporaryFinancing' and 'OtherDebt' all have some 'Creditor'.
2. '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'.

7.2. Capital spending as a percentage of total expenditures (supporting indicator) (ISO 37120: 9.2)

The second ISO 37120 Finance indicator is a supporting indicator, and is defined as the capital spending as a percentage of total expenditures. Since capital spending is defined in ISO 37120 as the total expenditure on fixed assets, we need to include classes representing fixed assets in our ontology, including specific types of fixed assets as listed in ISO37120:9.2.

In the following diagram, tables and contents, we use "iso37120:9.2" to represent the class "Capital spending as a percentage of total expenditures (supporting indicator)".
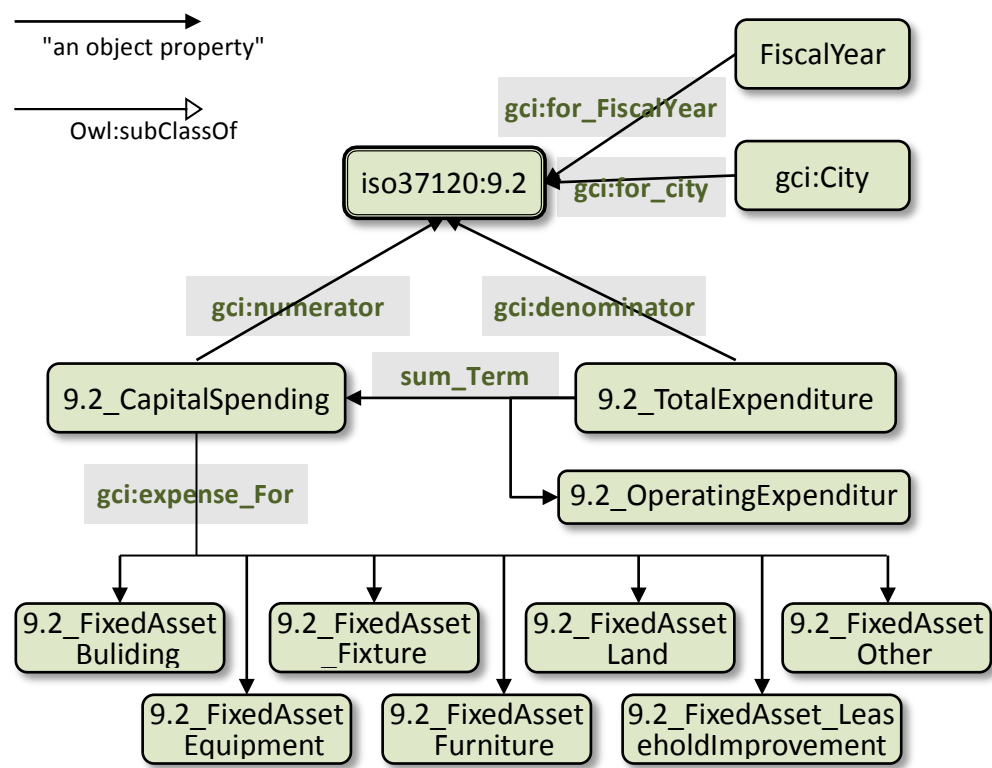
Figure 14: ISO 37120 - 9.2 Definition

Similar to ISO 37120: 9.1, indicator 9.2 defines the ratio between two monetary values – capital spending and total expenditure. The class 'iso37120:9.2' has been directly imported from GCI Foundation ontology, and ISO Finance ontology defines its properties including 'for city', for_FiscalYear, numerator and denominator.

Class	Property	Value Restriction
iso37120:9.2	owl: subClassOf	gci: 'Finance Indicators'
	gci: 'for city'	exactly 1 gci:City
	for_FiscalYear	exactly 1 FiscalYear
	gci: numerator	exactly 1 9.2_CapitalSpending
	gci: denominator	exactly 1 9.2_TotalExpenditure

ISO37120:9.2 indicates that total expenditure comprises capital spending and operating expenditure, and that capital spending is the expenditure on fixed assets, which can be building, equipment, fixture, furniture, land, leasehold improvement or other fixed asset.

