A Shelter Ontology for Global City Indicators (ISO 37120)

Yetian Wang, Mark S. Fox
Mechanical and Industrial Engineering
University of Toronto
5 King's College Road, Toronto ON, M5S 3G8
University of Toronto

Yetian Wang: yetian.wang@mail.utoronto.ca
Mark S. Fox: msf@eil.utoronto.ca

Abstract

This paper defines a shelter ontology that includes concepts of shelters, slums, households and homelessness. ISO 37120 defines 100 indicators to be used by cities to measure and compare their performance. There are 3 shelter themed indicators defined, namely 15.1 Percentage of city population living in slums, 15.2 Number of homeless per 100 000 population, and 15.3 Percentage of households that exist without registered legal titles. This ontology provides a Semantic Web-based representation of the ISO 37120 Shelter theme indicators' definitions, and of a city's indicator values and supporting data, in order to enable the analysis of a city's indicators by intelligent agents.

1. Introduction

In 2014 the international standard ISO 37120 "Sustainable development of communities - Indicators for city services and quality of life" was published. It defined 100 indicators to be used by cities to measure and compare their performance. The goal of this research is to provide a Semantic Web-based representation of the ISO 37120 Shelter theme indicators' definitions, and of a city's indicator values and supporting data, in order to enable the analysis of a city's indicators by intelligent agents.

This paper defines an ontology to represent the shelter theme indicators (section 15) defined in ISO 37120. It builds on our prior research in GCI-Foundation ontologies for representing city Indicators and their meta-data (Fox, 2013) (Fox 2015b). A GCI Shelters ontology is also needed to represent shelters-related concepts that are not represented in GCI Foundation ontology. The GCI Shelters ontology should cover all concepts represented in the ISO37120 shelters indicators and should be reusable for other shelters-related applications.

In the remainder of this paper we first reprint the Shelters indicators defined in section 15 of ISO 37120. Adopting the ontology engineering methodology of (Grüninger & Fox, 1995), for each indicator we define a set of competency questions the ontology must be able to answer. We then review how existing vocabularies and ontologies represent shelters related concepts to determine whether they

satisfy our competency requirements. The next section introduces our Shelters ontology, followed by a demonstration of how the ISO 37120 shelter indicators are represented using it. Finally, we evaluate the ontology from a competency perspective.

2. ISO37120 Indicators and Competency questions

In this section we reprint the shelter theme indicators' definitions as defined in ISO 37120. For each indicator, competency questions were developed based on its definition. The competency questions represent the types of knowledge necessary (though not sufficient) to analyse a city's indicators. Note that competency questions that refer to measurement theory, statistics, provenance, validity and trust are not included as they are addressed in the GCI Foundation ontology (Fox 2013). We will use the following to categorize the competency questions (Fox, 2013b):

- 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.

Following are the ISO 37120 shelter theme indicators.

15.1 Percentage of city population living in slums (core indicator)

As stated in the ISO 37120 standard, the percentage of city population living in slums is defined as:

> "The percentage of city population living in slums shall be calculated as the number of people living in slums (numerator) divided by the city population (denominator). The result shall then be multiplied by 100 and expressed as a percentage.
>
> The number of people living in slums shall be calculated as the number of slum households multiplied by current average household size."

In order to develop our competency questions for this indicator, we must understand what a slum household is. The ISO37120 definition of a slum household is based on the UN-HABITAT definition, which defines a slum household as a group of individuals living under the same roof in an urban area who lack one or more of the following (UN-Habitat, 2005):

1. "Durable housing of a permanent nature that protects against extreme climate conditions.
2. Sufficient living space which means not more than three people sharing the same room.
3. Easy access to safe water in sufficient amounts at an affordable price.
4. Access to adequate sanitation in the form of a private or public toilet shared by a reasonable number of people.
5. Security of tenure that prevents forced evictions."

Competency Questions

Below are the competency questions that the Shelter Ontology must satisfy in order to represent this indicator:

1. (F) What city is the indicator for?
2. (F) What is the city's average household size?
3. (F) What is the number of slum households in the city?
4. (F) What's the slum population size of the city?
5. (F) What's the city's total population size?
6. (CD) Is household X located in the city?
7. (F) Who are the individuals in household X?
8. (F) What is the household size of household x?
9. (D) Is a household X a slum household?
10. (D) Which living conditions outlined by UN-HABITAT is household X lacking of?

15.2 Number of homeless per 100 000 population

According to ISO 37120 the number of homeless per 100,000 population is defined as follows:

> "The number of homeless per 100 000 population shall be calculated as the total number of homeless people (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of homeless per 100 000 population.
>
> The following definition is used by the United Nations to define homelessness: Absolute homelessness refers to those without any physical shelter, for example, those living outside, in parks, in doorways, in parked vehicles, or parking garages, as well as those in emergency shelters or in transition houses for women fleeing abuse."

Competency questions

Below are the competency questions for this indicator:

1. (F) What is the city's homeless population?
2. (D) What percentage of the homeless population live outdoors?
3. (D) Is person X considered as homeless in the city being measured?
4. (F) What type of homeless person is person X?
5. (F) Which shelter does homeless person X live in?
6. (D) What type of shelter does person X live in?
7. (D) How many people live outside? In a shelter?
8. (D) How does city X define a homeless person?

15.3 Percentage of households that exist without registered legal titles

According to ISO 37120 the percentage of households that exist without registered legal titles indicator is defined as follows:

> "The percentage of households that exist without registered legal titles shall be calculated as the number of households that exist without registered legal titles (numerators) divided by the total

number of households (denominator). The result shall then be multiplied by 100 and expressed as a percentage.

Unregistered legal title includes the following tenure types: unregistered lease or leaseholds, rental, occupancy right, use right (including sub-lease, sub-rental and co-tenancy, and co-occupancy right)."

Competency questions

Below are the competency questions raised for this indicator:

1. (F) What's the city's total number of households?
2. (F) What's the city's number of households without legal title?
3. (D) Is household X considered as unregistered/without legal title?
4. (CI) If household X is without legal titles, does it have a house?
5. (F) What type of unregistered tenure does household X have?
6. (D) How many households are Rental? Lease? Use Right?

3. Background

Shelters and housing are ongoing social problems that most cities in different countries face. In Canada, "the federal government's National Homelessness Initiative estimated that approximately 150,000 Canadians are currently homeless; activists and advocates estimate that national homeless counts range between 200,000 and 300,000 Canadians with no fixed address", as of 2006 (Laird, 2007). In order to provide a solid shelter service, organizations have developed taxonomies that ease the process of searching for the most appropriate shelter service under a specific situation for both users and set a formal vocabulary for defining shelter services. The following vocabularies/specifications are some of the typical standards existing in social service sector. Note that none of these standards provides an actual ontology thus can only be used as reference for definitions of shelter related terms.

Existing Vocabularies

211 LA County Taxonomy

AIRS/211 LA County Taxonomy is a taxonomy developed by 211 LA County with more than 9,000 terms defined to cover a wide range of social services such as food and shelters (AIRS, 2011). The taxonomy classifies the social service terminologies into 6 levels according to how general or how specific the terms are, and assign each service with a unique code. Table 1 is an example of terms in the shelter category from 211 LA County Taxonomy of Human Services (AIRS, 211 LA County).

Level	Code	Term
Level I	B	Basic Need
Level II	BH	Housing/Shelter
Level III	BH-1800	Emergency Shelter
Level IV	BH-1800.8500	Homeless Shelter
Level V	BH-1800.8500-150	Community Shelters

Table 1 AIRS/211 LA County Taxonomy Structure

Although AIRS/211 LA County is a useful tool for various organizations offering social services such as food and shelter, it requires a subscription in order to access the taxonomy, as of 2015[1]. Also it provides a taxonomy in human readable language such as English and French but does not provide an ontology in machine-readable form.

Open Eligibility

Open Eligibility[2] Project was created to improve the accessibility of human service by classifying each type of services and categorizes them into groups. The taxonomy was created for both human services (classification of services) and human situation (classification of people). A glossary was also provided with definitions of terms used in social service. Table 2 below illustrates classifications that are related to shelters and could potentially be implemented with the ISO 37120 shelter indicators.

Human Situation	Human Service	
Household	Emergency Shelter	Residential Housing
• Individuals	Help Find Housing	• Long-Term Housing
• Families	Help Pay for Housing	o Assisted Living
Housing	Help Pay for Utilities	o Independent Living
• Home Owners	• Home & Renters Insurance	o Nursing Home
• Home Renters	• Housing Vouchers	o Public Housing
• Homeless	• Maintenance & Repairs	• Safe Housing
• Near Homeless	Housing Advice	• Short-Term Housing
• Runaways	• Foreclosure Counseling	o Nursing Home
	• Homebuyer Education	o Sober Living

Table 2 Open Eligibility Shelters Related Classification

The vocabulary is defined in XML that uses level of classification as tags. No ontology is provided. Never the less, the classification and definitions of each social services can be useful for our shelter ontology development[3].

Open Eligibility was created after AIRS/211 Taxonomy LA County Taxonomy discussed above. It was intended to distribute similar taxonomy as 211 Taxonomy LA County Taxonomy but simpler and free of charge.

Human Services Data Specification (HSDS) v1.0

The Human Services Data Specification (HSDS), formerly known as Open Referral, sponsored and funded by the Knight Foundation and Code for America, is "an exchange format for publishing machine readable data about health, human, and social services, their locations, and the organizations that provide them. For the purposes of this specification, human services are broadly defined, ranging from food assistance to job training and health care. This exchange format is meant to complement –not replace– existing

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[1] 211 LA County Subscription detail: https://211taxonomy.org/subscriptions/
[2] Open Eligibility http://openeligibility.org/
[3] The complete XML code can be found at:
https://github.com/auntbertha/openeligibility/blob/master/taxonomy

storage formats currently in use.[4] "Open Referral was instigated by the DC Open211 project, and has been co-sponsored by Code for America (CfA), in partnership with the Ohana project. It is now a community of practice with multiple pilot projects across the world."

