A Public Safety Ontology for Global City Indicators (ISO37120)

Kourosh Khazei, Mark S. Fox

Enterprise Integration Laboratory (eil.utoronto.ca)
University of Toronto
Kourosh.khazei@mail.utoronto.ca
msf@eil.utoronto.ca

EIL Working Paper, First Published: 28 April 2017

1. Introduction

Cities use a variety of metrics to evaluate themselves. With the introduction of ISO 37120, which contains over 100 indicators for measuring a city's quality of life and sustainability, it is now possible to consistently measure and compare cities, assuming they adhere to the Standard. With the growing adoption of Open Data principles by cities, it is becoming possible (in theory at least) to automate this analysis process. One major impediment to the open publishing of indicator data is the lack of standards.

In this paper we define a Public Safety Ontology for Global City Indicators that addresses the following issues:

1. How do we represent the (ISO 37120) definition of an indicator? In order for the analysis of indicators to be automated, we must be able to read and understand the definition of each indicator, which may change over time.
2. How do we represent ISO 37120 theme specific knowledge? Each theme such as Public Safety, Education, Health, Shelter, etc., has a core set of "common sense" 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.
3. How do we represent a city's theme specific knowledge? Each city may define concepts such as "Homicide", "Response Time", "Police Officer", etc. differently. Differences in indicator values may be due to differences in the interpretation of these terms between cities.
4. How do we represent the supporting data that a city uses to derive the value of an indicator? What was the source data? How was it aggregated?

In the remainder of this paper, section 2 defines the ISO 37120 Public Safety theme indicators and competency questions they entail. Section 3 provides background on city indicators and related ontologies. Section 4 defines the architecture of the Global City Indicator Ontology set. Section 5 defines our Public Safety Ontology. Section 6 defines our patterns for representing the ISO 37120 Public Safety indicators. Section 7 evaluates the ontology and patterns.

2. Indicators and their Competency Requirements

In this section we reprint the Public Safety indicators as defined in ISO 37120. For each indicator we define a set of competency questions (Gruninger & Fox, 1995), motivated by each indicator that the Public Safety ontology must be able to answer. These questions act as requirements on the design of the ontology. Note that questions that refer to measurement theory, provenance, validity and trust are not included as they are addressed in the GCI foundation ontology (Fox, 2013; Fox 2015).

Competency questions fall into the following categories:

- **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.

2.1. Number of police officers per 100 000 populations [14.1]

The first ISO 37120 public safety indicator focuses on measuring number of police officers:

> "The number of police officers per 100 000 populations shall be calculated as the number of permanent full-time (or full-time equivalent) sworn police officers (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of police officers per 100 000 populations. Sworn law enforcement officers should meet the following criteria: work in official capacity; have full arrest powers; carry identification; and, be paid from governmental funds set aside specifically for payment of sworn law enforcement representatives. Each year, law enforcement agencies shall report the total number of sworn law enforcement officers as of a locally determined date. Personnel counts shall be based on permanent, FTE. Part-time employees can be converted to full-time equivalent (e.g. four employees working 10 h per week would equal one full-time employee working 40 h week.) Temporary officers shall not be included in this count."

Competency Questions

1. (F) What types of police officers does a city have?
2. (F) Who is the police officer's employer?
3. (F) What is the employment type of police officers?
4. D) Does the police officer have full arrest powers?
5. (D) Does the police officer carry identification at work?
6. (D) Is the police officer paid from governmental funds?
7. (D) How many police officers does the city have?

2.2. Number of homicides per 100 000 population [14.2]

Following is the ISO 37120 definition of number of homicides:

> "The number of homicide per 100 000 populations shall be calculated as the number of reported homicides (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of homicides per 100 000 populations. Homicide shall include intentional and non-intentional homicide. Intentional homicide shall refer to death deliberately inflected on a person by another

person, including infanticide. Non-intentional homicide shall refer to death non-deliberately inflicted on a person by another person. This shall include manslaughter, but shall exclude traffic accidents that result in the death of a person, and suicides."

Competency Questions

1. (F) How many Victims in year X does the city have?
2. (F) How many Victims were due to non-intentional homicide?
3. (F) How many Victims were due to intentional homicide?
4. (F) How many infanticides were reported?
5. (F) How many Victims were due to manslaughter?
6. (F) How many Victims were due to traffic accidents?
7. (F) How many Victims were due to suicides?

2.3. Crimes against property per 100 000 population [14.3]

Following is the ISO 37120 definition of number of Crimes against property:

"The number of crimes against property shall be calculated as the total number of all property crimes reported (numerator) divided by one 100 000th of the city's total population (denominator).The result shall be expressed as the number of property crimes per 100 000 populations. Crimes against property shall be defined as all offences involving the unlawful taking or destruction of property, but without the threat of use of force against a person.
Crime against property should include: burglary; larceny-theft; motor vehicle theft; and, arson."

Competency Questions

1. (F) What types of property crimes does the city have?
2. (F) How many burglaries were reported against privately owned properties?
3. (F) How many larceny-theft were reported against privately owned properties?
4. (F) How many motor vehicle thefts were reported against privately owned properties?
5. (F) How many arsons were reported against privately owned properties?

2.4. Response time for police department from initial call [14.4]

According to ISO37120, Police Response time is defined as follows:

"The response time for police department from initial call shall be calculated as the sum of number of all initial distress calls to the on-site arrival of the police department personnel for the year in minutes and seconds (numerator) divided by the number of police department responses in the same year (denominator). The result shall be expressed as the response time for police department from initial call in minutes and seconds. The total number of minutes and seconds taken to respond to all emergency calls shall include the time elapsed from receiving the initial call for assistance to arrival on-site of police department personnel is calculated for the preceding 12 months."

Competency Questions

1. (F) What types of distress calls did the city receive?

2. (F) How long did it take from initial distress call to the on-site arrival of police department for the distress call?
3. (D) What's total number of hours and minutes for distress call Y in the same year?
4. (F) What is the total number of distress calls that the police department responded to in the year?

2.5. Violent crime rate per 100 000 population [14.5]

Following is the ISO 37120 definition of violent crime rate as follows:

> "The violent crime rate per 100 000 populations shall be calculated as the total number of all violent crimes reported (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of violent crimes per 100 000 populations. Violent crimes shall include offences that involve force or the threat of force to a person. Total violent crimes reported shall be calculated as the total sum of the numbers of murders and non-negligent manslaughters, the number of rapes, the number of robberies and the number of aggravated assaults. Furthermore, a violent crime should be classified as one of the following four offences (in order of severity): murder and non-negligent manslaughter; rape; robbery and, aggravated assault. For a multiple-offence, only the most serious /severe offence shall be counted."

Competency Questions

1. (F) What types of violent crime does city report?
2. (D) What's the order of violent crimes severity?
3. (F) How many of murder and non-negligent manslaughter was reported in the city?
4. (F) How many rapes were reported in the city?
5. (F) How many robberies were reported in the city?
6. (F) How many aggravated assaults were reported in the city?
7. (D) If a person was involved in more than one violent crime, which one was more severe?

3. Background

3.1. City Indicators

In this section we will review non-ISO37120 Public Safety indicators, including National public safety information sharing efforts.

National Public Safety

In Canada, within the public safety sector, interoperability refers to the ability of government agencies and organizations to share the right information at the right time to keep Canadians safe. Leading collaborative efforts with other federal departments and agencies, provinces, territories, municipalities, industry and international partners including radio and voice communications interoperability, development of data standards, and the horizontal coordination of efforts across stakeholders in the adoption and implementation of standards to support improved automated information exchange for the broader public safety and security communities.[1]

[1] Public Safety Canada 2013–14 Departmental Performance Report

A Canadian Communications Interoperability Plan is in place to ensure that critical gaps in first responder communications and across the public safety and security communities are addressed consistently and founded on common standards, models and practices as follows:

Expected Results	Performance Indicators	Targets	Actual Results
Operational information regarding public safety and security is shared in an effective and timely manner	Percentage of provinces, territories, regions, municipalities within targeted deployment area, linked to the newly deployed national interoperable communications infrastructure using the 700 MHz spectrum	≥ 2% by end of 2014, ≥ 5% by end of 2015, ≥ 10% by end of 2016, ≥ 25% by end of 2017, ≥ 40% by end of 2018, and ≥ 50% by end of 2019 of the 4G LTE deployed network	N/A
	Level of satisfaction from respondent Canadian Emergency Operation Centers regarding the accuracy and reliability of the information being displayed on the Multi-Agency Situational Awareness System	≥ 80% satisfied by end of 2013	87.29%
	Percentage of provinces and territories participating in federally coordinated activities targeted toward objectives set out in the Canadian communication Interoperability Continuum	≥ 76%	N/A

Public Safety Ontology, New York, city of Troy

This project[2] focused on translating, curating and publishing public safety data in RDF. Two different sources of information were used:

1. Reports from the Rensselaer Polytechnic Institute Public Safety department (RPS)
2. Information from the Troy Police Department (TPD).

In order to integrate TDP and RPS, a lightweight ontology was created to include events in both datasets. The taxonomy of public safety events depicted as follows:

The Honorable Steven Blaney, P.C., M.P. Minister of Public Safety and Emergency Preparedness.