Class	Property	Value Restriction
9.2_CapitalSpending_MonetaryValue	owl: subClassOf	gcif:ExpenseMonetaryValue
	gcif:amount_Of	exactly 1 9.2_CapitalSpending
9.2_CapitalSpending	owl: subClassOf	gcif:CapitalSpending
	gcif:expense_For	only (9.2_FixedAsset_Building or 9.2_FixedAsset_Equipment or 9.2_FixedAsset_Fixture or 9.2_FixedAsset_Furniture or 9.2_FixedAsset_Land or 9.2_FixedAsset_LeaseholdImprovement or 9.2_FixedAsset_OtherFixedAsset
9.2_TotalExpenditure	owl: subClassOf	gcif:TotalExpenditure
	gcif:sum_Term	only (9.2_CapitalSpending and 9.2_OperatingExpenditure)

7.3. Own-source revenue as a percentage of total revenues (supporting indicator) (ISO 37120: 9.3)

The third ISO 37120 Finance indicator is a supporting indicator, and is related to only public revenues. It is defined as the ratio between own-source revenue and total revenues.

In the first Finance indicator, we have already defined and expanded on own-source revenue. Here ISO37120:9.3 provides another definition of own-source revenue: the total amount of funds obtained through permit fees, user charges for city services, and taxes collected for city purposes only. This definition is different from the one in 9.1, and here we don't need total revenue to calculate own source revenue. 9.3 indicates that total revenue includes operating revenue and re-occurring revenue, which is captured in the ISO37120 Finance ontology.

We will use iso37120:9.3 to represent the main class 'Own-source revenue as a percentage of total revenues (supporting indicator)' in the following.
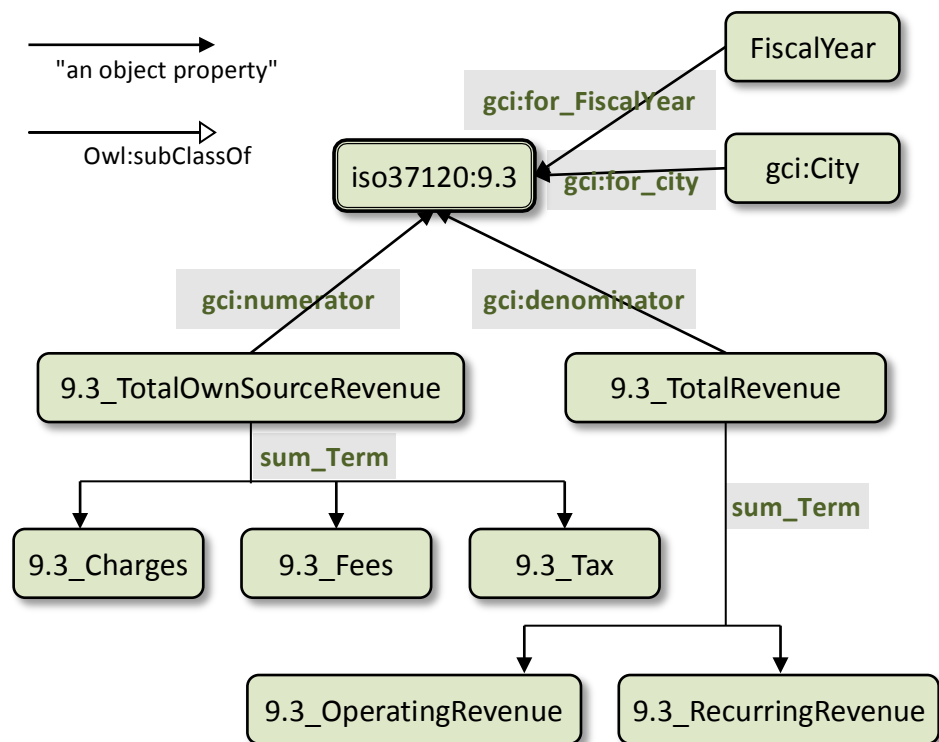
Figure 15: ISO 37120 - 9.3 Definition

Like previous indicators, ISO37120:9.3 also captures the city and fiscal year that the indicator is for. 'iso37120:9.3' has been imported from under 'Finance Indicators' class in GCI Foundation ontology.