Open Referral has just released HSDS version 1.0 in 2015. HSDS stores data in CSV formatted files with one CSV file per entity. A JSON file contains general metadata such as the name of the package, date published, publisher, etc.

HSDS is a controlled vocabulary for Human Service Data that can be referenced when creating shelter related ontologies. But most of the terms are general social services terms and only a few of those terms are related to concepts mentioned in ISO37120 shelter indicators such slum households, homeless person, and households without registered legal titles. Nor does it provide machine-readable definitions of the vocabulary terms in a language such as OWL.

Existing Ontologies

The ISO37120 shelters indicators covers concepts such as slum households, homeless person and households without registered legal titles. Thus an ontology that covers all these concepts is necessary before building the ISO37120 shelter indicator ontologies. In order to answer the competency questions for the Shelter indicators, we need additional concepts, properties and axioms that span:

- The definition of a household,
- the living conditions a household lacks to be considered a slum household,
- the types of homeless shelters a homeless person can use, and
- the types of unregistered legal titles that a household has.

Before we start to create our own shelter ontology we will first review some of the existing ontologies that have represented shelter-related concepts as part of their ontology.

GCI Foundation

Our focus is to develop a shelter ontology that will represent the definition of each shelter indicator and answer their corresponding competency questions. We build on the Global City Indicator Foundation ontology (Fox, 2013). That work integrates and extends existing ontologies depicted in Figure 1:

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[4] http://openreferral.org
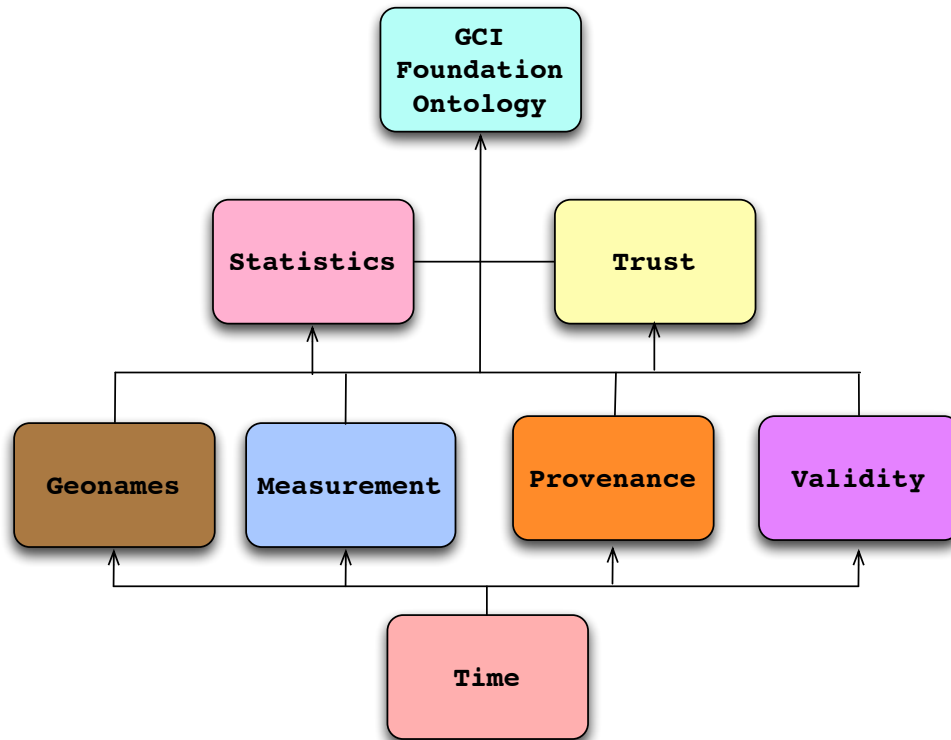
Figure 1 GCI Foundation Ontology Components

The ontologies included are:

- Time (Hobbs & Pan, 2006).
- Placenames (www.geonames.org).
- Measurement (Rijgersberg et al., 2011)
- Provenance (Lebo et al., 2013)
- Validity (Fox & Huang, 2005).
- Statistics (Pattuelli, 2009).
- Trust (Huang & Fox, 2006).

Generic Slum Ontology (GSO)

The generic slum ontology (GSO) (Kohli et al., 2011) was developed upon the ontological work of Hofmann et al. (2008) to reinforce relevant indicators that can be used for slum identification based on satellite images. The indicator used was "durable housing" defined by UN-HABITAT (2003a), which defines a slum household as a household that lacks of one or more of the following five factors: secure tenure, access to safe water, access to sanitation, sufficient living area and durability of housing. GSO also uses knowledge from experts to identify slum characteristics, building upon the study by Ebert et al. (2009), who used a set of image-derived physical proxy variables to assess urban social vulnerability. GSO uses the slum characteristics of the urban environment apparent from images as indicators to characterize slums using the GSO as a basis. The slum characteristics include building characteristics, access network, density, settlement shape, location, and neighborhood characteristics. These

characteristics were then categorized into three spatial categories, namely, Enviros, Settlement, and Object as shown in Figure 2.
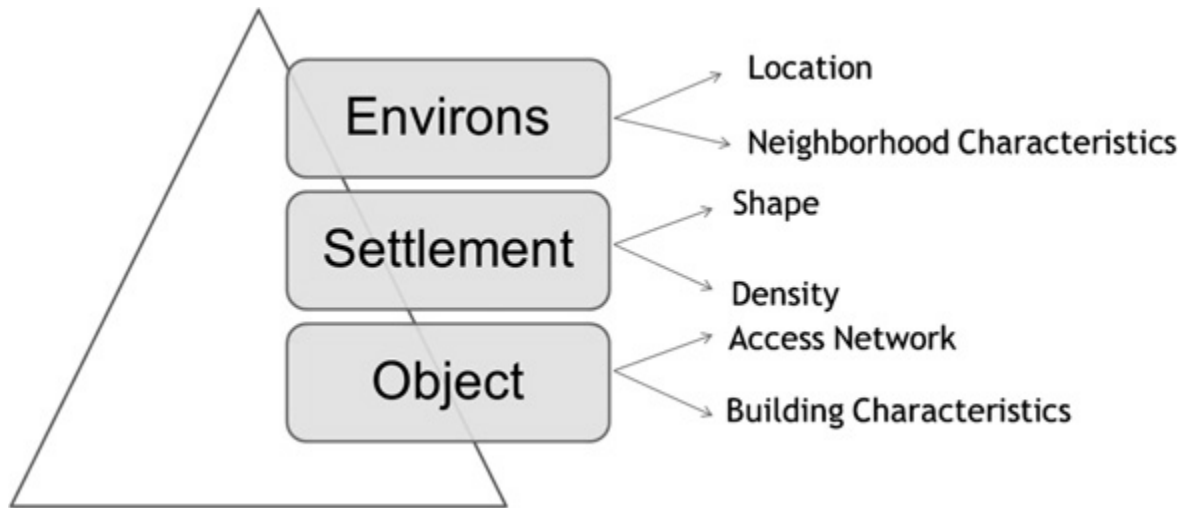

Figure 2 GSO Slum Characteristics (Kohli et al. 2011)

Digital Environment Home Energy Management System (DEHEMS)

DEHEMS is EU funded initiative to influence energy consumption behavior of household by providing the advice on efficient energy consumption and visibility to their energy consumption data.

"This project focuses on development of home electrical appliances domain ontology in particular inheriting from concepts and relationship described in SUMO ontology (Standard Upper Ontology Working Group) (Niles & Pierce, 2001). The proposed ontology provides a knowledge structure for reasoning sub-system in DEHEMS system. DEHEMS encodes knowledge of home appliances, their energy efficiency, and knowledge of energy saving strategies/tips." (Shah & Chao, 2011)

DEHEMS also includes a household class which was imported from SUMO. The household class could play a part since slum households and households without registered legal titles are essential components outlined in ISO37120 shelter indicators.

SUMO

SUMO is an upper level ontology that provides definitions for general-purpose terms and acts as a foundation for more specific domain ontologies (Niles & Pierce, 2001). It attempts to provide an overarching taxonomy of knowledge and concepts that span most of specific themed ontologies wish to represent.

The SUMO ontology merges publicly available ontological contents into a single, comprehensive structure. In SUMO classes are represented by entities that are further divided into Physicals and Abstracts. The former category includes everything that has a position in space/time, and the latter category includes everything else. A classification of SUMO's entities is shown in Figure 3.

```
Physical
    Object
        SelfConnectedObject
            ContinuousObject
            CorpuscularObject
        Collection
    Process
Abstract
    SetClass
            Relation
    Proposition
    Quantity
        Number
        PhysicalQuantity
    Attribute
```

Figure 3 SUMO top level (Niles & Pierce, 2001)

As stated by Shah & Chao (2011), "SUMO promotes the interpretability among various ontologies by providing more general concepts and allowing the implementation of domain ontologies by using these concepts. The SUMO ontology comprises low-level details ontologies for various domains such as computing military finance, geography, time, economy, and transportations, etc."

OpenCYC

OpenCYC (Matuszek et al., 2006) is a large ontology that is both very broad and very deep. It has been under development for over 15 years. The ontology is very rich in the areas of intelligence/defence. OpenCYC contains classes that represent shelter related concepts such as household, homeless shelter, and homeless person. These classes are classified into categories such as 'group of humans', 'facility', and person respectively but with very few axioms defined. Never the less, they can be extended to represent shelter related concepts that is suitable in our case.

Schma.org

Schema.org is an initiative primarily led by the major search engine vendors. Its goal is to enhance search results by providing a vocabulary of concepts and properties that web page creators can embed in their web pages using RDFa. Schema.org includes generalized classes such as Residence, Place (City, State, Country), and Organization that could potentially be used in our Shelter ontology. But it does not contain any class related to specific shelter related concepts such as shelters and households.