[2] https://www.researchgate.net/publication/221584658_Integrating_and_publishing_public_safety_data_using_semantic_technologies

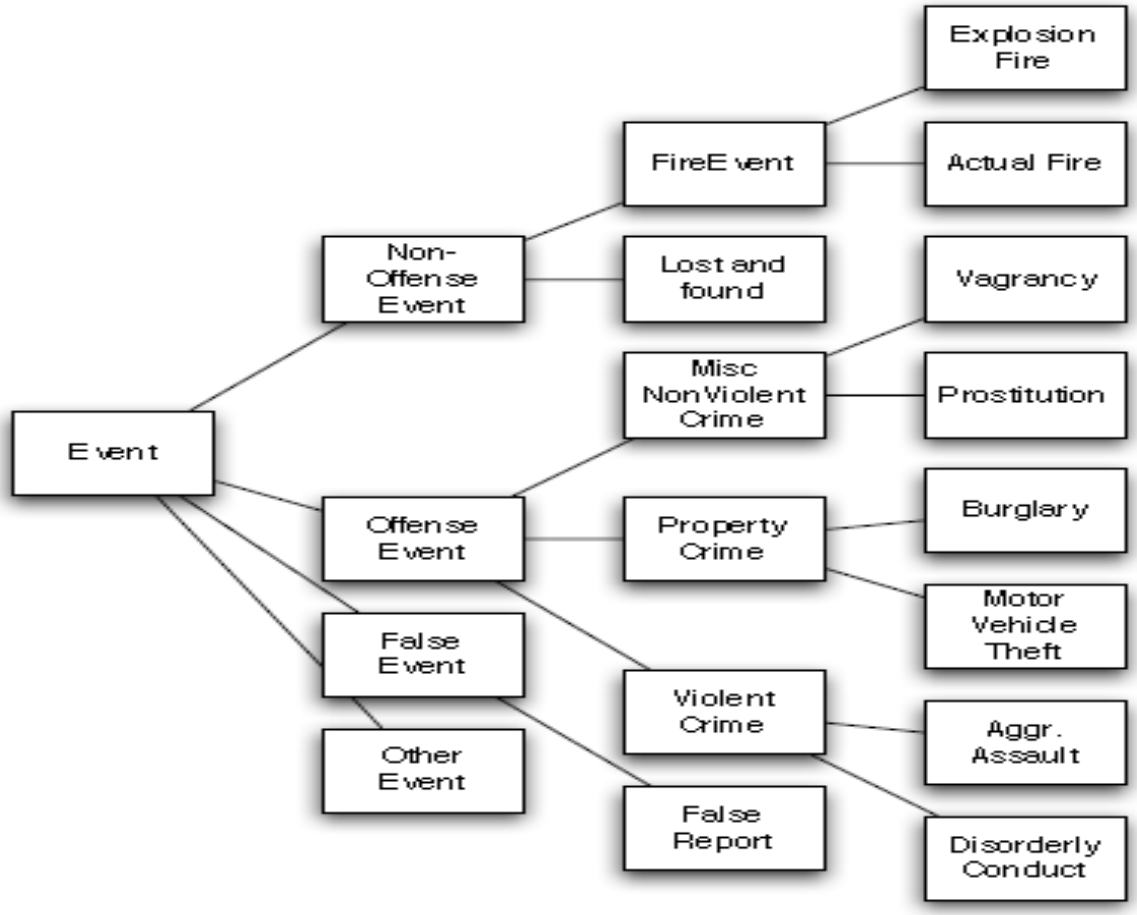


Figure 1: Public Safety Ontology, New York

As the Taxonomy shows, Classes are divided into four major categories Non-offense, Offense, False and Others:

- **Offense Events:** including Offence events based on "Offenses Known to Law Enforcement "
  This include violent crimes (forcible rape, aggravated assault) as well as property crimes (robbery, burglary) as defined by the FBI.
- **Non-offense Events:** Non-offense events are events that cannot be classified as "crimes" such as "Accident" or "Fire" and it's already in RPS dataset.
- **False Events:** such as "False Alarm".
- **Other Events:** indicates anything other than above.

Each event was described by the following properties: **"Event number"**, **"date and time of the report"**, **"date and time"** (when the event started and finished),**" type of event"** and **"report number ".**

The following shows the representation of a medical-related event in **RDF/XML** format:

```
<Medical rdf:about=”http://publicsafetymap.org/US/NY/Troy/RPS/Event/09-02-03-002330”>
<Disposition rdf:datatype=”xsd:String”>MEDICAL REPORT FILED</Disposition>
<HasSource rdf:resource=”http://publicsafetymap.org/US/NY/Troy#RPIPublicSafety”/>
<Location rdf:datatype=”xsd:String”>ACADEMY HALL</Location>
<Report rdf:datatype=”xsd:String”>090068</Report>
<eventEnd rdf:datatype=”xsd:dateTime”>2009-02-03T09:43</eventEnd>
<eventStart rdf:datatype=”xsd:dateTime”>2009-02-03T09:07</eventStart>
<reportDate rdf:datatype=”xsd:dateTime”>2009-02-03T09:03</reportDate>
<map:Has LatLong rdf:datatype=”xsd:String”>42.7274,-73.67862</map:Has LatLong>
</Medical>
```

DATA.POLICE.UK

The individual crime and anti-social behavior (ASB) incidents[3] dataset, includes street-level location information and subsequent police and court outcomes associated with the crime covers time period December 2010 to July 2016. It has an API implemented as a standard JSON web service. The API provides a rich data source for information, including:

- Neighborhood team members
- Upcoming events
- Street-level crime and outcome data
- Nearest police stations

For example Street-level crime is implemented in JSON as follows:

1) Request parameters for street-level crimes - specific point including 3 following fields for location and date of crime:

Field Name	Description
lat	Latitude of the requested crime area
lng	Longitude of the requested crime area
date	Optional. (YYYY-MM) Limit results to a specific month.

[3] https://data.police.uk/docs/

2) Response parameters for street-level crimes - specific point including following fields:

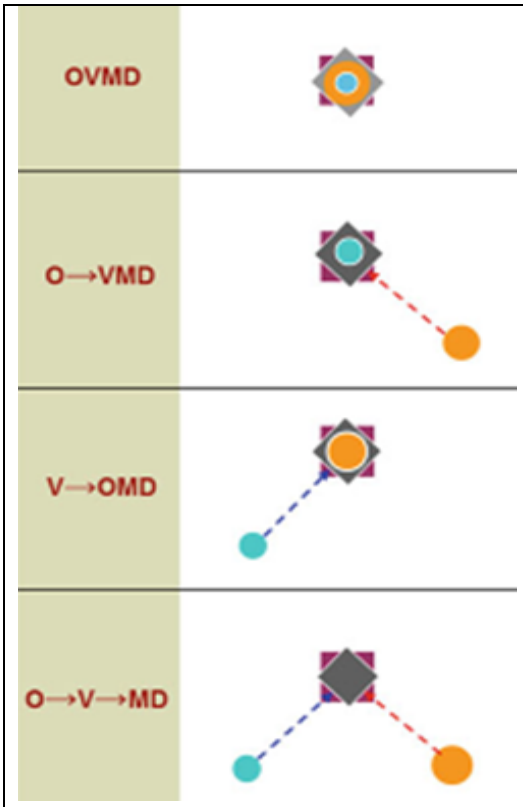
Field Name	Description
Category	Category of the crime
persistent_id	64-character unique identifier for that crime.
Month	Month of the crime
Location	Approximate location of the incident
Latitude	Latitude
Street	The approximate street the crime occurred
Id	Unique identifier for the street
Name	Name of the location.
longitude	Longitude
Context	Extra information about the crime
Id	ID of the crime.
location_type	Force or BTP: Force indicates a normal police force location; BTP indicates a British Transport Police location. BTP locations fall within normal police force boundaries.
location_subtype	For BTP locations, the type of location at which this crime was recorded.
outcome_status	The category and date of the latest recorded outcome for the crime
Category	Category of the outcome - example : not-guilty
Date	Date of the outcome

(SCHC) Model - Spatial Configurations of Homicide Crime

H. Kim et al. (2013) proposed Conceptual model named Spatial Configurations of Homicide Crime (SCHC)[4] which is defined by combinations of locations including following sub-classes: Offender's residence (O), Victim's residence (V), Murder location (M),and Disposal location of victim (D), all of which are expressed as a set of (O, V, M, D). In detail, each SCHC set (O, V, M, D) defines a distinct situation of criminal homicide as follows:

Victim's Residence	Offender's residence	Murder location	Disposal location

[4] Crime Modeling and Mapping Using Geospatial Technologies 2013 - chapter 8
www.springer.com/us/book/9789400749962

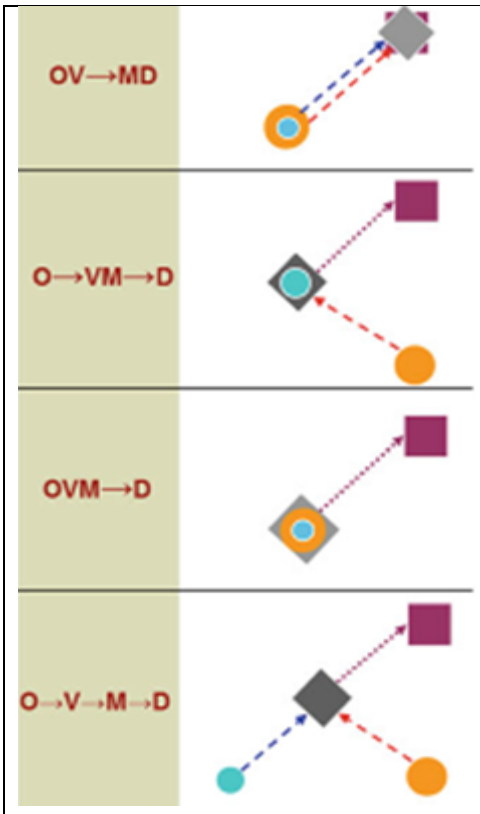


• (OVMD): An offender and a victim reside together, a murder occurred in the shared household, and the victim's body was not transported to another location.

• (O → VMD): An offender and a victim lived in separate residences. A murder occurred at the victim's residence. In this situation, no movement of the victim occurs after the homicide.

• (V → OMD): An offender and a victim lived in separate residences. A murder occurred at the offender's residence. In this situation, the deposition of the victim's body remains at the homicide location.

• (O → V → MD): An offender and a victim resided at different locations, and a murder occurred in a location other than their homes. No movement of the victim's body occurs after homicide.



• (OV → MD): An offender and a victim reside together but a murder occurred elsewhere and the victim's body was not transported to another location.

• (O → VM → D): An offender and a victim lived in separate residences. A murder occurred at the victim's residence, but the victim's body was transported to another location after the homicide and deposited.