Class	Property	Value Restriction
iso37120:9.3	owl: subClassOf	gci: 'Finance Indicators'
	gci: 'for city'	exactly 1 gci:City
	for_FiscalYear	exactly 1 FiscalYear
	gci: numerator	exactly 1 9.3_TotalOwnSourceRevenue
	gci: denominator	exactly 1 9.3_TotalRevenue

As explained above, total own source revenue is the sum of fees, charges and tax, and total public revenue is the sum of operating revenue and re-occurring revenue.

Class	Property	Value Restriction
9.3_TotalOwnSourceRevenue	owl:subClassOf	gcif:TotalOwnSourceRevenue
	gcif:sum_Term	only (9.3_Charges and 9.3_Fees and 9.3_Tax)
9.3_TotalRevenue	owl: subClassOf	gcif:TotalRevenue
	gcif:sum_Term	only (9.3_OperatingRevenue and 9.3_Recurring_Revenue)

7.4. Tax collected as a percentage of tax billed (supporting indicator) (ISO 37120: 9.4)

The fourth indicator is also a supporting indicator. It focuses on tax, which is a form of public revenue. It is defined as the ratio of the actual tax collected to the mandated tax (tax billed). This indicator is distinct from the previous three indicators, because in order to answer some of its competency questions we need to consider not only the financial activities and monetary values, but also individual tax payers, either person or organization.

Each tax item, collected or billed, is imposed by one or more organizations/agents. It also has at least one of individual taxpayers or organization taxpayers. These properties are shown in the following diagram.