4. Architecture of the ISO 37120 Ontology

Figure 4 depicts the organization of files used to define the ISO 37120 ontology the PolisGnosis project is developing (Fox, 2015a). At the highest level, i.e., ISO 37120 Ontology level, the ISO 37120 module contains the globally unique identifier (IRI) for each ISO 37120 indicator (Fox 2015a). For example, for "percentage of city population living in slums" indicator, the IRI is:
http://ontology.eil.utoronto.ca/ISO37120.owl#15.1.

For each category of indicators in the ISO 37120 specification, for example Shelter, there is a separate file that provides the definition of each indicator in that theme. For example, ISO37120/Shelter.owl provides a complete OWL definition for the shelter theme indicators in the ISO 37120 specification.

The GCI Ontology level provides the theme-specific, generic ontologies required to define each theme's indicators. For example, to define the ISO 37120 Shelters indicators, we need an ontology covering shelter-related concepts such as homeless shelters, homeless person, households, slum areas, etc. GCI-Shelter.owl provides the classes used by ISO37120/Shelters.owl.

All of the theme specific indicator ontologies rely about the GCI Foundation ontology for more generic concepts such as population counts and ratios, meta-information, etc.
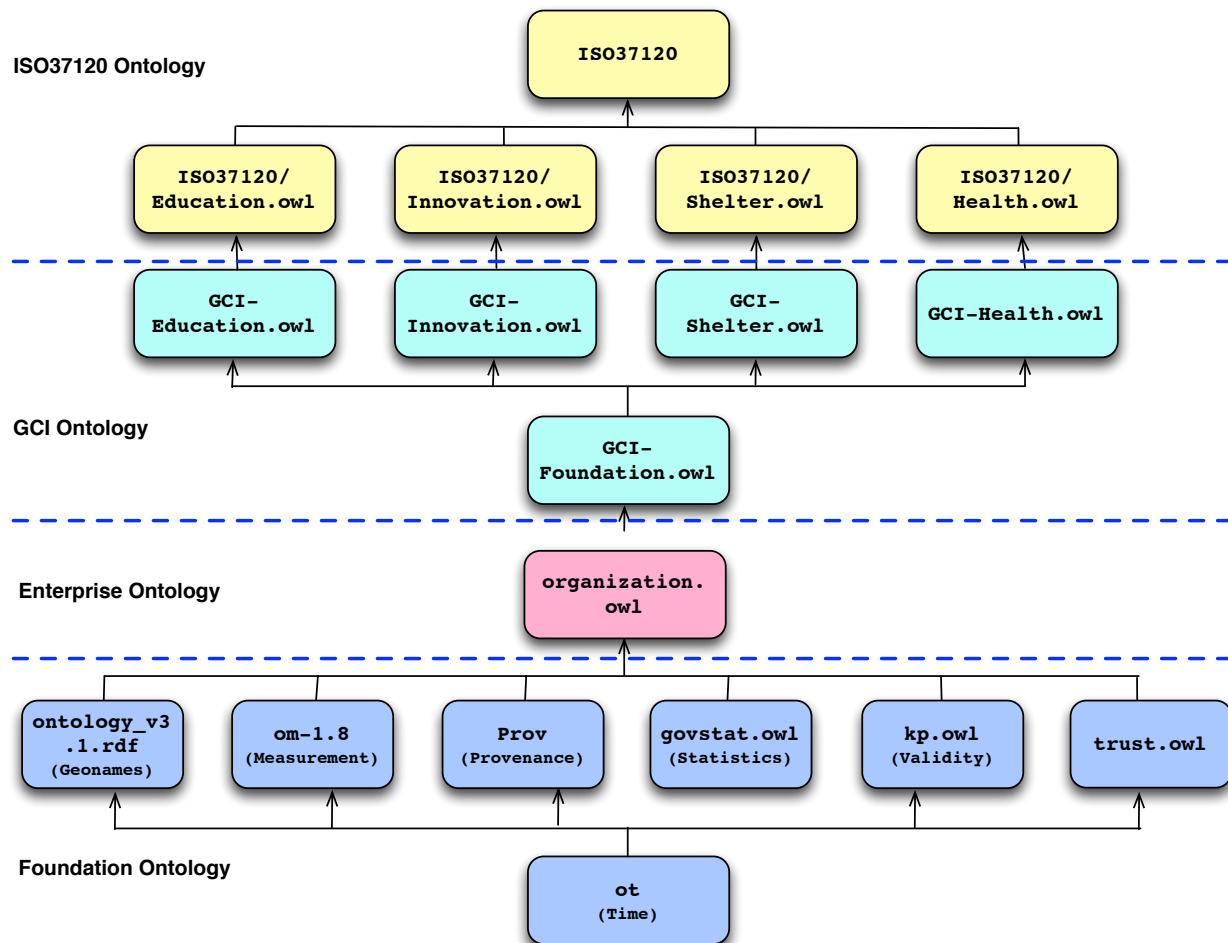

Figure 4 ISO 37120 Ontology Modules

As stated by (Fox, 2014), the Enterprise Ontology level builds on the TOVE Enterprise Modelling ontologies (Fox, 1992; Fox & Grüninger, 1998). In this figure we only show the Organization Ontology file (Fox et al., 1998), which is one of the TOVE Enterprise Modelling ontologies. In addition to the Organization ontology, TOVE has ontologies spanning:

- Activities and States (Gruninger & Fox, 1994)
- Resources (Fadel et al., 1994; Fadel, 1994).

- Quality Measurement (Kim & Fox, 1994).
- Activity-Based Costing (Tham et al., 1994).
- Product (Lin et al., 1997).
- Product Requirements (Lin et al., 1996).
- Human Resources (Fazel-Zarandi & Fox, 2012).

Finally, the Foundation Ontology level provides very basic ontologies that were selected as the foundation for the GCI-Foundation.owl ontology described in previous section.

5. Foundation Ontology Infrastructure

In this section we review the basic structure of a ratio indicator, its unit of measure, population and population size as defined in the GCI Foundation ontology (Fox, 2013), and upon which the shelter indicators are based.

At the core of the GCI Foundation ontology is the OM measurement ontology (Rijgersberg et al., 2011). The purpose of a measurement ontology is to provide the underlying semantics of a number, such as what is being measured and the unit of measurement. The importance of grounding an indicator in a measurement ontology is to assure that the numbers are comparable, not that they are measuring the same thing, but the actual measures are of the same type, e.g., the population size of homeless person and population size of city, are of the same scale (i.e., thousands vs millions) and are for the same city.

Figure 5 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 the both 'Quantity' and 'Unit of Measure'. For example, a 'slum population ratio' is a subclass of 'Quantity' (om:Quantity) that has a value that is a subclass of 'Measure' whose units are a 'Population cardinality unit' that is a subclass of 'Unit of Measure'. The actual value measured is a property of the 'Measure' subclass 'slum population ratio measure'.
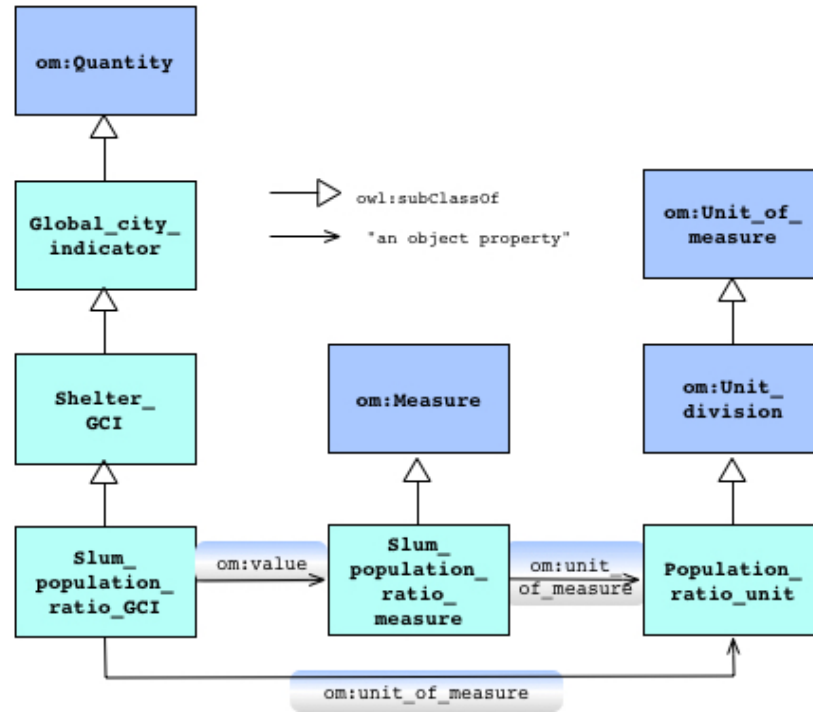
Figure 5 Measurement Ontology - modified based on (Fox, 2015b)

The Number of homeless per 100 000 population is based on a measure of the number of homeless and the size of the population of the city. One can view both as a statistical measurement in the sense that there is a population that we want to perform a measurement of, the measurement being a count of the number of members that satisfy a description of a homeless person and a city's resident, respectively. While the indicators require a count of members of the population, other measures may require statistics such as mean, standard deviation, etc. The GCI Foundation ontology includes the GovStat[5] general statistics ontology (Pattuelli, 2009). The core class is the 'Population' to be measured. 'Population' is linked to a parameter (e.g., mean, standard deviation) by the is_described_by property, and the parameter is a subclass of 'Parameter'. In order to define what portion of a city we are determining the size of, the GCI Foundation ontology extended the GovStat ontology with a property to located_in, that identifies the area (i.e., city) that the Population is drawn from, and the property defined_by, that identifies the class that all members of the Population are subsumed by.

All shelter indicators are ratio indicators (Fox, 2013). All ratio indicators have a numerator and denominator and are both represented by "population" class. A population is a collection of the same object such as people in a city and households. A ratio indicator (Figure 6) has a unit of measure defined to be a 'Population Ratio Unit' that specifies that the indicator is the ratio of the sizes (cardinalities) of two populations. One population size is the numerator and the other the denominator. A 'Population Size' is defined as the cardinality of a 'Population', and 'Population' is defined by a 'City' that the population is located in, and by a description of a 'Person' within the 'City' (Fox, 2013). For example, the 'Person' could be a homeless person (gcis:Homeless_person). Hence the population size

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[5] The GovStat Ontology is not available online, but a version with the GCI extensions can be found at: http://ontology.eil.utoronto.ca/govstat#.