• (OVM → D): An offender and a victim reside together and a murder occurred in the shared household, but the victim's body was transported to another location and deposited.

• (O → V → M → D): An offender and a victim lived in separate residences and a murder occurred in a location other than their homes. In addition, the victim's body was transported to another location other than the residences of the offender, victim, and the place of murder.

Web-Based Crime Geointelligence Platform for Mexico City's Public Safety

This project aimed to develop a geointelligence capacity by inserting a geospatial dimension in the information systems and decision making processes of Mexico City's Public Safety Ministry[5].For managing geospatial information at organizational and technological levels, a Geospatial Data Infrastructure (GDI) was designed and implemented to solve the related requirements. Also a key element is the adoption of standards, which includes geospatial Web services based on worldwide standards, those sponsored by the Open Geospatial Consortium (OGC) and the World Wide Web Consortium (W3C) being the most important.

GDI enables integration of data from different sources. Platforms and systems were implemented along with models for space and space-time analysis of crime incidence, as part of the analytic processes routinely performed by the Ministry's internal users of the GDI. Also the concentration of police resources in hot spots has proven its effectiveness by reducing crime incidence rates and emergency calls. Spatial and Space-Time Analysis is available for detection of crime hot areas and hot spots in urban spaces.

The following graph shows the temporal pattern of carjacking and car robbery in 2009. Carjacking involving some kind of violence tends to concentrate during the evening reaching a critical time at late evening hours, while car robberies without violence show a more uniform distribution with clear concentrations in specific weekdays and daytimes.

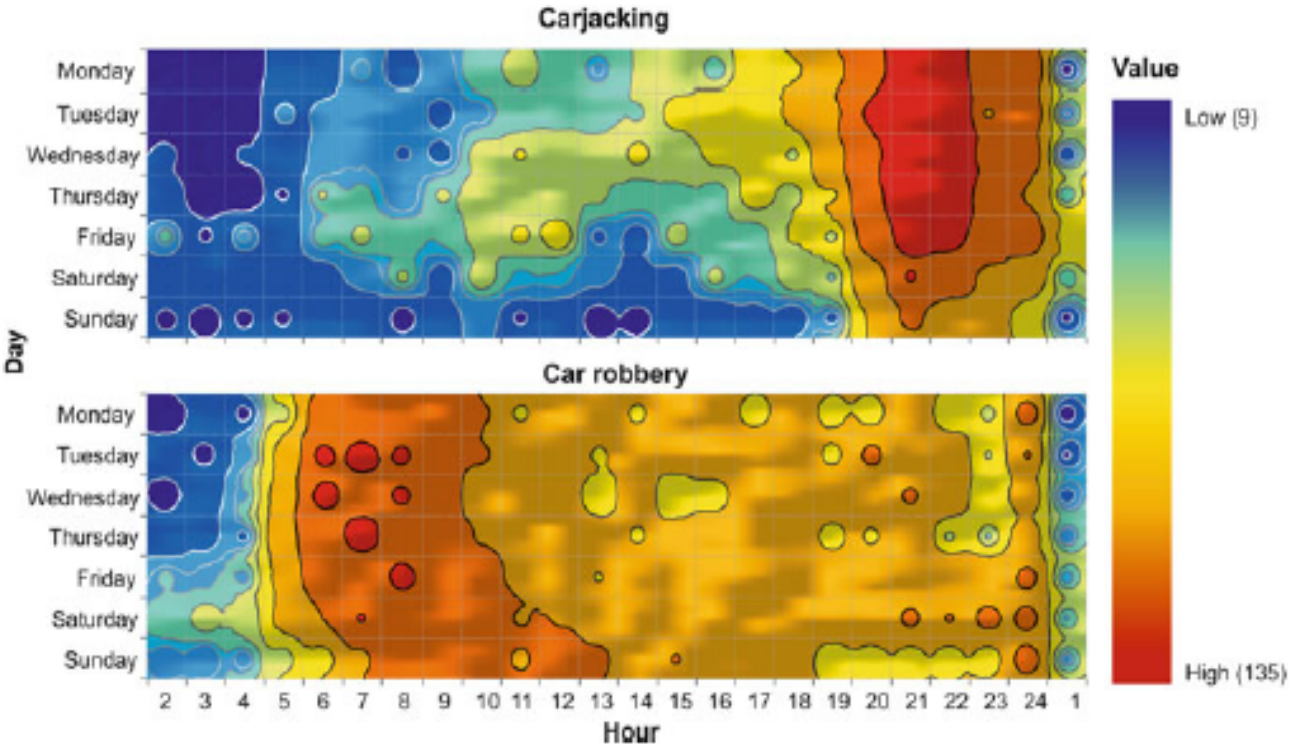
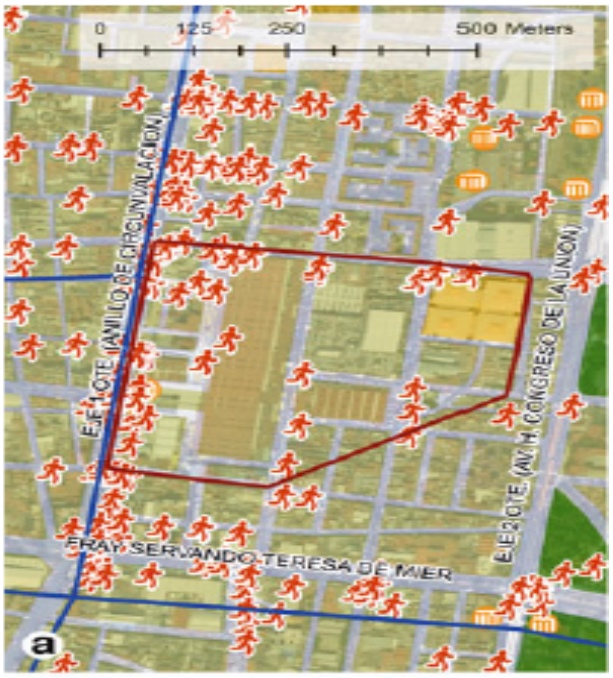


Figure 2: Crime Geointelligence Platform for Mexico City

Source: Authors' elaboration based on data from Mexico City's Justice Attorney, contained in the Mexico City's Public Safety Ministry Geospatial Database.

[5] Crime Modeling and Mapping Using Geospatial Technologies 2013 - chapter 18
www.springer.com/us/book/9789400749962

- Examples of places in Mexico City affected by different crime types:



(a)Larceny theft incidence in Congreso-Mixcalco-Heraldo Area with dense pedestrian flows Due to the location of important markets (Red outlined polygon).

Figure 3: crime density pattern (a)

(b) Robberies in public transportation; the density pattern shows a hot spot in the Glorieta - Insurgentes, a busy city landmark where three modes of public transportation converge (subway, bus and taxis).

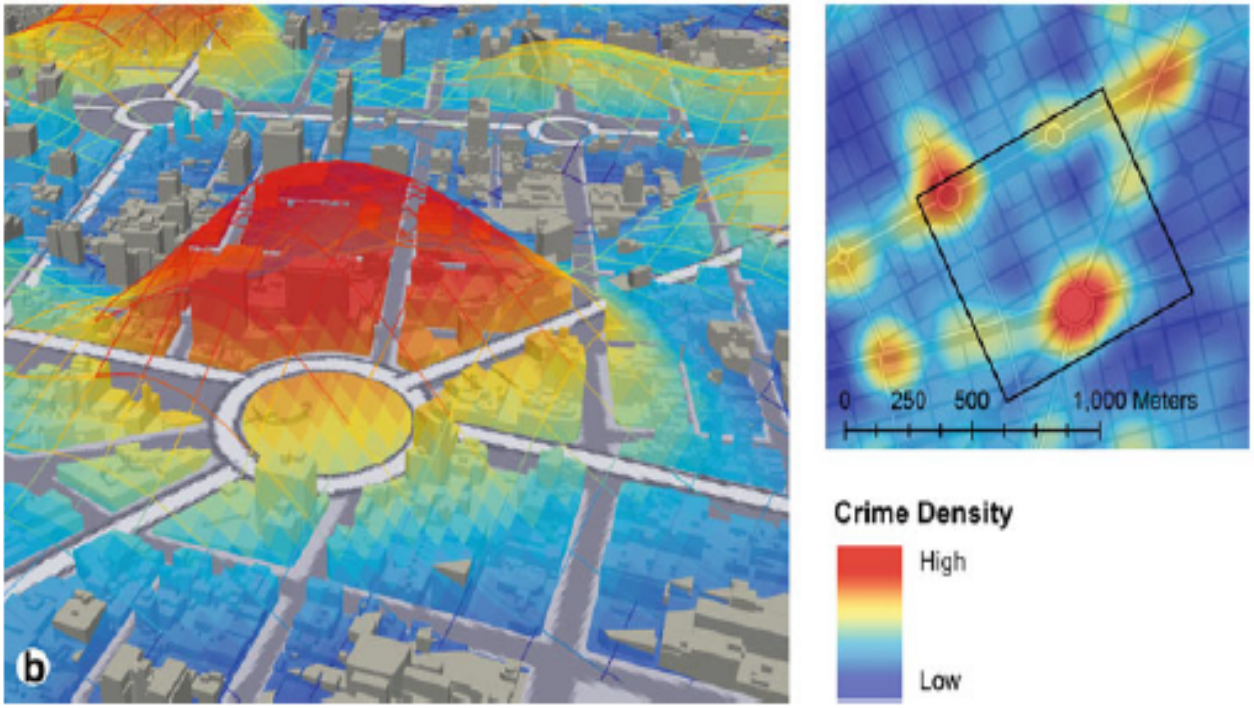


Figure 4: crime density pattern (b)

3.2. Standards

As part of a new series of International Standards being developed for a holistic and integrated approach to sustainable development and resilience, ISO37120 defines a set of standardized indicators that provides a uniform approach to what is measured, and how that measurement is to be undertaken. As a list, it does not provide a value judgement, or threshold or a target numerical value for the indicators. These indicators can be used to track and monitor the progress of city performance. The indicators and associated test methods in this International Standard have been developed in order to help cities:

- Measure performance management of city services and quality of life over time
- Learn from one another by allowing comparison across a wide range of performance measures
- Share best practices [6]

3.3. Ontologies

Ontologies provide a formal approach, using logic, to define concepts (i.e., entities/classes, properties and values). Ontologies are used to represent concepts that span domains of applications, such as time, activities and events, and concepts specific to a domain such as manufacturing, finance, and medicine. Description logic and first order logic are the two most often used logics for representing concepts. Description logic is the basis of the OWL language that is the dominant language for representing ontologies on the semantic web. In this section we review a number of domain independent and domain specific ontologies of relevance to public safety.