For each TaxpayerIndividual, we have defined property "resident_Of" in order to capture whether the tax payers reside in the city that the indicator is for. This class also inherits properties such as birth date and employment status, which are used to answer competency questions that concern the individuals' background information. 9.4_TaxpayerOrganization is a subclass of "gcif:TaxpayerOrganization", and we define its ownership as "9.4_Ownership", a property inherited from gci:Organization.
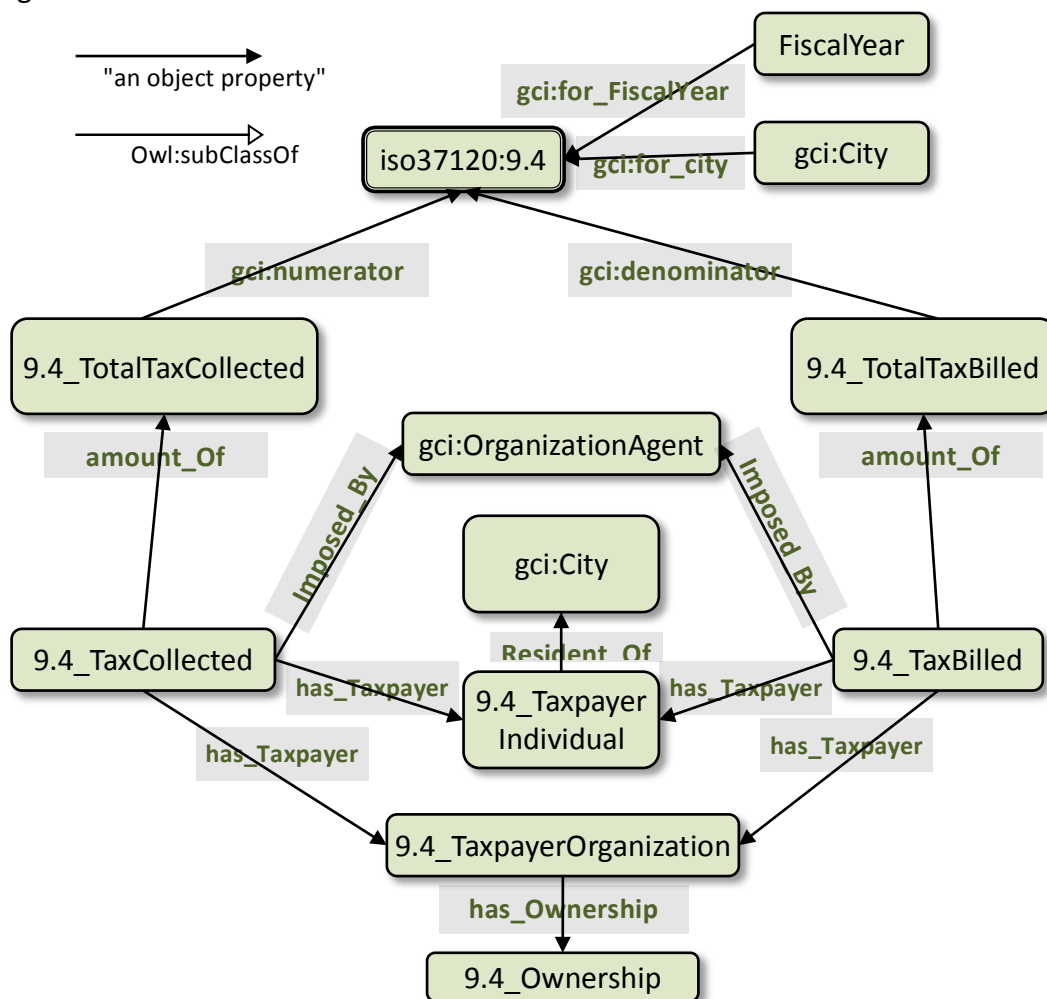

Figure 16: ISO 37120 - 9.4 Definition

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This table shows how iso37120:9.4 defines the main class which captures the ratio of the indicator.

Class	Property	Value Restriction
iso37120:9.4	owl: subClassOf	gci: 'Finance Indicators'
	gci: 'for city'	exactly 1 gci:City
	for_FiscalYear	exactly 1 FiscalYear
	gci: numerator	exactly 1 9.4_TotalTaxCollected
	gci: denominator	exactly 1 9.4_ TotalTaxBilled

As explained above, tax collected and tax billed need properties to capture their imposing agent and taxpayer information. Because each tax can be enforced by 1 or more organization agents, 9.4_TaxBilled and 9.4_TaxCollected have property "imposed_By min 1 OrganizationAgent".

Class	Property	Value Restriction
9.4_TotalTaxCollected	owl: subClassOf	gcif: TotalTaxCollected
	gcif:sum_Term	only (9.4_CapitationTaxCollected and 9.4_ConsumptionTaxCollected and 9.4_EffectiveTaxCollected and 9.4_FeesTollsTaxCollected and 9.4_IncomeTaxCollected and 9.4_OtherTaxCollected and 9.4_PayrollTaxCollected and 9.4_PropertyTaxCollected and 9.4_TariffTaxCollected)
	owl: subClassOfowl: subClassOf	gcif:TotalTaxBilled9.4_Things
9.4_TotalTaxBilled	gcif:sum_Termowl: subClassOf	only (9.4_CapitationTaxBilled and 9.4_ConsumptionTaxBilled and 9.4_EffectiveTaxBilled and 9.4_FeesTollsTaxBilled and 9.4_IncomeTaxBilled and 9.4_OtherTaxBilled and 9.4_PayrollTaxBilled and 9.4_PropertyTaxBilled and 9.4_TariffTaxBilled)gcif:TotalTaxBilled

All the subtypes of TaxBilled and TaxCollected have the following properties:

Class	Property	Value Restriction
9.4_IncomeTaxBilled	imposed_By	some 9.4_OrganizationAgent
	gcif:has_Taxpayer	only (9.4_TaxpayerIndividual or 9.4_TaxpayerOrganization)

In order to complete the above definitions, we need additional axioms regarding taxpayer and ownership:
1. Each 'TaxpayerIndividual' is a 'resident_Of' a 'City'.
2. Each 'TaxPayerOrganization has an 'Ownership'.