(gci:Population_size) could be the number of 'gcis:Homeless_person' in a particular city (gci:City). This general ontology structure is used in the indicator definitions outlined in Section 7.
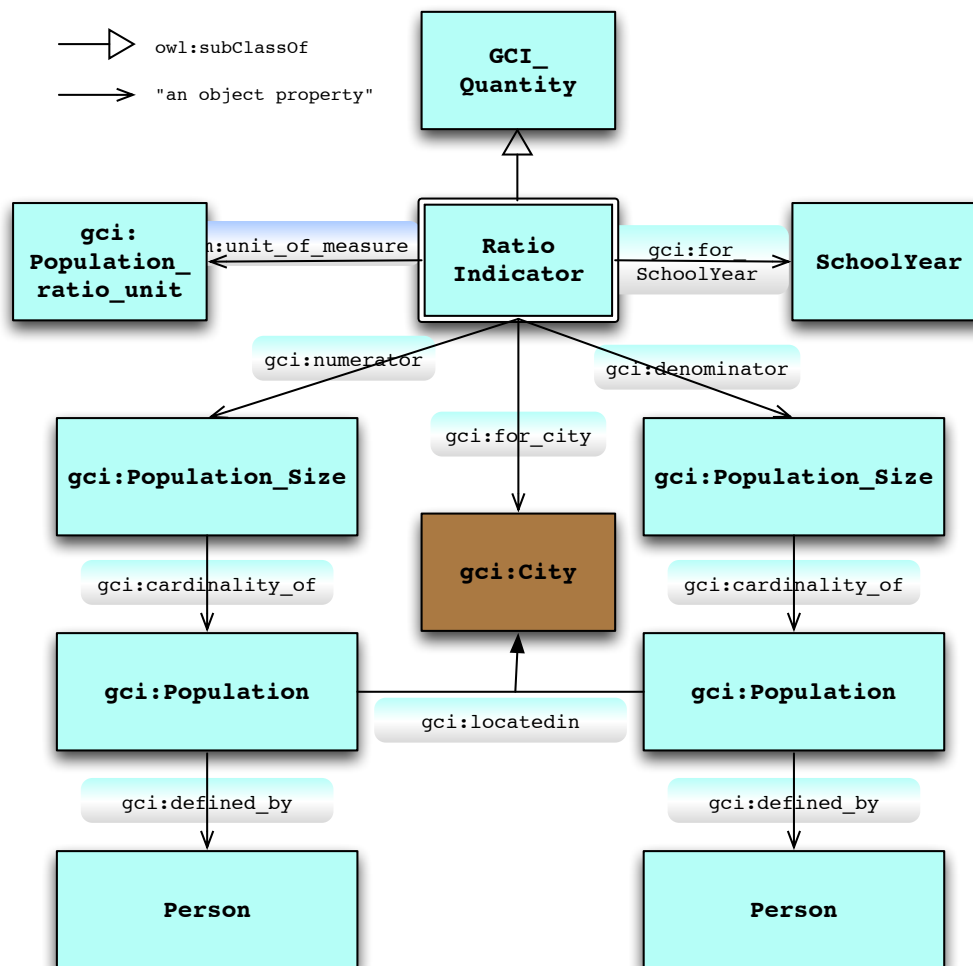

Figure 6 Foundation Ontology Ratio definition

6. GCI Shelters Ontology

The GCI Shelters ontology provides a generalized representation of shelter related concepts that are required to satisfy the ISO37120 Shelter theme indicators' competency questions. The three main concepts that comprise the GCI Shelters ontology are Slum Household (gcis:Slum_household), Homeless Person (gcis:Homeless_person), and House without registered legal titles (gcis:Household_unregsitered_legal_titles). These three classes were then expanded to cover a wide range of shelter related concepts. Thus the GCI Shelter ontology provides a more precise definition of the three classes and is also able to represented shelter related concepts that are not directly used in ISO37120 shelter indicators.

The GCI Shelter ontology includes basic classes and properties from the Global City Indicators Foundation ontology such as gci:City, gci:Population, gci:locatedIn, and gci:population_cardinality_unit,

etc. The GCI Foundation ontology was imported directly into GCI Shelter ontology along with Enterprise level ontologies discussed in section 4.

A variety of classes in SUMO were also imported into the GCI Shelter ontology. These classes include sumo:House, sumo:SocialUnit, sumo:LandArea, sumo:Agreement, and sumo:ResidentialBuilding. Since SUMO contains over 25,000[6] classes thus only the ones mentioned above, along with their axioms are imported to GCI Shelter ontology.

Detailed class definition and properties created for GCI Shelter ontology, as well as the extensions of imported concepts from GCI Foundation and SUMO, are listed later in this section. But first it is necessary to review the following competency questions that the shelter ontology must answer. Some of the questions are selected from competency questions for ISO37120 shelter indicators and some are questions related to general shelter concepts.

Shelter Ontology competency question

1. (F) What city is the indicator for?
2. (F) What is the city's average household size?
3. (F) What is the number of slum households in the city?
4. (F) What's the slum population size of the city?
5. (F)What's the city's total population size?
6. (CD) Is household X located in the city?
7. (F) Who are the individuals in household X?
8. (F) What is the household size of household x?
9. (D) Is a household X a slum household?
10. (D) Which living conditions outlined by UN-HABITAT is household X lacking of
11. (F) What type of homeless person is person X?
12. (D) Is person X considered as homeless in the city being measured?
13. (F) Which shelter does homeless person X live in?
14. (D) What type of shelter does person X live in?
15. (D) How does city X define a homeless person?
16. (D) Is household X considered as unregistered/without legal title?
17. (CI) If household X is without legal titles, does it have a house?
18. (F) What type of unregistered tenure does a household X have?

The prefix "gcis" represents the URI of GCI Shelter ontology (http://ontology.eil.utoronto.ca/GCI/Shelters/GCI-Shelters.owl#), while GCI Foundation ontology has prefix "gci" (http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl#), and class definitions from SUMO has the prefix "sumo" (http://www.ontologyportal.org/SUMO.owl#).

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[6] As stated on http://www.adampease.org/OP/ as of June 2015
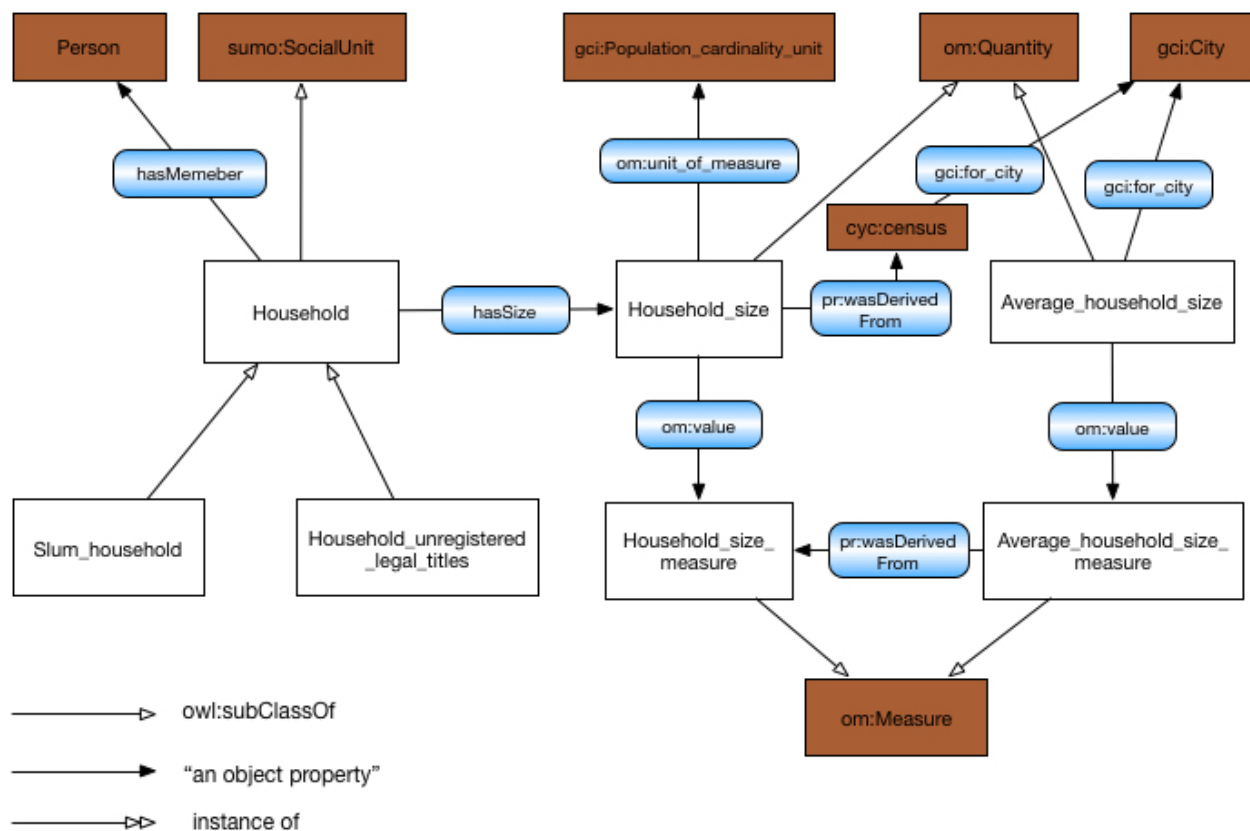
Figure 7 Household and Household_size Class

Household

Class	Property	Value Restriction
Household	owl:subClassOf	sumo:SocialUnit
	gcis:hasSize	only Household_size
	gci:located_in	some gci:City
	gcis:hasHouseholder	min 1 gci:Person
	org:hasMember	some gci:Person

Statistics Canada defines a household to be "*a person or group of persons who occupy the same dwelling and do not have a usual place of residence elsewhere in Canada or abroad. The dwelling may be either a collective dwelling or a private dwelling. The household may consist of a family group such as a census family, of two or more families sharing a dwelling, of a group of unrelated persons or of a person living alone. Household members who are temporarily absent on reference day are considered part of their usual household*" (Statistics Canada, 2012). It is a collection of a group of people therefore it shall be distinguished from a house which is a physical structure that a household lives in. A household is a subclass of a social unit (sumo:SocialUnit) which is defined to be "*A GroupOfPeople who all have the same home*" according to SUMO. Note that a gcis:Household does not necessarily possess a

gcis:ResidentialBuilding (i.e. Homeless households) thus the property gcis:livesIn is not required for the gcis:Household class. E.g. A household can be homeless. A gcis:Household may be linked to a gcis:House via the object property gcis:hasHouse. The class gcis:Household has the following subclasses: gcis:Slum_househould and gcis:Household_without_registered_legal_title.