SUMO

SUMO (Niles & Pierce, 2001) is an upper level ontology that contains a broad set of concepts[7], including classes pertinent to our competency questions. There are number of SUMO concepts that we have imported into the GCI Public Safety Ontology, such as 'internal change' and 'intentional process' (Figure 7). Also 'pay check 'and 'member status' have been applied as depicted in Figure 9.

DBpedia

The DBpedia Ontology[8] is a shallow, cross-domain ontology, which has been manually created based on the most commonly used infoboxes within Wikipedia. The ontology currently covers 685 classes that form a subsumption hierarchy and are described by 2,795 different properties. The DBpedia Mappings Wiki enables the interested public to contribute to the definition of DBpedia and helps communities to create new mappings or update the old ones. The DBpedia Mappings Wiki, besides the Infobox mappings, can edit the DBpedia ontology. Infobox displays an article's most relevant facts as a table of attribute-value pairs on the top right-hand side of the Wikipedia page.

Criminal Class	**Murderer Class**
Super Class: Person	Super Class: Criminal
Properties of Criminal:(some of them) : Achievement – Domain: Person, Range: owl -Thing Activity – Domain: Person, Range: owl –Thing Birth Sign – Domain: Person, Range: owl –Thing blood type– Domain: Person, Range: owl –Thing victim– Domain: Person, Range: xsd:string	Properties of Murderer: kindOfCriminal - Domain: Criminal, Range: xsd:string kindOfCriminalAction - Domain: Criminal, Range: xsd:string

[6] https://www.iso.org/obp/ui/#iso:std:iso:37120:ed-1:v1:en

[7] http://www.adampease.org/OP/

[8] http://mappings.dbpedia.org/server/ontology/classes/

Schema.org

Schema.org [9] is a collaborative, community activity with a mission to create, maintain, and promote schemas (i.e., classes and properties) for structured data on the Internet. Schema.org vocabulary can be used with many different encodings, including RDFa, Microdata and JSON-LD. These vocabularies cover entities, relationships between entities and actions, and can easily be extended through a well-documented extension model. Over 10 million sites use Schema.org to markup their web pages and email messages. Many applications from Google, Microsoft, Pinterest, Yandex and others already use these vocabularies to power rich, extensible experiences. Some of classes from Schema.org such as sc: City or sc: Person are imported into the GCI Public Safety Ontology.

iContact (International Contact Ontology)

The main purpose of iContact ontology [10] is to represent international contact information such as address information that is consistent with addresses found in the UK, India, etc. and the GCI Public Safety ontology 'address' concepts from iContact.

Global City Indicator Ontology

The Global City Indicator Ontology project is the first step of the PolisGnosis Project (Fox, 2017), whose goal is to construct an intelligent agent that can analyze open data to determine the root cause of a city's performance. Building on the ISO 37120 standard, the PolisGnosis agent takes as input an indicator definition, the value published by a city, and the data used to derive the value. In order to achieve this, the indicator definition, the value and the supporting data needs to be represented using a standard vocabulary/ontology. Hence the first step of the PolisGnosis project is to construct a set of ontologies for representing both indicator definitions and the data used to derive a city's indicator values.

The first ontology developed by the PolisGnosis project was a Foundation Ontology [11] that provides a set of concepts required by almost all indicators in the ISO 37120 standard (Fox, 2013):

- 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)

The GCI Foundation ontology builds on these concepts by introducing a set of design patterns for representing the structure that underlies most indicators (Fox, 2015), such as ratios of population counts.

ISO 37120 is divided into seventeen themes, including Education, Finance, Shelter and Public Safety. For many of the themes, the PolisGnosis project has developed a theme specific ontology to represent the theme's common sense knowledge. For example, Fox

[9] https://schema.org/

[10] http://ontology.eil.utoronto.ca/icontact.html

[11] 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

(2014) defines Education ontology and shows how the ISO 37120 Education theme indicators are defined and city supporting data represented using the Education ontology. Other theme related ontologies have or are being developed for Innovation (Forde & Fox, 2015), Shelter (Wang & Fox 2015), Finance (Wang & Fox, 2016a; 2016b), Energy (Komisar & Fox, 2017), Environment (Dahleh & Fox, 2016), Health (Fiode & Fox, 2017), and Fire & Emergency (Rauch & Fox, 2017). The GCI Public Safety ontology is another theme specific ontology that builds on the GCI Foundation Ontology (Fox, 2013).

Figure 5, depicts the organization of files used to define the ISO37120 ontology we are developing. The internationalized resource identifier (IRI) for each ISO 37120 indicators is contained in the ISO37120 module at the highest level. For example, the IRI for 'Number of homicides per 100K population' indicator is:
"http://ontology.eil.utoronto.ca/ISO37120.owl#14.2".

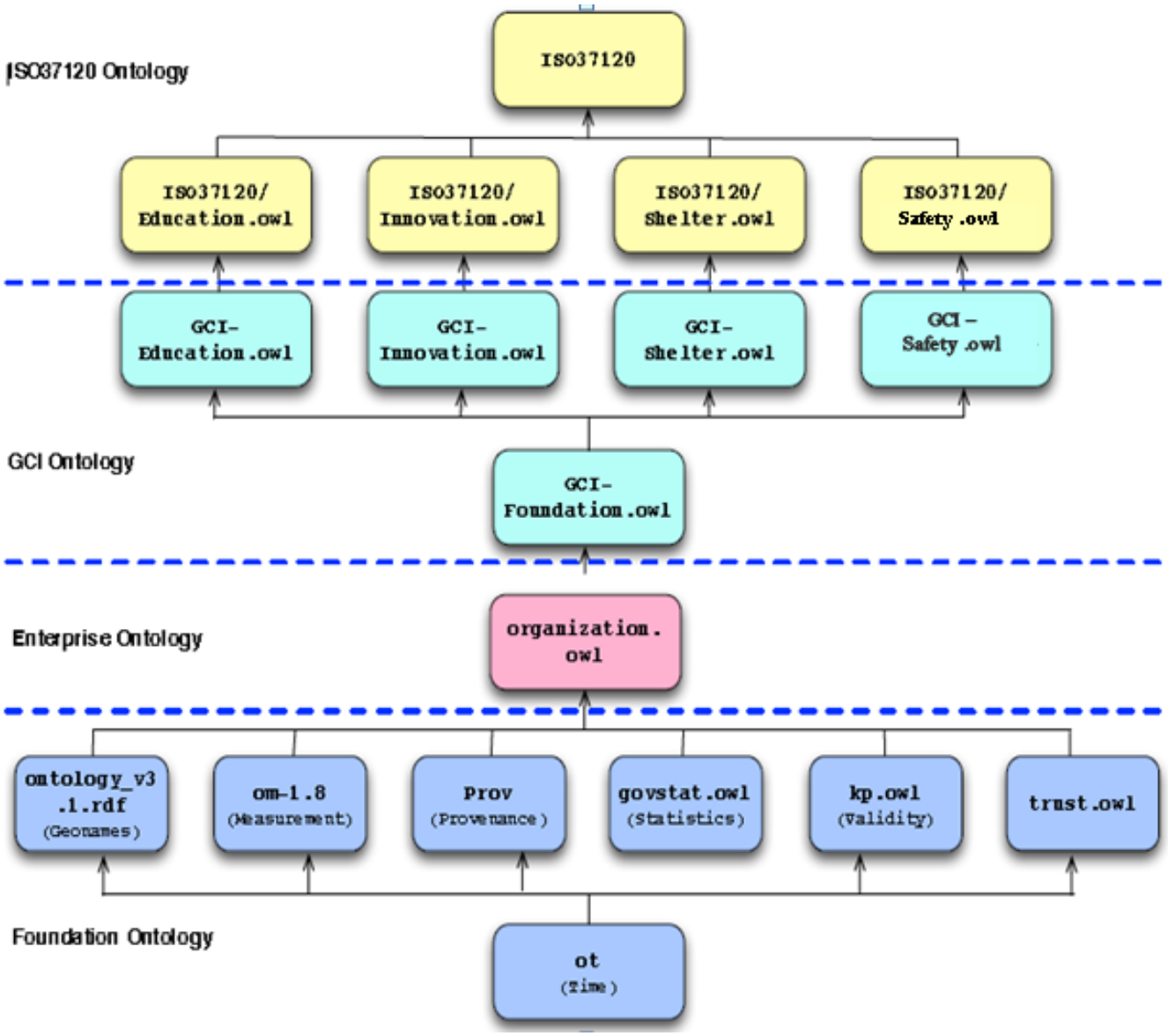


Figure 5: ISO 37120 Ontology Modules

4. GCI Public Safety Ontology

The GCI Public Safety ontology provides a representation of Public Safety related concepts necessary to represent the Public Safety theme indicators definitions and the supporting data used to derive a city's indicators' values. Their design is driven by the ISO37120 Public Safety indicators' competency questions. This section defines the GCI Public Safety ontology (prefix "gcip") implemented at:
http://ontology.eil.utoronto.ca/GCI/PublicSafety/GCI-PublicSafety.owl.