Class	Property	Value Restriction
9.4_Taxpayer	owl: subClassOf	gcif: TaxPayer
9.4_TaxpayerIndividual	owl: subClassOf	9.4_Taxpayer
	owl: subClassOf	gcif: TaxPayerIndividual
	resident_Of	gci: City
9.4_TaxpayerOrganization	owl: subClassOf	9.4_Taxpayer
	owl: subClassOf	gcif: TaxPayerOrganization
	has_Ownership	9.4_Ownership
9.4_Ownership	owl: subClassOf	gci: Ownership

8. Evaluation

In this section we verify the Finance ontology by demonstrating that it can answer the competency questions. We use the City of Toronto in the Province of Ontario, Canada to answer the competency questions. In the following we define the example from the City of Toronto, using our ontology, that will used to answer the competency questions.

Instance	Property	Value
gn:6251999	rdfs:label	Canada
	rdfs:type	gn:Feature
	rdfs:type	sc:Country
gn:6093943	rdfs:label	"Ontario"
	rdfs:type	gn:Feature
	rdfs:type	sc:Province
gn:6167865	rdfs:label	"Toronto"
	rdfs:type	gn:Feature
	rdfs:type	sc:City
alan_inc	rdfs:type	gcif:CreditorOrganization
	gci:hasLegalName	"Alan Incorporated"
	gci:has_Ownership	"Alan Group"

Instances that instantiate the 6.1 indicator are defined in the following table:

Instance	Property	Value
9.1_ex *(instance of 9.1)*	rdfs:type	iso:9.1
	gci:numerator	9.1_DE_total
	gci:denominator	9.1_OSR_total
	gcif:for_FiscalYear	9.1_FiscalYear
	gci:for_City	gn:6167865

	om:phenomenon	gn:6167865
	om:value	9.1_ex_value
9.1_ex_value *(the value of 9.1)*	rdfs:type	om:Measure
	om:numerical_value	0.018
	om:Unit	gci:Monetary_Ratio_Unit (change to instance)
9.1_DE_total *(numerator of 9.1)*	rdfs:type	isof:9.1_TotalDebtExpenditure
	gcif:sum_Term	9.1_LP
	gcif:sum_Term	9.1_ODC
	gcif:sum_Term	9.1_TFP
	om:value	9.1_DE_total_value
9.1_DE_total_value *(value of the numerator of 9.1)*	rdfs:type	om:Measure
	om:numerical_value	153,838,048
	gcif:originalCurrency	gci:Monetary_Unit (change to instance)
	gcif:exchangeRatio	Double (change to instance)
	om:unit	gci:Monetary_Unit (change to instance)
9.1_OSR_total *(denominator of 9.1)*	rdfs:type	isof:9.1_TotalOwnSourceRvenue
	om:value	9.1_OSR_total_value
9.1_OSR_total_value *(value of the denominator of 9.1)*	rdfs:type	om:Measure
	om:numerical_value	8,546,558,272
	gcif:originalCurrency	gci:Monetary_Unit (change to instance)
	gcif:exchangeRatio	Double (change to instance)
	om:unit	gci:Monetary_Unit (change to instance)
9.1_DE_total *(Numerator monetary sum)*	rdfs:type	isof:9.1_DebtExpenditure_MonetaryValue
	gcif:sum_Term	9.1_LP
	gcif:sum_Term	9.1_ODC
	gcif:sum_Term	9.1_TFP
9.1_LP	rdfs:type	isof:9.1_LeasePayments
	gcif:expense_For	9.1_LF
9.1_LF	rdfs:type	isof:9.1_LeaseFinancing
9.1_ODC	rdfs:type	isof:9.1_OtherDebtCharges
	gcif:expense_For	9.1_OtherDebt
9.1_OD	rdfs:type	isof:9.1_OtherDebt
9.1_TFP	rdfs:type	isof:9.1_TemporaryFinancingPayments
	gcif:expense_For	9.1_TF
9.1_TF	rdfs:type	isof:9.1_TemporaryFinancing
9.1_exp_total	rdfs:type	isof:9.1_TotalExpenditure
	gcif:for_FiscalYear	9.1_FiscalYear
	gci:for_City	gn:6167865
	om:value	9.1_totalexp_value
9.1_totalexp_value	rdfs:type	om:Measure
	om:numerical_value	10,650,071,000
	om:unit	gci:Monetary_Unit (change to instance)