Household_size and Average_household_size

Class	Property	Value Restriction
Household_size	owl:subClassOf	om:Quantity
	om:value	only Household_size_measure
	om:unit_of_measure	only gci:Population_cardinality_unit
	pr:wasDerivedFrom	some cyc:census
Household_size_measure	owl:subClassOf	om:Measure
	om:unit_of_measure	only gci:Population_cardinality_unit
	om:numeric_value	exactly 1 xsd:string
Average_household_size	owl:subClassOf	om:Quantity
	gci:for_city	only gci:City
	om:value	only Household_size_measure
	om:unit_of_measure	only gci:Population_cardinality_unit
Average_household_size_measure	owl:subClassOf	om:Measure
	pr:wasDerivedFrom	some Household_size_measure
	om:unit_of_measure	only gci:Population_cardinality_unit
	om:numeric_value	exactly 1 xsd:string

A gcis:Household_size represents the quantity (om:Quantity) of number of members of a household. It has a measure (gcis:Household_size_measure) which is a subclass of om:Measure that consists of the actual numerical value and a unit of measure. More detailed structure and relationships between om:Quantity class and om:Measure class are described in section 5. The household size needs to be derived from (pr:wasDerivedFrom) an official document such as a census (cyc:census). The census class was implemented from OpenCYC ontology described in section 3. The cyc:census class was extended to be a subclass of sumo:Document and has a gci:for_city property that links to a city class (gci:City).

The average household size of a city was constructed in similar manner but with a pr:WasDerivedFrom property from the PROV-O ontology[7]. This property relates the gcis:Average_household_size_measure class with gcis:Household_size_measure class since the result of the former class is always based on the latter.

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[7] http://www.w3.org/TR/prov-o/

Figure 8 Subclass of Household

Slum_household

Class	Property	Value Restriction
Slum_household	owl:subClassOf	Household
	gci:located_in	some gci:Slum
	isLackOf	some Living_condition

A gcis:Slum_household is a household that resides in a slum area. According to UN-Habitat, a slum household is defined to be lack of one or more living conditions (UN-Habitat, 2005). These living conditions are grouped under the class gcis:Living_condition which is linked to the gcis:Slum_household class by the object property gcis:isLackOf which has a minimum cardinality of 1. A distinct class (shown in bracket) was defined for each of the living conditions listed below.

1. Durable housing (gcis:Durable_housing)
2. Sufficient living space (gcis:Sufficient_living_area)
3. Access to improved water (gcis:Access_to_improved_water)
4. Access to sanitation (gcis:Access_to_sanitation)

5. Security of tenure (gcis:Secure_tenure)

Since cities may have different definitions of slum households therefore a 'for city' object property was assigned to the class gcis:Slum_household. For example, 'gcis:Toronto_slum_household' is a subclass of both gcis:Slum_household and gcis:Toronto_household class that has its value of gci:for_city explicitly assigned to 'gn:6167865' which is an individual that represents the city of Toronto from Placenames (http://sws.geonames.org/) as shown in table below.

Class	Property	Value Restriction
Toronto_household	owl:subClassOf	Household
	gci:for_city	value gn:6167865
Toronto_slum_household	owl:subClassOf	Toronto_household
	owl:subClassOf	Slum_household

Slum_household class was linked to gcis:Slum class via the object property gci:locate_in.

Slum

Class	Property	Value Restriction
Slum	owl:subClassOf	gn:Feature
	gci:located_in	some gci:City
	ic:hasGeoCoordinate	only sch:GeoCoordinate
	hasGeoShape	only sch:GeoShape

Slum is subclass of gn:Feature from Placenames (http://sws.geonames.org/). Since each city has a different definition for an area to be considered as a slum, a gci:for_city property was used to link gcis:Slum class and gci:City class. The object properties ic:hasGeoCoordinate and gcis:hasGeoShape links the Slum class with the class sch:GeoCoordinate and sch:GeoShape from Schema.org respectively. This gives the ability to represent the slum area in terms of geographical coordinates and shapes that is useful for any researches about urban slum areas.

Household_unregistered_legal_title

Class	Property	Value Restriction
Household_unregistered_legal_title	owl:subClassOf	Household
	hasTenureType	only Tenure_type
	livesIn	min 1 sumo:ResidentialBuilding
	hasLegalTitle	min 1 Unregistered_legal_title
	gci:for_city	only gci:City

Class	Property	Value Restriction
cyc:title	owl:subClassOf	cyc:'ownership agreement'
	hasTenureType	only Tenure_type
Registered_legal_title	owl:subClassOf	cyc:title
	gcis:isRegisteredAt	only org:GovernmentOrganization
Unregistered_legal_title	owl:subClassOf	cyc:title
	not gcis:isRegisteredAt	some org:GovernmentOrganization

A household without registered legal titles was represented as a subclass of household (gcis:Household) that has at least 1 unregistered legal title (hasLegalTitle min 1 gcis:Unregistered_legal_title). The class Unregistered_legal_title and Registered_legal_title are defined as a subclass of cyc:title implemented from OpenCYC. A title, or title agreement was defined by OpenCYC as "The collection of LegalAgreements conferring ownership of some property upon an IntelligentAgent. All ownership rights in the property indicated in a TitleAgreement belong to the holder of the TitleAgreement, specified within that agreement." (CYCorp, 2012). The cyc:title class was extended with the object property gcis:hasTenureType that points to the gcis:Tenure_type class.

According to the definition outlined by ISO37120 described in section 2, unregistered legal titles include the following tenure types. The classes defined are shown in bracket accordingly.

- Lease or leaseholds (gcis:Lease)
- Rental (gcis:Rental)
- Occupancy right (gcis:Occupancy_right)
- Use right (gcis:Use_right)

The gcis:Household_unregistered_legal_title class has a 'lives in' (gcis:livesIn) property that links to a residential building (sumo:ResidentialBuilding) with unregistered tenure types listed above. A class gcis:Tenure_type was created to generalize the tenure types. The 'cyc:title' class was then linked to gcis:Tenure_type by the object property gcis:hasTenureType. Tenure type (gcis:Tenure_type) is a subclass of sumo:Agreement which is defined to be "Agreement is the class of Propositions that express the contents of agreements entered into by CognitiveAgents. Agreement includes treaties, contracts, purchase orders, pledges, marriage vows, etc." according to (SUMO).
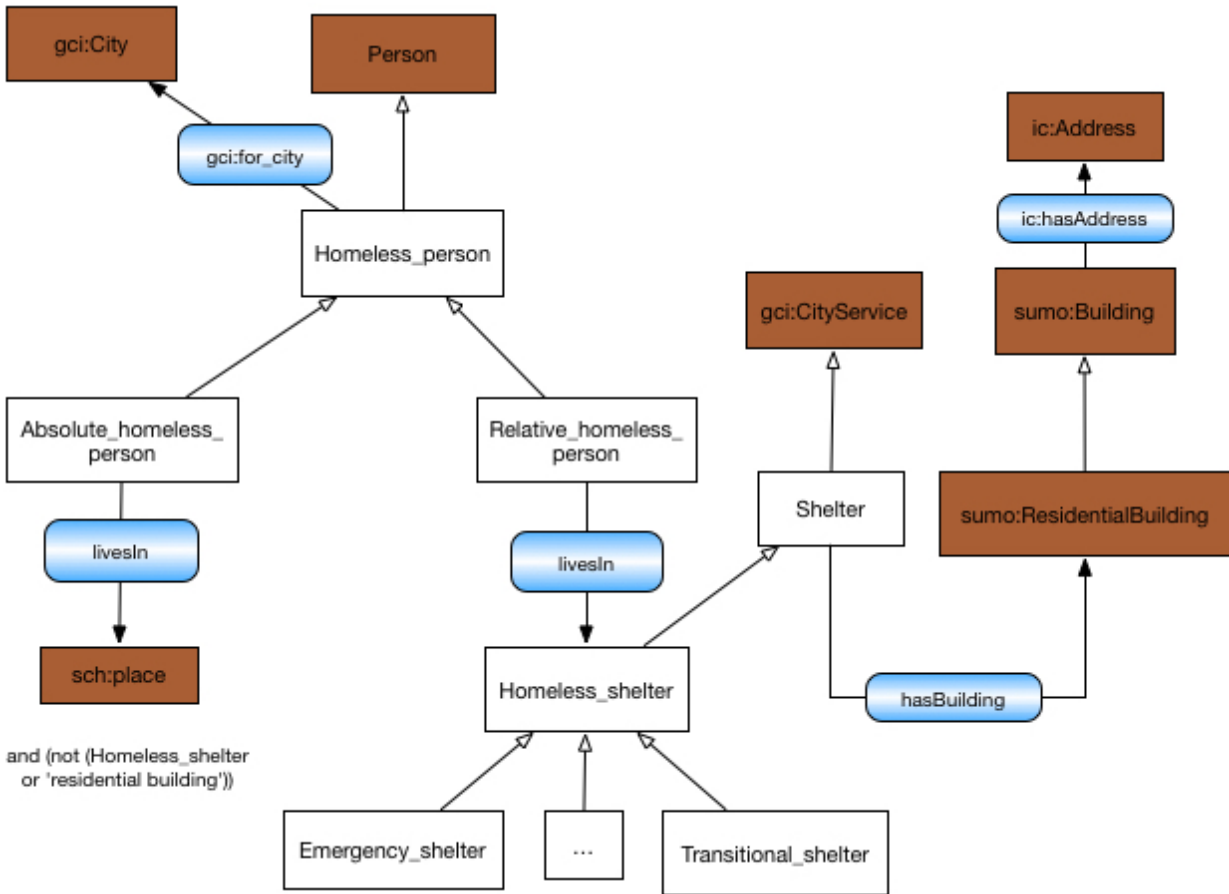
Figure 9 Homeless Person Class