4.1. Homicide, Crime and Victim Classes

The first category of classes defined in this ontology covers the concepts of homicides, crime and victims. The design of these classes is guided by the following competency questions from section 3:

1. (F) What types of property crimes does the city have?
2. (F) How many type Y crimes against privately owned properties?
3. (F) What types of violent crimes was a person involved in the same year?
4. (D) If a person involved in more than one violent crime, which one was more severe?
5. (F) How many Victims were due to manslaughter?
6. (F) How many Victims were due to traffic accident?
7. (F) What types of violent crime does the city report?
8. (D) What's the order of violent crimes severity?
9. (D) Which violent crime is most severe?
10. (F) How many infanticides were reported?
11. (F) How many manslaughters did city have?
12. (F) How many traffic accidents did the city have?

In OpenCYC, Crime and Homicide classes do not exist however in SUMO; there is a taxonomy that defines Types of Criminal Offenses[12]. Criminal Homicides are separated into two categories:

a) **Murder and Non-negligent Manslaughter:** defined as the willful (non-negligent) killing of one human being by another.
b) **Negligent Manslaughter:** defined as any death caused by injuries received in a fight, argument, quarrel, assault or commission of a crime and does not classify as Murder and Non-negligent Manslaughter. Suicides, Fetal deaths, Traffic fatalities, and Accidental deaths are some of examples for this type of Criminal homicide.

Figure 6 depicts a Murder as a subclass of a Killing, which is an internal change, and a Criminal Action, which is an intentional process:

[12] https://www2.ed.gov/campus-crime/HTML/pdf/cs_murder.pdf

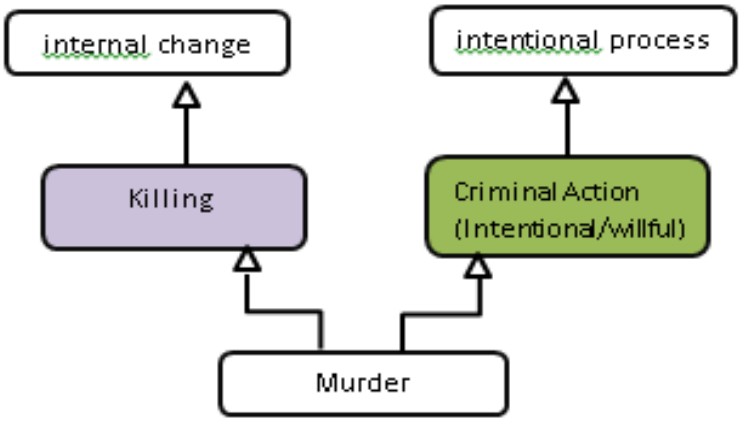


Figure 6: SUMO taxonomy – Intentional and Non-Intentional

The following (Figure 7) depicts the complete SUMO taxonomy for Criminal Action and Damaging classes:

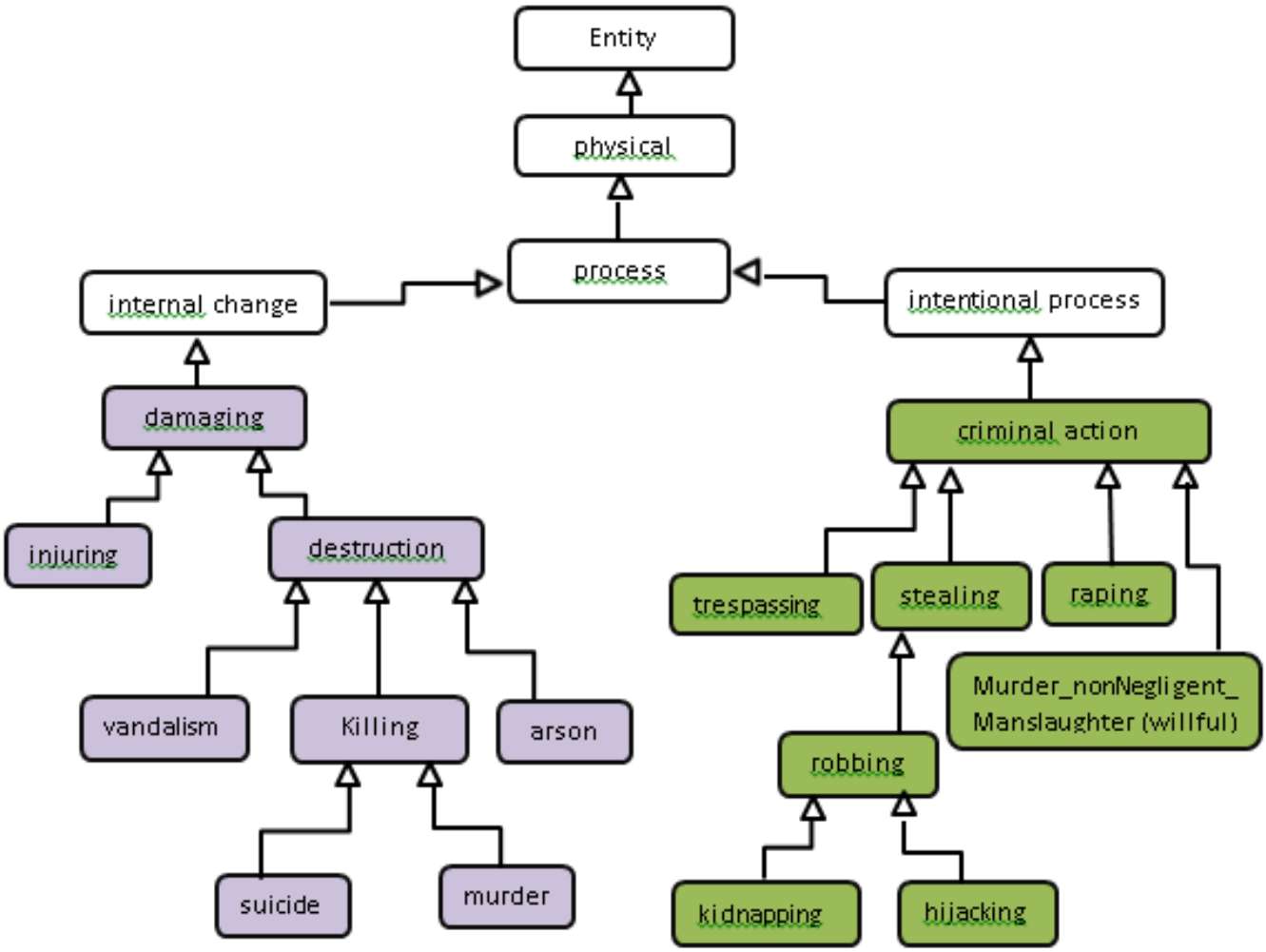


Figure 7: SUMO taxonomy – criminal action and damaging subclasses

In the GCI Public Safety Ontology, the following Classes (pink color) are added to the above SUMO taxonomy as follows:

- Traffic accident subclass of Injuring which is subclass of Damaging – Traffic accident causing death should be excluded in the total count of number of Homicide per 100000 population
- Motor Vehicle Theft subclass of vandalism which is subclass of Destruction Class
- Larceny Theft subclass of Vandalism which is subclass of Destruction Class
- Manslaughter (non-intentional) subclass of Murder which is subclass Killing Class
- Aggravated assault subclass of Criminal Action which is subclass of Intentional Process Class
- Infanticide subclass of Murder-non-Negligent-Manslaughter which is subclass of Criminal Action
- Burglary subclass of Trespassing and stealing which are subclass of Criminal Action Class

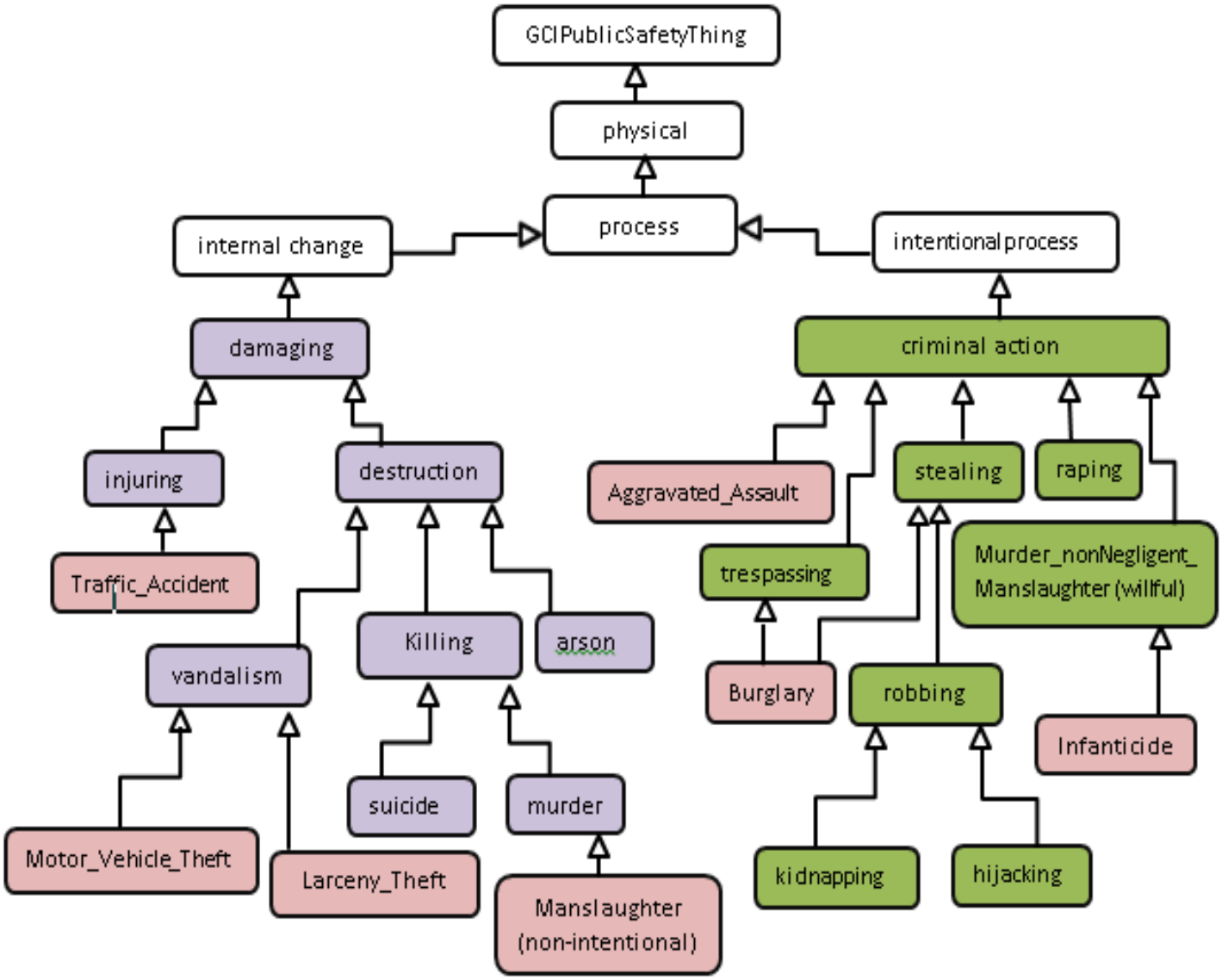


Figure 8: GCI-PublicSafety taxonomy – criminal action and damaging extended subclasses

The following defines ‘Victim’ as a ‘Person’, and supports answers to 14.2, 14.3 and 14.5 competency questions.