9.1_TR_amt	rdfs:type	isof:9.1_TransferRevenue_MonetaryValue
	gcif:amount_Of	9.1_TR
	om:phenomenon	9.1_TR
	om:value	9.1_TR_value
9.1_TR_value	rdfs:type	om:Measure
	om:numerical_value	3,174,610,000
	om:unit	CAD
9.1_TR	rdfs:type	isof:9.1_TransferRevenue
	gcif:for_FiscalYear	9.1_FiscalYear
	gci:for_City	gn:6167865
	gcif:revenueSource	String (Change to instance)
9.1_rev_total	rdfs:type	isof:9.1_TotalRevenue
	gcif:sum_Term	9.1_OSR_total
	gcif:sum_Term	9.1_TR
	om:value	9.1_totalrev_value
9.1_totalrev_value	rdfs:type	om:Measure
	om:numerical_value	11,345,858,000
	om:unit	gci:Monetary_Unit (change to instance)
9.1_totaldebt	rdfs:type	isof:9.1_TotalDebt
	gcif:sum_Term	isof:9.1_LF
	gcif:sum_Term	isof:9.1_TF
	gcif:sum_Term	isof:9.1_OD
	om:value	9.1_totaldebt_value
9.1_totaldebt_value	rdfs:type	om:Measure
	om:numerical_value	3,418,623,309
	om:unit	CAD
bond_payment	refs:type	isof:9.1_DebtExpenditure
	gcif:expense_For	10yr_gov_bond
bond_payment_amt	refs:type	isof:9.1_DebtExpenditure_MonetaryValue
	gcif:amount_Of	bond_payment
	om:value	bond_payment_value
bond_payment_value	rdfs:type	om:Measure
	om:numerical_value	250
	om:unit	CAD
10yr_gov_bond	rdfs:type	isof:9.1_TemporaryFinancing
	org:memberOf	9.1_TF
	gcif:paymentTerms	Principal due on maturity date; interest due first month of each year
	gcif:due_Date	"2022/10/10"
	gcif:interestRate	"0.025"
	gcif:has_Creditor	alan_inc
10yr_bond_amt	rdfs:type	gcif:'monetary value'

	gcif:amount_Of	10yr_gov_bond
	om:value	10yr_bond_value
10yr_bond_value	rdfs:type	om:Measure
	om:numerical_value	12,500
	om:unit	CAD
9.1_FiscalYear	gcif:starting_Year	2012
	gcif:starting_Month	January
	gcif:ending_Year	2012
	gcif:ending_Month	December

The following illustrates how the competency questions for ISO37120:9.1 are implemented in SPARQL.

1. (F) What city is the indicator for?

   SELECT ?cityname WHERE
           {9.1_ex gci:for_City ?city
           ?city rdfs:label ?cityname}

   Answer: "Toronto"

2. (CI) 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?