Homeless_person

Class	Property	Value Restriction
Homeless_person	owl:subClassOf	gci:Person
	gci:for_city	only gci:City
Absolute_homeless_person	owl:subClassOf	Homeless_person
	gcis:livesIn	only sumo:PostalPlace and not (Homeless_shelter or sumo:ResidentialBuilding)
Relative_homeless_person	owl:subClassOf	Homeless_person
	gcis:livesIn	only Homeless_shelter

A homeless person can live on street, in a park or other temporary place as well as a homeless shelter. By definition of UN-Habitat a homeless person is defined as follows: "Cooper (1995) discusses the ideas of relative and absolute homelessness. Absolute homelessness occurs when there is neither access to shelter nor the elements of home. A person may be in relative homelessness; that is, they may have a shelter but not a home" (Habitat, 2000).

Homeless_person is a subclass of Person class. It is further classified as Absolute_homeless_person and Relative_homeless_person as per definition above. Both subclasses of Homeless_person possess an object property gcis:livesIn but with different constraint values. Relative_homeless_person lives in homeless shelters (gcis:Homeless_shelter) while Absolute_homeless_person can live in any place throughout the city but not a homeless shelter or a home. We use the class 'sumo:Place' to represent places that an absolute homeless person can live in. But an absolute homeless person does not have access to neither homeless shelter nor a residence. This is represented with the following Description Logic sentence.

$$
\begin{aligned}
Absolute\_homeless\_person \\
\equiv Homeless\_person \sqcap \ \forall livesIn.(sumo:PostalPlace \\
\sqcap \ \neg(homeless\_shelter \sqcup sumo:ResidentialBuilding))
\end{aligned}
$$

Thus Absolute_homeless_person can then be represented in Manchester syntax (Horridge et al., 2006) as follows:

```
Homeless_person AND
livesIn only (    PostalPlace AND
                  NOT(   Homeless_shelter OR
                         ResidentialBuilding
                         )
                  )
```

Note that both subclasses are made disjoint with each other.

Shelter

Class	Property	Value Restriction
Shelter	owl:subClassOf	gci:CityService
	hasBuilding	some sumo:ResidentialBuilding

Class	Property	Value Restriction
gci:Service	gci:goalOf	org:Organization
gci:CityService	owl:subClassOf	gci:Service

gcis:Shelter is a subclass of gci:CityService that is defined in GCI Foundation ontology. Shelters are generally city services that provides a place to live for people in needs. The gcis:hasBuilding links gcis:Shelter class to the sumo:ResidentialBuilding class which was then extended with ic:hasAddress that links the residential building to ic:Address from iContact ontology[8]. We also outlined gci:CityService and

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[8] International Contacts Ontology can be found at: http://ontology.eil.utoronto.ca/icontact.owl

its superclass, gci:Service in the table. The gci:Service class is a goal of (gci:goalOf) an organization (org:Organization)[9] which operates the shelter service.

Homeless_shelter

gcis:Homeless_shelter is a subclass of Shelter class. It serves as a superclass of different types of homeless shelters such as emergency shelters and 'all female homeless shelter'. Below are the types of homeless shelters operated by the City of Toronto (2009).

- All Female shelter
- All Male shelter
- Emergency Shelter
- Family Shelter
- Longterm Housing
- Overnight Shelter
- Refugee Shelter

- Single Adult Shelter
- Substance Use Shelter
- Temporary Shelter
- Transgender Shelter
- Transitional Shelter
- Youth Shelter

gcis:Homeless_shelter is linked to gcis:Relative_homeless_person via the object property gcis:livesIn as described earlier.

7. ISO37120 Shelter Indicators Definitions

In this section we define each shelter indicator using a combination of the GCI Foundation ontology and the GCI Shelter ontology.

Common to shelter indicators 15.1 and 15.2 is the city's population. Therefore the class isos:City_population_size will be used as the denominator of shelter indicator 15.1 and 15.2. It is a subclass of gci:Population_size and is a "gci:cardinality_of" isos:City_population which is a subclass of gci:Population. See table below for detailed class definition of isos:City_population_size and isos:City_population.

Class	Property	Value Restriction
City_population	owl:subClassOf	gs:Population
	gci:located_in	exactly 1 gci:City
	gci:defined_by	exactly 1 Person
City_population_size	owl:subClassOf	gci:Population_size
	gci:cardinality_of	exactly 1 City_population

Table 3 City population class for ISO 37120 Shelter indicators

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[9] Organization Ontology can be found at: http://ontology.eil.utoronto.ca/organization.owl

15.1 Percentage of city population living in slums (core indicator)

As stated in section 2 the 15.1 indicator is determined by the ratio of number of people living in slums to the city's total population size. Number of people living in slums was then further defined to be the product of number of slum households and the average household size of the city. The table below and Figure 10 illustrate the components of the 15.1 indicator.

Class	Property	Value Restriction
iso37120:15.1	om:numerator	15.1_Slum_population_size
	om:denominator	City_population_size
15.1_Slum_population_size	owl:subClassOf	gci:Population_size
	om:term_1	15.1_Slum_household_population_size
	om:term_2	gcis:Average_household_size
15.1_slum_household_population_size	owl:subClassOf	gci:Population_size
	gci:cardinality_of	15.1_slum_household_population
15.1_slum_household_population	owl:subClassOf	gs:Population
	gci:located_in	gci:City
	gci:defined_by	gcis:Slum_household

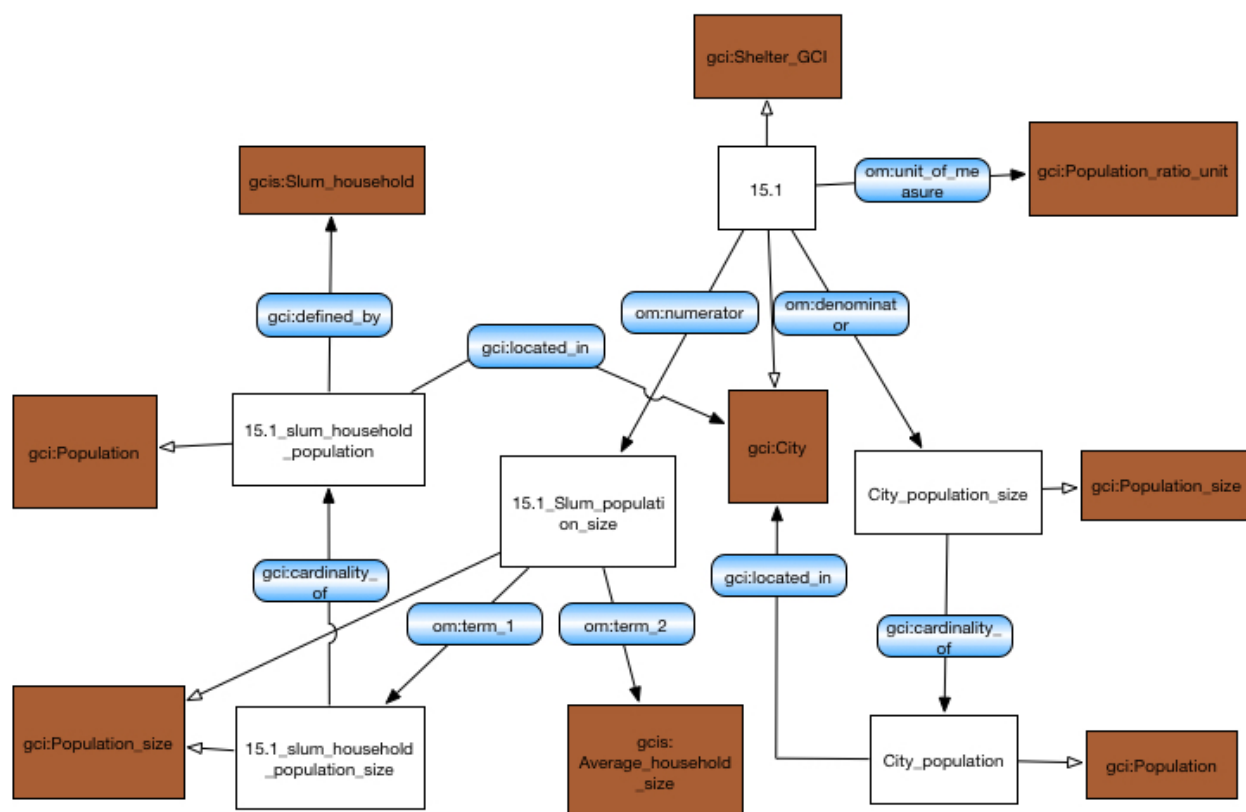*Table 4 15.1 Shelter indicator class definitions*

Figure 10 15.1 shelter indicator definitions

15.2 Number of homeless per 100 000 population

The definition of this indicator has two components: the homeless population size and the city's total population size. Table below and Figure 11 illustrates the numerator.