- If a ‘Person’ is ‘Victim’ of ‘Homicide’, then one type of ‘Homicide’ instance such as ‘infanticide’, ‘manslaughter’, ‘Traffic accident’ or ‘Suicides’ that is created or imported from SUMO, would be linked to the ‘Victim’ through ‘victimOf’ property.
- If a ‘person’ is ‘Victim’ of ‘Violent_Crime’, then one type of ‘Violent_Crime’ instance such as ‘murder and non-negligent manslaughter’, ‘rape’, ‘robbery’ or ‘aggravated assault’ that is created or imported from SUMO, would be linked to the ‘Victim’ through ‘victimOf’ property.
- If a ‘person’ is ‘Victim’ of ‘Property_Crime, then one type of ‘Property_Crime’ instance such as ‘burglary’, ’larceny-theft’, ’motor vehicle theft’ or ‘arson’ that is created or imported from SUMO, would be linked to the ‘Victim’ through ‘victimOf’ property, also the ownership that the default value in this case is (privately_owned) defined to support property ownership competency question.

Class	Property	Value Restriction
Victim	owl:subClassOf	sc:Person
	victimOf	only (Homicide or Violent_Crime or Property_Crime)
	org: has_Ownership	only org:Ownership
	gci: for_city	exactly 1 sc: City
	ot: hasDateTimeDescription	exactly 1 ot:DateTimeDescription

The following defines ‘Homicide’ Class to cover the different types of Homicides for indicator 14.2.

Class	Property	Value Restriction
Homicide	owl:subClassOf	sumo:CriminalAction
	owl:subClassOf	sumo:Killing

The following defines the ‘Property_Crime’ class to cover the different types of ‘Property_Crime’ for indicator 14.3.

Class	Property	Value Restriction
Property_Crime	owl:subClassOf	sumo:CriminalAction
	owl:subClassOf	sumo:damaging

The following defines ‘Violent_Crime’ and ‘Violent_CrimeSeverity’ classes that cover indicator 14.5. ‘Violent_CrimeSeverity’ class defines severity of violent crime through the ‘has_Severity’ property.

Class	Property	Value Restriction
Violent_Crime	owl:subClassOf	sumo:CriminalAction
	has_Severity	exactly 1 rdfs: Literal

The following defines the classes created (Figure 8 – pink color classes) or imported from SUMO (Figure 8 – except pink color classes) for the different types of crimes inflicted on a Victim. As mentioned earlier in description of 'Victim' class, the instance of following classes are related to the 'Victim' through following properties:
'has_Homicide', 'has_Violent_Crime', 'has_Property_Crime'

Class	Property	Value Restriction
sumo:process	owl:subClassOf	sumo:physical
	has_Category	exactly 1 rdfs: Literal
sumo:IntentionalProcess	owl:subClassOf	sumo:process
sumo:InternalChange	owl:subClassOf	sumo:process
sumo:CriminalAction	owl:subClassOf	sumo:InternalChange
sumo:damaging	owl:subClassOf	sumo:InternalChange
sumo: Murder_nonNegligent_Manslaughter	owl:subClassOf	sumo:Killing
infanticide	owl:subClassOf	sumo:murder
sumo:destruction	owl:subClassOf	sumo:damaging
sumo:injuring	owl:subClassOf	sumo:damaging
Traffic_Accident	owl:subClassOf	sumo:injuring
sumo:Killing	owl:subClassOf	sumo:destruction
sumo:murder	owl:subClassOf	sumo:Killing
Manslaughter	owl:subClassOf	sumo:murder
sumo:suicide	owl:subClassOf	sumo:Killing
sumo:trespassing	owl:subClassOf	sumo:CriminalAction
Burglary	owl:subClassOf	sumo:trespassing
sumo:arson	owl:subClassOf	sumo:destruction
sumo:vandalism	owl:subClassOf	sumo:destruction
Larceny_Theft	owl:subClassOf	sumo:vandalism
Motor_Vehicle_Theft	owl:subClassOf	sumo:vandalism
Aggravated_Assault	owl:subClassOf	sumo:CriminalAction
sumo:raping	owl:subClassOf	sumo:CriminalAction

sumo:stealing	owl:subClassOf	sumo:CriminalAction
sumo:robbing	owl:subClassOf	sumo:stealing
sumo:hijacking	owl:subClassOf	sumo:robbing
sumo:kidnapping	owl:subClassOf	sumo:robbing

4.2. Police Officer Classes

The description of Sworn Police Officer is a core concept of the Public Safety indicators. The following competency questions focus on Sworn Police Officer information.

1. (F) What types of police officers does a city have?
2. (F) Who is the police officer's employer?
3. (F) What is the employment type of police officers?
4. (F) Is the police officer's employer owned by Government?
5. (D) Does the police officer work in an official capacity?
6. (D) Does police officer have full arrest power?
7. (D) Does the police officer carry identification at work?
8. (D) Is the police officer paid from governmental funds?
9. (D) How many police officers does a city have?

In the GCI Public Safety Ontology, the following Classes (pink color) are added to existing classes as follows:

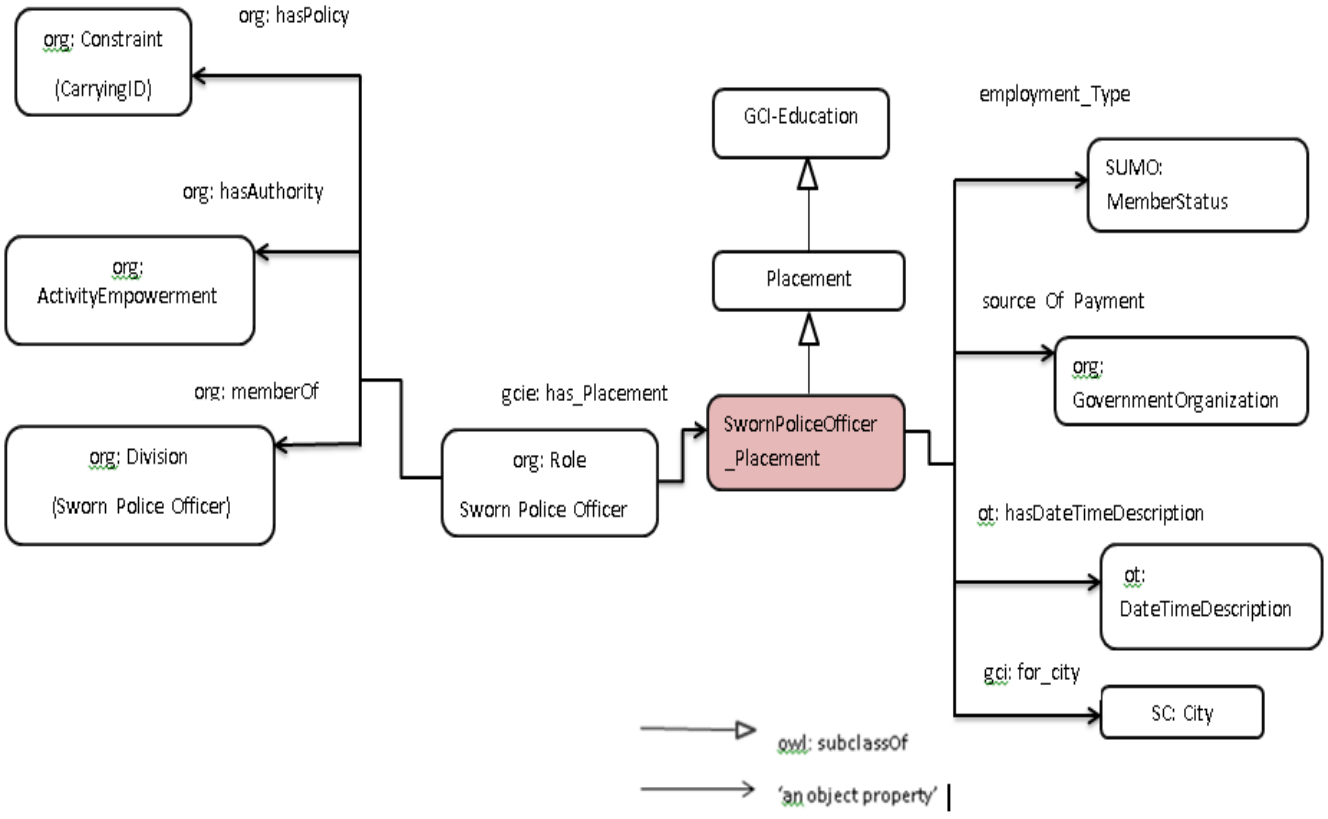


Figure 9: Police Officer taxonomy

As it's shown in Figure 9 and following table, 'SwornPoliceOfficer' is an organization role. 'SwornPoliceOfficer' has at least one 'SwornPoliceOfficer_Placement' which is a subclass of GCIE: 'Placement' from Education ontology, and provides the details of where 'SwornPoliceOfficer' works. The following classes and properties are defined to answer 14.1 indicator competency questions:

Class	**Property**	**Value Restriction**
SwornPoliceOfficer	owl:subClassOf	only org:Role
	org:hasAuthority	min 1 FullArrestEmpowerment
	org:hasPolicy	exactly 1 CarryingID
	org:memberOf	only SwornPoliceOfficer Division
	gcie: has_Placement	exactly 1 SwornPoliceOfficer_Placement
FullArrestEmpowerment	owl:subClassOf	org:ActivityEmpowerment
CarryingID	owl:subClassOf	org:Constraint
SwornPoliceOfficer_Placement	owl:subClassOf	gcie: Placement
	employment_Type	exactly 1 sumo:MemberStatus
	source_Of_Payment	exactly 1 org:GovernmentOrganization
	ot: hasDateTimeDescription	exactly 1 ot: DateTimeDescription
	gci: for_city	exactly 1 sc:City
SwornPoliceOfficerDivision	owl:subClassOf	only org:GovernmentOrganization
	owl:subClassOf	only org:Division
	org: has_Ownership	value org:government_owned
	org:hasName	exactly 1 xsd: string

- The 'SwornPoliceOfficer' subclass of 'org: Role' defined as a role for 'org: OrganizationAgent' through 'org: Plays' property.
- The 'SwornPoliceOfficerDivision' subclass of 'org: Division' defined as a division for sworn police officer through 'org: memberOf' property.
- The 'org: government_owned' instance of 'org: Ownership' used as a value for 'SwornPoliceOfficerDivision' ownership through 'org: has_Ownership' property.
- The instance of 'CarryingID' subclass of 'org: Constraint' defined for carry identification competency question through 'org: hasPolicy' role property.
- The 'SwornPoliceOfficer_Placement' answers 14.1 competency questions including where 'SwornPoliceOfficer' worked, employment type, source of payment, census year and city as follows:
    - 'FullTime' instance of 'sumo: MemberStatus' subclass of 'sumo: relationalAttribute' defined as a value for 'employment_Type' property.
    - The instance of 'Government Organization' subclass of Organization ontology used as a value for 'source_of_payment' property.

- The 'ot: DateTimeDescription' from time ontology used to answer starting and ending census year competency questions through 'ot: hasBeginning and 'ot: hasEnd'.
- The instance of 'sc: City' used as a value for 'gci: for_city' property.

- The 'FullArrestEmpowerment' subclass of 'org:ActivityEmpowerment' defined to answer arrest empowerment competency question through 'org:hasAuthority' property

4.3. Distress call Classes

The definition of 'EmergencyResponse', addresses the following Distress call competency questions:

1. (F) What types of distress calls does city received?
2. (F) How long did it take from initial distress call to the on-site arrival of police department for distress call Y?
3. (D) What's total number of hours and minutes for distress call Y in the same year?
4. (F) What is the total number of distress call Y police department responded in the same year?

EmergencyResponse defines the response activity of any emergency organization, including the police. It specifies the duration of the event, minutes to respond, call time, arrival time, type of response and action. minutes_To_Respond_Var specifies the variable in the emergency response population that will be summed over for 14.4.

Class	Property	Value Restriction
EmergencyResponse	owl:subClassOf	org:Activity
	ot: hasDateTimeDescription	exactly 1 ot:DateTimeDescription
	minutes_to_respond	exactly 1 Response_Quantity
	arrivalDateTime	exactly 1 ot:DateTimeInterval
	distressCallDateTime	exactly 1 ot:DateTimeInterval
	gci:for_city	exactly 1 sc: City
	has_EmergencyResponse_Type	exactly 1 rdfs:Literal
	response_status	exactly 1 org:Action
Response_Quantity	owl:subClassOf	om: Quantity
	om:unit_of_measure	value om:minute-time
minutes_To_Respond_Var	rdf:Type	gs:Variable
	gs:has_name	"minutes_to_respond"
PoliceResponse	owl:subClassOf	org:Action

5. Public Safety Indicator Design Pattern

In this section we present a design pattern that underlies all of the Public Safety indicators. The basic structure of a ratio indicator has already been defined in the GCI Foundation ontology (Fox, 2013), and upon which the Public Safety indicators are based.

The OM measurement ontology (Rijgersberg et al., 2011) is the core of Foundation ontology. The purpose of 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, i.e., the actual measures are of the same type; the population size of homicides and population size of the city, are of the same scale (i.e., thousands vs millions).

Figure 10 depicts the basic classes of the OM ontology used to represent an indicator value. 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, homicide population Ratio is a subclass of 'Quantity' that has a value that is a subclass of 'Measure' whose units are a 'Population ratio unit' that is a subclass of 'Unit of Measure'. The actual value measured is a property of the 'Measure' subclass 'homicide population ratio measure'.

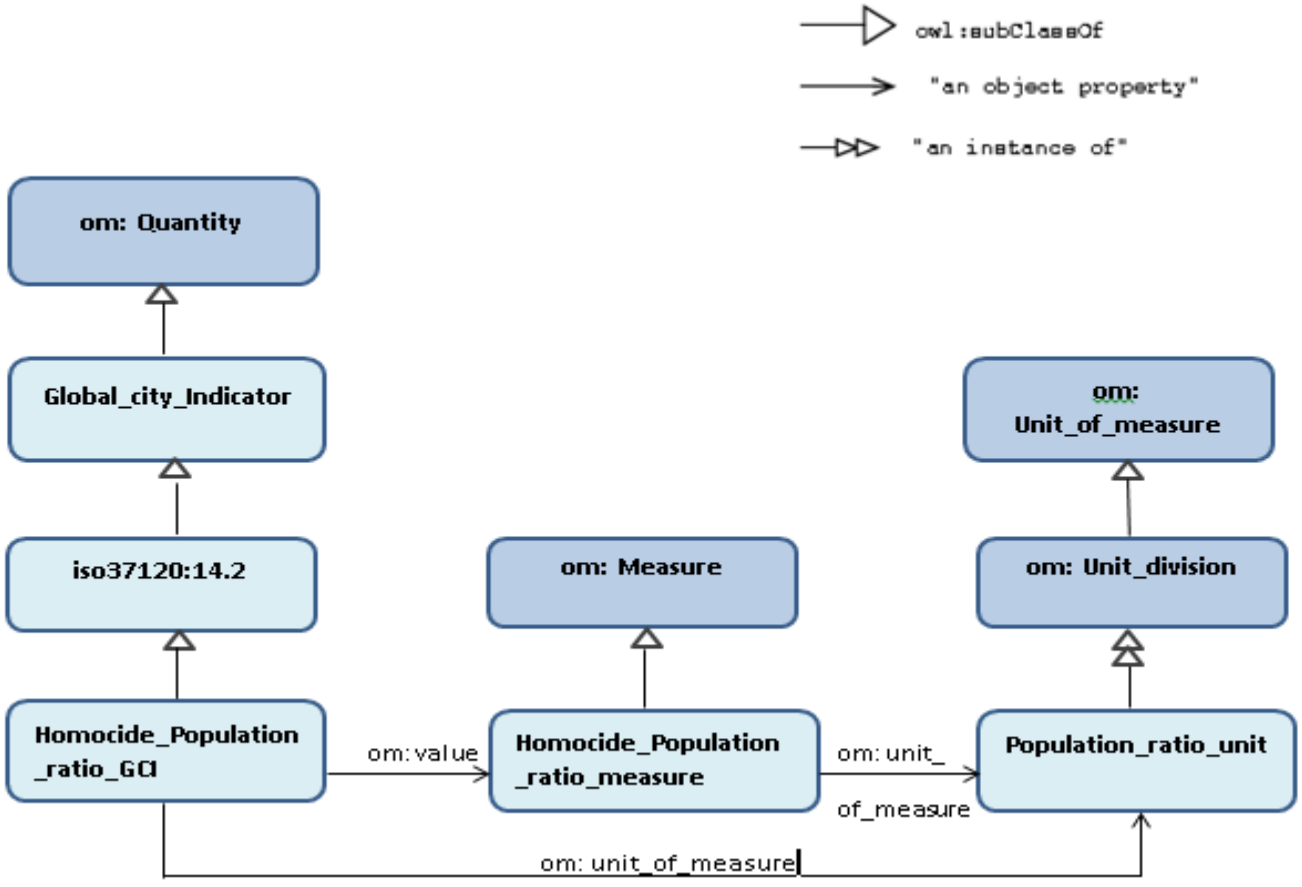


Figure 10: Measurement Ontology

The ‘Homicide Population ratio’ indicator is based on a measure of the number of Homicides that satisfy the indicator’s definition for a city. This measure can be viewed as a statistical measure in that the population we want to perform a measurement of, is determined by the definition of ‘Homicide Resident’. In order to define what portion of a city we are determining the size of, the GCI Foundation ontology extended the GovStat ontology with the property ‘located_in’ that identifies the ‘City’ that the Population is drawn from, and the property ‘defined_by’, that identifies the class that all members of the Population are included based on the indicator definition and in the following figure 11, we define a pattern for the size of a city's population, which is used as the denominator for most Public Safety indicators:

The GCI Foundation ontology provides a standard representation for the population of a city measured in 100,000 people: 100K_Population_Size. It will be used as the denominator for many of the indicators in section 6.