   SELECT ?startyear1 ?startmonth1 ?endyear1 ?endmonth1 WHERE
           {9.1_TDE gcif:for_FiscalYear ?fyear1 .
           ?fyear1 gcif:starting_Year ?startyear1 .
           ?fyear1 gcif:starting_Month ?startmonth1 .
           ?fyear1 gcif:ending_Year ?endyear1 .
           ?fyear1 gcif:ening_Month ?endmonth1 }

   Answer: 2011 January   2011   December

   SELECT ?startyear2 ?startmonth2 ?endyear2 ?endmonth2 WHERE
           {9.1_TOSR gcif:for_FiscalYear ?fyear2 .
           ?fyear2 gcif:starting_Year ?startyear2 .
           ?fyear2 gcif:starting_Month ?startmonth2 .
           ?fyear2 gcif:ending_Year ?endyear2 .
           ?fyear2 gcif:ening_Month ?endmonth2 }

   Answer: 2011 January   2011   December

3. (F) What are the municipality's total expenditure and debt for the fiscal year?

SELECT ?expvalue WHERE
       {9.1_ex gci:for_City ?city .
       9.1_ex gcif:for_FiscalYear ?fyear .
       ?expamt om:value ?expvalue .
       ?expamt gcif:amount_Of ?totalexp .
       ?totalexp gci:for_City ?city .
       ?totalexp gcif:for_FiscalYear ?fyear .
       ?totalexp rdfs:type isof:9.1_TotalExpenditure }

Answer: 10 650 071 000

SELECT ?debtvalue WHERE
       {9.1_ex gci:for_City ?city .
       9.1_ex gcif:for_FiscalYear ?fyear .
       ?debtamt om:value ?debtvalue .
       ?debtamt gcif:amount_Of ?debt .
       ?debt gcif:sum_term 9.1_LF .
       ?debt gcif:sum_term 9.1_TF .
       ?debt gcif:sum_term 9.1_OD .
       ?debt gci:for_City ?city .
       ?debt gcif:for_FiscalYear ?fyear }

Answer: 4 411 296 000

4. (D) What percentage of the total debt is repaid?

SELECT (?debtexpvalue/?debtvalue) AS ?percentage WHERE
       {9.1_ex gci:for_City ?city .
       9.1_ex gcif:for_FiscalYear ?fyear .
       9.1_ex gci:numerator ?debtexpvamt .
       ?debtexpamt om:value ?debtexpvalue .
       ?debtamt om:value ?debtvalue .
       ?debtamt gcif:amount_Of ?debtagg .
       ?debtagg gcif:defined_by ?debt .
       ?debt gci:for_City ?city .
       ?debt gcif:for_FiscalYear ?fyear .
       ?debt rdfs:type isof:9.1_TotalDebt }

Answer: 0.35

5. (F) 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 }
```

Answer: 9.1_LF   9.1_OD   9.1_TF

6. (D) For each debt expenditure type X, what percentage does it contribute to the total debt expenditure?

```
SELECT (?bondpayvalue/?debtexp) as ?debtcontribution WHERE
        {?bondpayamt om:value ?bondpayvalue .
        ?bondpayamt gcif:amount_Of ?bondpay .
        ?bondpay gcif:expense_For 10yr_gov_bond .
        ?debtamt om:value ?debtvalue .
        ?debtamt gcif:amount_Of ?debt .
        ?debt gcif:sum_term 9.1_LF .
        ?debt gcif:sum_term 9.1_TF .
        ?debt gcif:sum_term 9.1_OD }
```

Answer: 0.00008

7. (F) 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?

```
SELECT ?creditor ?interest ?due ?terms WHERE
        {10yr_gov_bond gcif:has_Creditor ?creditor .
        10yr_gov_bond gcif:interestRate ?interest .
        10yr_gov_bond gcif:paymentTerms ?terms}
```

Answer: alan_inc   "0.025"   "2022/10/10" "Principal due on maturity date; interest due first month of each year"

8. (D) What percentage of each debt type X is repaid?