Class	Property	Value Restriction
iso37120:15.2	om:numerator	15.2_Homeless_population_size
	om:denominator	City_population_size
15.2_Homeless_population_size	owl:subClassOf	gci:Population_size
	gci:cardinality_of	15.2_Homeless_population
15.2_Homeless_population	owl:subClassOf	gs:Population
	gci:located_in	gci:City
	gci:defined_by	15.2_Homeless_person
15.2_Homeless_person	owl:subClassOf	gcis:Homeless_person
	gci:for_city	gci:City

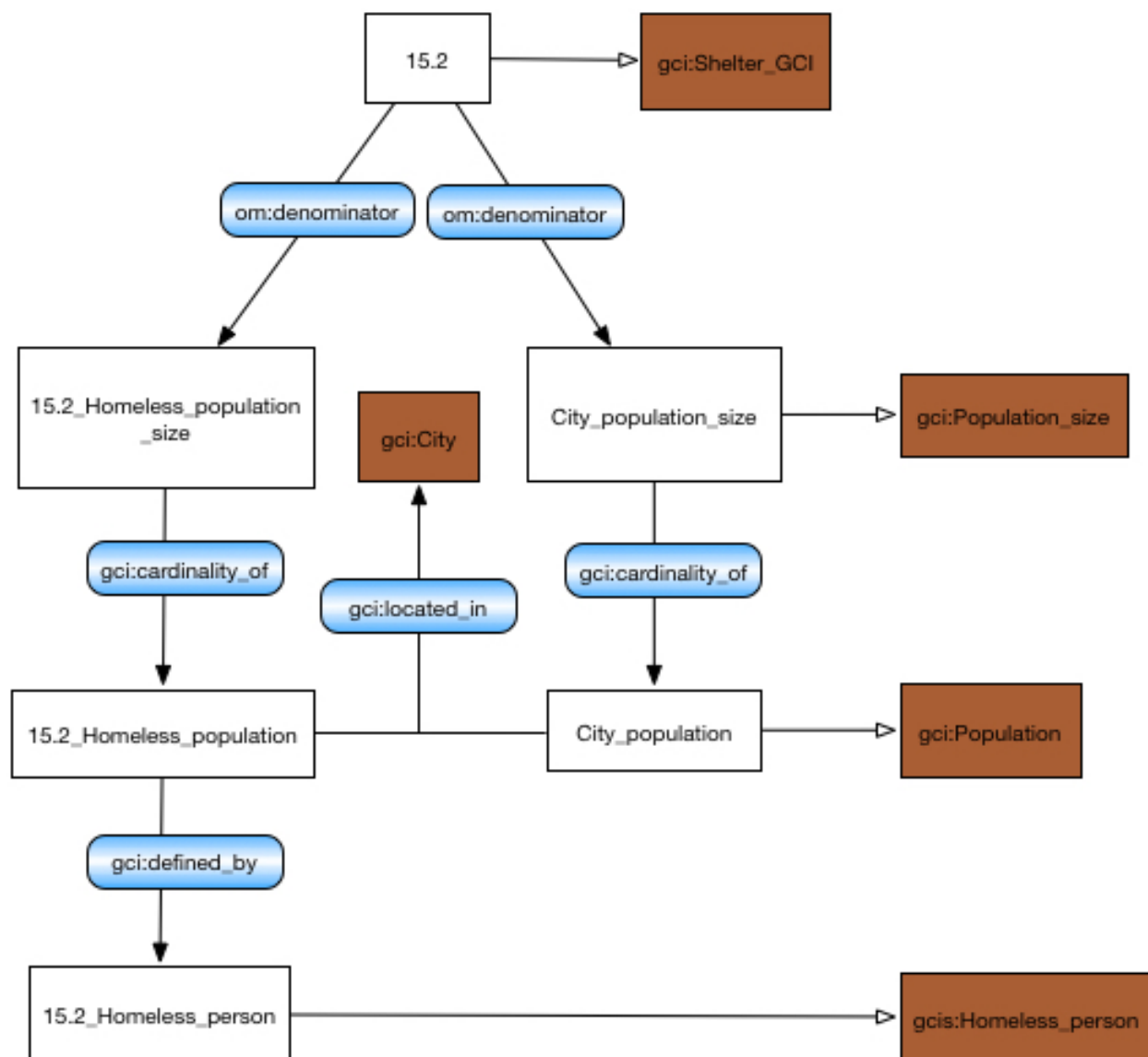*Table 5 15.2 Shelter indicator class definitions*

Figure 11 15.2 shelter indicator definitions

15.3 Percentage of households that exist without registered legal titles

According to ISO37120 the 15.3 indicator shall be calculated as the number of households without legal titles divided by the total number of households in the city. The definition of household without legal title and general household can be found in section 6. The table below and Figure 12 illustrate components of 15.3 indicator and their properties and value restrictions.

Class	Property	Value Restriction
iso37120:15.3	om:numerator	15.3_Household_unregistered_legal_title_population_size
	om:denominator	15.3_Household_population_size
15.3_Household_population_size	owl:subClassOf	gci:Population_size
	gci:cardinality_of	15.3_Household_population

15.3_Household_population	owl:subClassOf	gs:Population
	gci:located_in	gci:City
	gci:defined_by	gcis:Household
15.3_Household_unregistered_legal_title_population_size	owl:subClassOf	gci:Population_size
	gci:cardinality_of	15.3_Household_unregistered_legal_title_population
15.3_Household_unregistered_legal_title_population	owl:subClassOf	gs:Population
	gci:located_in	gci:City
	gci:defined_by	gcis:Household_unregistered_legal_title

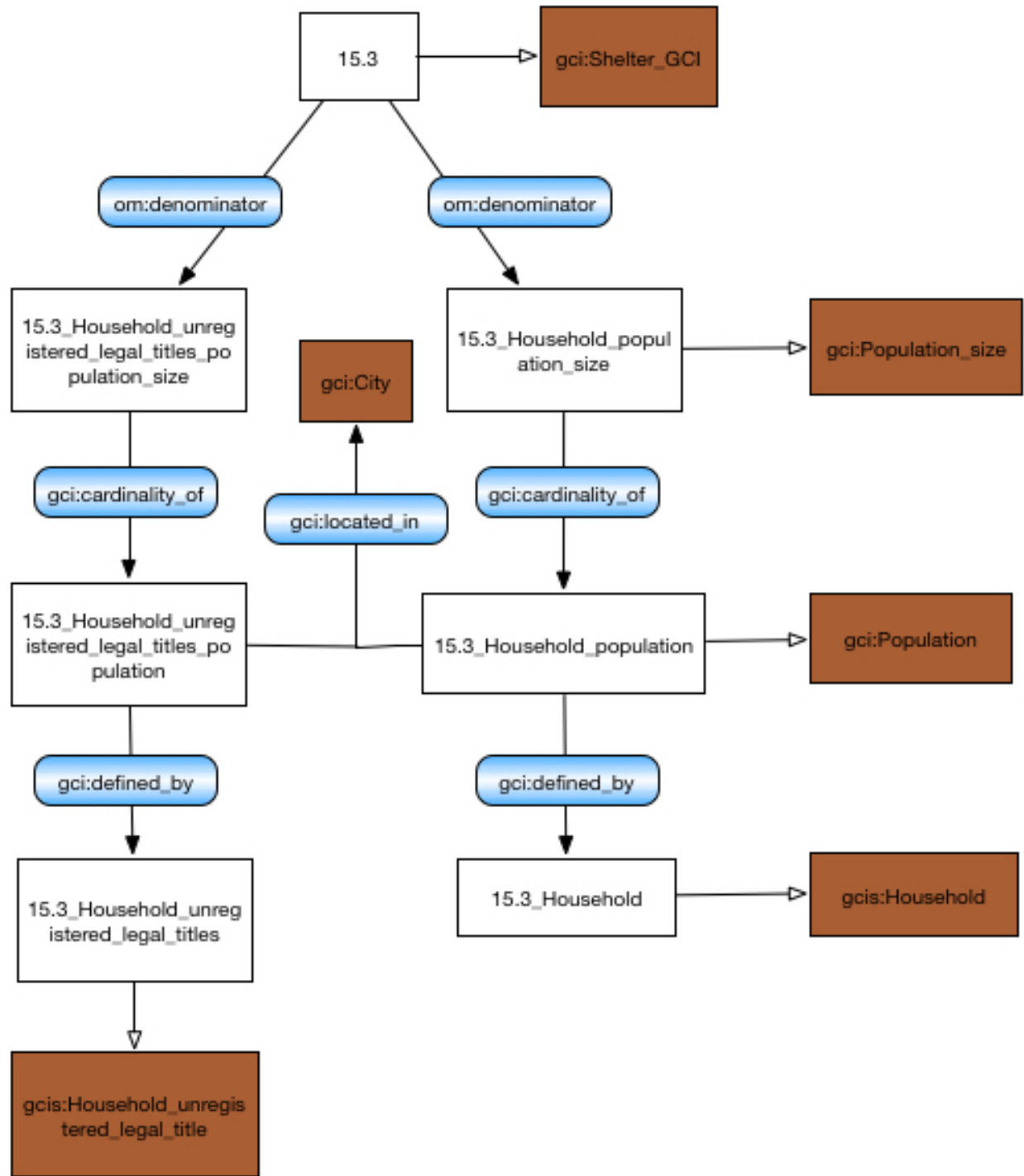*Table 6 15.3 Shelter indicator class definitions*

Figure 12 15.3 shelter indicator definitions

8. Evaluation

In the next two subsections, we use the City of Toronto in the Province of Ontario, Canada to illustrate the competency questions. For ease of understanding we will first show the instances in table form. Prefixes are defined as follows:

- iso: http://ontology.eil.utoronto.ca/ISO37120.owl#
  - URIs for each ISO37120 indicator
- isos: http://ontology.eil.utoronto.ca/GCI/ISO37120/Shelters.owl#
  - The ISO37120 shelter indicators definitions defined in section 7.
- gcis: http://ontology.eil.utoronto.ca/GCI/ Shelters/GCI-Shelters.owl#
  - The Shelter ontology defined in section 6.
- gci: http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl#
  - The foundation ontology
- sumo: http://www.ontologyportal.org/SUMO.owl#
  - Suggested Upper Merged Ontology (SUMO)
- gn: http://sws.geonames.org/
- sch: http://schema.org/
- ic: http://ontology.eil.utoronto.ca/icontact.owl#
  - An internationalized address ontology.
- om: http://www.wurvoc.org/vocabularies/om-1.8/
  - OM Measurement ontology.