```
SELECT (?bondpayvalue/?bondvalue) as ?repayperc WHERE
        (?bondpayamt om:value ?bondpayvalue .
        ?bondpayamt gcif:amount_Of ?bondpay .
        ?bondpay gcif:expense_For 10yr_gov_bond .
        ?bondamt gcif:amount_Of 10yr_gov_bond .
        ?bondamt om:value ?bondvalue }
```

Answer: 0.02

9. (F) What is the total revenue for the fiscal period?

   SELECT ?revvalue WHERE
           {9.1_ex gci:for_City ?city .
           9.1_ex gcif:for_FiscalYear ?fyear .
           ?revamt om:value ?revvalue .
           ?revamt gcif:amount_Of ?totalrev .
           ?totalrev gci:for_City ?city .
           ?totalrev gcif:for_FiscalYear ?fyear .
           ?totalrev rdfs:type isof:9.1_TotalRevenue }

   Answer: 11 345 858 000

10. (F) What is the total transfers revenue for the fiscal period?

    SELECT ?tranvalue WHERE
            {?tranamt om:value ?tranvalue .
            ?tranamt gcif:amount_Of 9.1_TR }

    Answer: 2 799 300 000

11. (F) What is a municipality's own-source revenue?

    SELECT (?revvalue - ?tranvalue) as ?osrvalue WHERE
            {?revamt om:value ?revvalue .
            ?revamt gcif:amount_Of 9.1_totalrev.
            ?tranamt om:value ?tranvalue .
            ?tranamt gcif:amount_Of 9.1_TR }

    Answer: 8 546 558 000

12. (D) 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 }

    Answer: 0.753

13. (F) From which sources do transfer revenues originate?

> SELECT ?revsource WHERE
> >   {9.1_ex gci:for_City ?city .
> >   9.1_ex gcif:for_FiscalYear ?fyear .
> >   ?tranrev gci:for_City ?city .
> >   ?tranrev gcif:for_FiscalYear ?fyear .
> >   ?tranrev rdfs:type isof:9.1_TransferRevenue .
> >   ?tranrev gcif:revenueSource ?revsource}

> Answer: "Internal transfers"

14. (F) 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 }

> Answer: "CAD"   "1"   "CAD"   "1"

9. Conclusions

The goal of this research was to define an ontology for the representation of ISO37120 Finance theme indicator definitions and the data use to derive a city's specific indicator value. In order to construct this ontology, we had to define a generic (aka common sense) ontology for Finance knowledge. The ISO definitions rely on this common sense finance knowledge in constructing their definitions. For example, information that isn't directly included in the indicators, such as creditor, asset and tax payer, is captured in the Finance ontology. In constructing the generic finance ontology, we found a lack of finance ontologies that cover universally used financial entities and relationships.

In summary, this research has made the following contributions:
1) Defines a finance ontology that covers a broader range of financial concepts related to public finance and may also be applicable to some domains with corporate finance, as well as more in-depth definitions and properties for these classes;
2) Uses the above concepts to support and expand the definitions for indicators in "ISO 37120: 9. Finance";

3) Defines each of the ISO 37120: 9 Finance indicators using the foundation and GCI Finance ontology, providing a formalized computationally precise definition; and

4) Provides a standard representation for general finance knowledge related to indicators, city specific versions of finance knowledge and the data used to derive an indicator's value.

10. Acknowledgements

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12.   Appendix

The Global City Indicator Foundation ontology can be found in:
http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Founation.owl.

The Global City Indicator Finance ontology can be found in:
http://ontology.eil.utoronto.ca/GCI/Finance/GCI-Finance.owl.

URIs for all of the ISO37120 indicators can be found in:
http://ontology.eil.utoronto.ca/ISO37120.owl.

Definitions of the ISO37120 Finance indicators, using the GCI Foundation and Finance ontologies can be found in:
http://ontology.eil.utoronto.ca/GCI/ISO37120/Finance.owl.