This first table defines the instances that provide background information on the city of Toronto, the second table defines instances of concepts related to ISO37120 15.1 indicator.

Instance	Property	Value
gn:6251999	rdfs:label	Canada
	rdfs:type	gn:Feature
	rdfs:type	sch:Country
gn:6093943	rdfs:label	Ontario
	rdfs:type	gn:Feature
	rdfs:type	sch:Province
gn:6167865	rdfs:label	Toronto
	rdfs:type	gn:Feature
	rdfs:type	sch:City
toronto_slum_area_1	rdfs:type	gcis:Slum
	gci:located_in	gn:6167865
toronto_slum_household_1	rdfs:type	gcis:Tonroto_slum_household
	gcis:isLackOf	toronto_slum_houshold_1_access_water
	gcis:isLackOf	toronto_slum_houshold_1_durable_house
	gci:located_in	toronto_slum_area_1
	gcis:hasHouseholder	person_1
	org:hasMember	person_1

	gcis:hasHouse	house_1
	gcis:hasSize	toronto_slum_household_1_size
	org:memberOf	isos:15.1_SH_pop
toronto_slum_household_1_size	rdfs:type	gcis:Household_size
	om:value	toronto_slum_household_1_size_value
	om:unit_of_measure	gci:Population_cardinality_unit
toronto_slum_household_1_size_value	rdfs:type	om:Measure
	om:unit_of_measure	gci:Population_cardinality_unit
	om:numerical_value	5
toronto_slum_household_1_access_water	rdfs:type	gcis:Access_to_improved_water
toronto_slum_household_1_durable_house	rdfs:type	gcis:Durable_housing
person_1	rdfs:type	Person
	org:memberOf	isos:toronto_city_pop
	org:memberOf	toronto_slum_household_1
	ic:hasAddress	address_1
house_1	rdfs:type	gcis:House
	ic:hasAddress	address_1
address_1	rdfs:type	ic:Address
	hasCity	gn:6167865
	hasState	gn:6093943
	hasCountry	gn:6251999
toronto_city_pop	rdfs:type	isos:City_population
	gci:located_in	gn:6167865
toronto_city_pop_size	rdfs:type	isos:City_population_size
	gci:cardinality_of	toronto_city_pop
	om:value	toronto_city_pop_size_value
	om:unit_of_measure	gci:Population_cardinality_unit
toronto_city_pop_size_value	rdfs:type	om:Measure
	om:numerical_value	2615000
	om:unit_of_measure	gci:Population_cardinality_unit

Table 7 Instances defined based on GCI Shelter ontology

Instance	Property	Value
15.1_ex	rdfs:type	iso:15.1
	om:value	15.1_ex_value

	gci:numerator	15.1_Slum_pop_size
	gci:denominator	toronto_city_pop_size
	gci:for_city	gn:6167865
	om:unit_of_measure	gci:Population_ratio_unit
15.1_ex_value	rdfs:type	om:Measure
	om:numerical_value	500
	om:unit_of_measure	gci:Population_ratio_unit
15.1_ex_avg_household_size	rdfs:type	gcis:Average_household_size
	om:value	15.1_ex_avg_household_size_value
	om:unit_of_measure	gci:Population_cardinality_unit
	gci:for_city	gn:6167865
15.1_ex_avg_household_size_value	rdfs:type	om:Measure
	om:numerical_value	2.8
	om:unit_of_measure	gci:Population_cardinality_unit
15.1_SH_pop	rdfs:type	15.1_slum_household_population
	gci:located_in	gn:6167865
15.1_SH_pop_size	rdfs:type	15.1_slum_household_population_size
	gci:cardinality_of	15.1_SH_pop
	om:value	15.1_SH_pop_size_value
	om:unit_of_measure	gci:Population_cardinality_unit
15.1_SH_pop_size_value	rdfs:type	om:Measure
	om:numerical_value	100000
	om:unit_of_measure	gci:Population_cardinality_unit
15.1_slum_pop_size	rdfs:type	15.1_slum_population_size
	om:term_1	15.1_SH_pop_size
	om:term_2	15.1_ex_avg_household_size
	om:value	15.1_slum_pop_size_value
	om:unit_of_measure	gci:Population_cardinality_unit
15.1_slum_pop_size_value	rdfs:type	om:Measure
	om:numerical_value	280000
	om:unit_of_measure	gci:Population_cardinality_unit

Table 8 Instances defined based on ISO 37120 Shelter indicator ontology

8.1 Verification

We will verify our ontology using ISO37120 shelter indicator 15.1 as an example.

Below are the competency questions raised for 15.1 indicator and SPARQL queries and results associated with each question:

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX gci: <http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl#>

PREFIX gcis: <http://ontology.eil.utoronto.ca/GCI/Shelters/GCI-Shelters.owl#>
PREFIX om: <http://www.wurvoc.org/vocabularies/om-1.8/>
PREFIX ic: <http://ontology.eil.utoronto.ca/icontact.owl#>
PREFIX org: <http://ontology.eil.utoronto.ca/organization.owl#>
PREFIX sch:<http://schema.org/>
PREFIX isos: <http://ontology.eil.utoronto.ca/GCI/ISO37120/Shelters.owl#>
PREFIX : <http://ontology.eil.utoronto.ca/ISO37120/Toronto/2015/ISO37120_15_2015_TO.owl#>

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

```
SELECT ?city WHERE{
        :15.1_ex gci:for_city ?city
}
```

Result

City
Toronto

2.   (F)What is the city's average household size?

```
SELECT  ?city (?avghs_m_value AS ?Average) WHERE{
        ?avghs rdf:type gcis:Average_household_size.
        ?avghs gci:for_city ?city.
        ?avghs om:value ?avghs_m.
        ?avghs_m om:numerical_value ?avghs_m_value
}
```

Result

City	Average Household Size
Toronto	"1.95"^^xsd:decimal

3.   (F)What is the number of slum households in the city?

```
SELECT ?city ?slumHPopSize_m_value WHERE{
        ?slumHPop rdf:type isos:15.1_slum_household_population.
        ?slumHPop gci:located_in ?city.
        ?slumHPopsize gci:cardinality_of ?slumHPop.
        ?slumHPopSize rdf:type isos:15.1_slum_household_population_size.
        ?slumHPopSize om:value ?slumHPopSize_m.
        ?slumHPopSize_m om:numerical_value ?slumHPopSize_m_value
}
```

Result

City	Slum Household Population Size
Toronto	"19725"^^xsd:integer

4.   (F)What's the slum population size of the city?

```
SELECT ?city ?slumPopSize_m_value WHERE{
        :15.1_ex gci:for_city ?city.
        ?slumPopSize rdf:type isos:15.1_Slum_population_size.
        ?slumPopSize om:value ?slumPopSize_m.
        ?slumPopSize_m
        om:numerical_value ?slumPopSize_m_value
}
```

City	Slum Population Size
Toronto	"54000"^^xsd:integer

5.   (F)What's the city's total population size?

```
SELECT ?city ?cityPopSize_m_value WHERE{
        ?cityPop rdf:type isos:City_population.
        ?cityPop gci:located_in ?city.
        ?cityPopSize gci:cardinality_of ?cityPop.
        ?cityPopSize om:value ?cityPopSize_m.
        ?cityPopSize_m om:numerical_value ?cityPopSize_m_value
}
```

City	City Population Size
Toronto	"2615000"^^xsd:integer

6.   (CD) Is household X located in the city?

```
SELECT ?city WHERE{
        :toronto_slum_household_1 gci:located_in ?city.
        ?city rdf:type sch:City
}
```

City
Toronto

7.   (F) Who are the individuals in household X?

```
SELECT ?member WHERE{
        :toronto_slum_household_1
        org:hasMember ?member
}
```

Householder
person_1

8.   (F) What is the household size of household x?

```
SELECT ?householdsize_m_value WHERE{
        :toronto_slum_household_1 gcis:hasSize ?householdsize.
        ?householdsize om:value ?householdsize_m.
        ?householdsize_m om:numerical_value ?householdsize_m_value
}
```

Household size
5^^xsd:integer

9.   (D)Is a household X a slum household?

```
ASK {
:toronto_slum_household_1 rdf:type gcis:Slum_household
}
```

Result
True

10.   (F) Which living conditions outlined by UN-HABITAT is household X lacking of?

```
SELECT DISTINCT ?livingCondition WHERE {
        :toronto_slum_household_1 gcis:isLackOf ?livingCondition.
        ?livingCondition rdf:type ?condtion.
        ?condition rdfs:subClassOf gcis:Living_condition
}
```

Living Condition
toronto_slum_household_1_access_water
toronto_slum_household_1_durable_house

9. Conclusion

A GCI Shelter ontology was defined to represent shelter related concepts that were used in the definitions of ISO37120 shelter theme indicators. Each indicator's definition was then represented using the GCI Shelter ontology, GCI Foundation ontology and other ontologies as described. It was difficult to decide the boundary of concepts that should be covered by the GCI Shelter ontology. Although some concepts covered such as 'Homeless shelters', 'Living condition' and 'Slum area' are not required by ISO37120 shelter indicators, in order to create an ontology with some degree of reusability, we decided to represent these more general shelter related concepts to enhance reuse.

In summary, this research makes three contributions:

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

10. Acknowledgements

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Appendix

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

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

URIs for all of the ISO 37120 indicators can be found in:
http://ontology.eil.utoronto.ca/ISO 37120.owl.

Definitions of the ISO 37120 shelter indicators, using the GCI Foundation and GCI Shelter ontologies can be found in:
http://ontology.eil.utoronto.ca/GCI/ISO 37120/Shelters.owl.

The implementation file for ISO37120 Shelter theme indicators can be found in:
http://ontology.eil.utoronto.ca/ISO37120/Toronto/2015/ISO37120_15_2015_TO.owl