Public Safety indicators are ratios. A ratio indicator, Figure 11, has a unit of measure defined to be a ‘Population Ratio Unit’ (except ‘Police Response Time’ indicator which has ‘Temporal Ratio Unit’) and for both specifies that the indicator is the ratio of the sizes (cardinality) of two populations. A ‘Population Size’ is defined as the cardinality of a ‘Population’, and ‘Population’ is specified by a ‘City’ that the population is located in, and by a description of a ‘Person’ within the ‘City’. For example, the ‘Person’ could be a ‘Victim’. Hence the ‘Population Size’ could be the number of ‘Homicide Resident’ in a particular ‘City’. The indicators definition has been structured as follows:

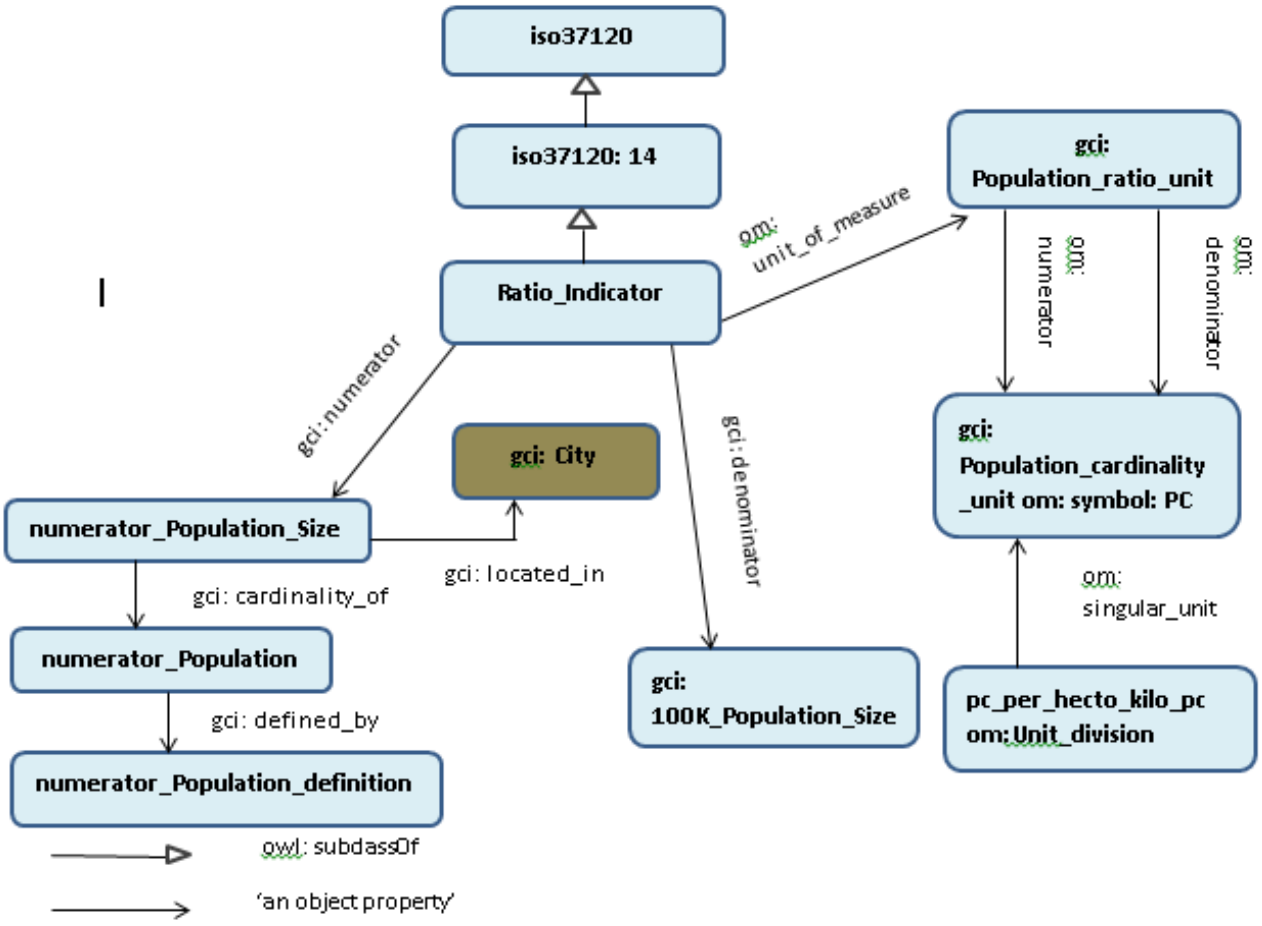


Figure 11: Foundation Ontology Ratio definition

6. ISO37120 Public Safety Indicators Ontology

In the following, the representation of the five ISO 37120 Public Safety indicators will be described. The OWL representation of the Public Safety indicator definitions can be found at: http://ontology.eil.utoronto.ca/GCI/ISO37120/PublicSafety.owl.

6.1. Number of police officers per 100 000 population (14.1)

The following is a partial depiction of indicator 14.1:

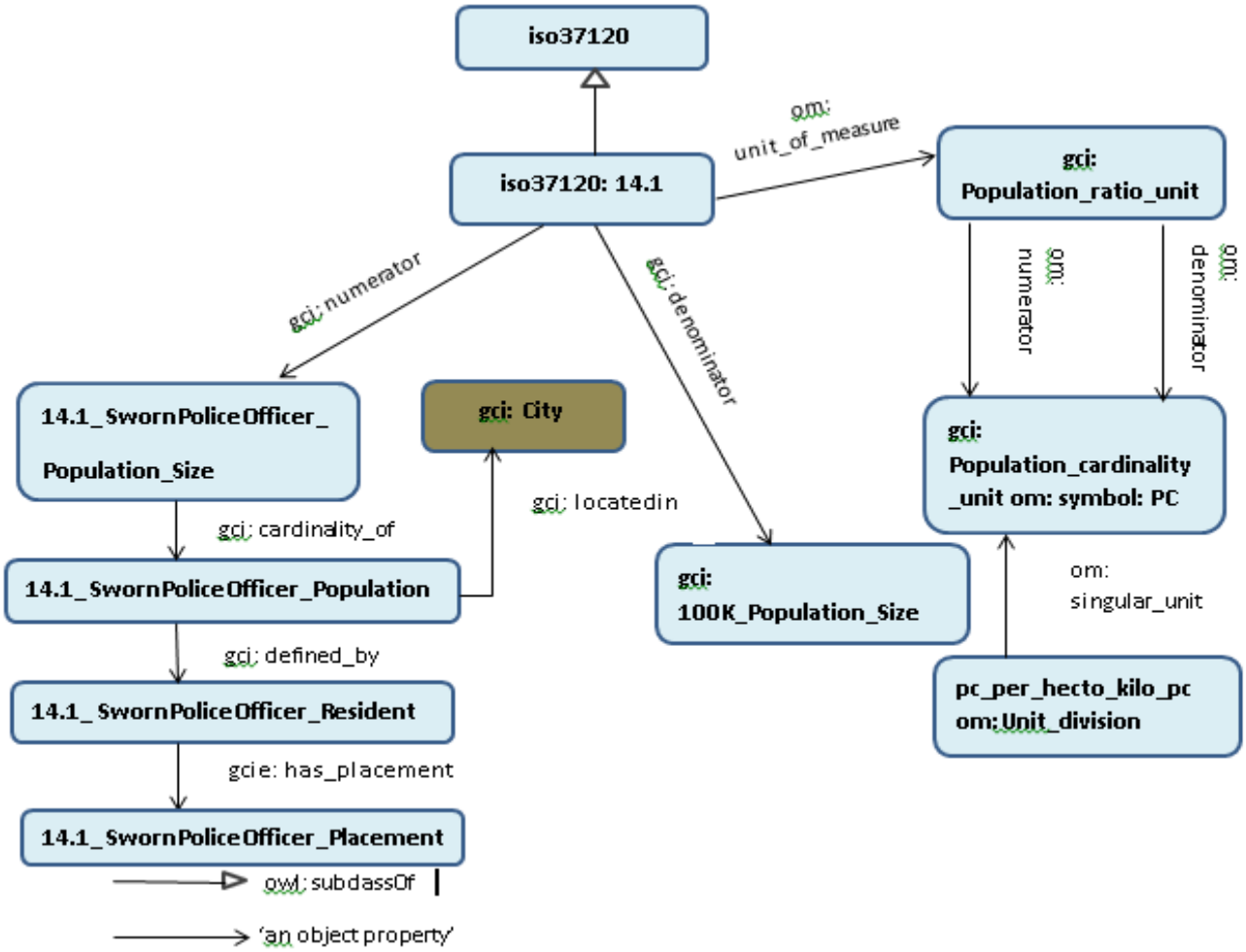


Figure 12: 14.1 Number of police officers per 100 000 population Ontology

Class	Property	Value Restriction
iso37120:14.1	gci:numerator	exactly 1 14.1_SwornPoliceOfficer Population Size
	gci:denominator	exactly 1 gci:100K_Population_Size
	om:unit_of_measure	value pc_per_hecto_kilo_pc
14.1_SwornPoliceOfficer _Resident	owl:subClassOf	org:OrganizationAgent

	gcie:has_Placement	min 1 SwornPoliceOfficer_Placement
14.1_SwornPoliceOfficer_Placement	owl:subClassOf	SwornPoliceOfficer_Placement
	employment_Type	exactly 1 MemberStatus
	source_of_payment	exactly 1 org:GovernmentOrganization
	ot: hasDateTimeDescription	exactly 1 DateTimeDescription
	gci:for_city	exactly 1 sc: City
14.1_SwornPoliceOfficer Population	owl:subClassOf	gs: Population
	gci: defined_by	exactly 1 14.1_SwornPoliceOfficer Resident
	gci: located_in	exactly 1 sc: City
14.1_SwornPoliceOfficer Population Size	owl:subClassOf	gci:PopulationSize
	gci: cardinality_of	exactly 1 14.1_SwornPoliceOfficer Population

We specialize the design pattern using the 'SwornPolicOfficer_Resident' to define the population being measured. The 'SowrnPoliceOfficer_Placement' meets the requirements through 'has_Placement' property for 'SwornPolicOfficer_Resident' and the details of the pattern explained in Figure 9 and its following table.

6.2. Number of homicides per 100 000 population (14.2)

The basic structure of the ratio is similar to '14.1' and the partial definition of ISO37120:14.2 will be explained in the following however some of the subClassOf links have been excluded but can be found in the OWL definition file.

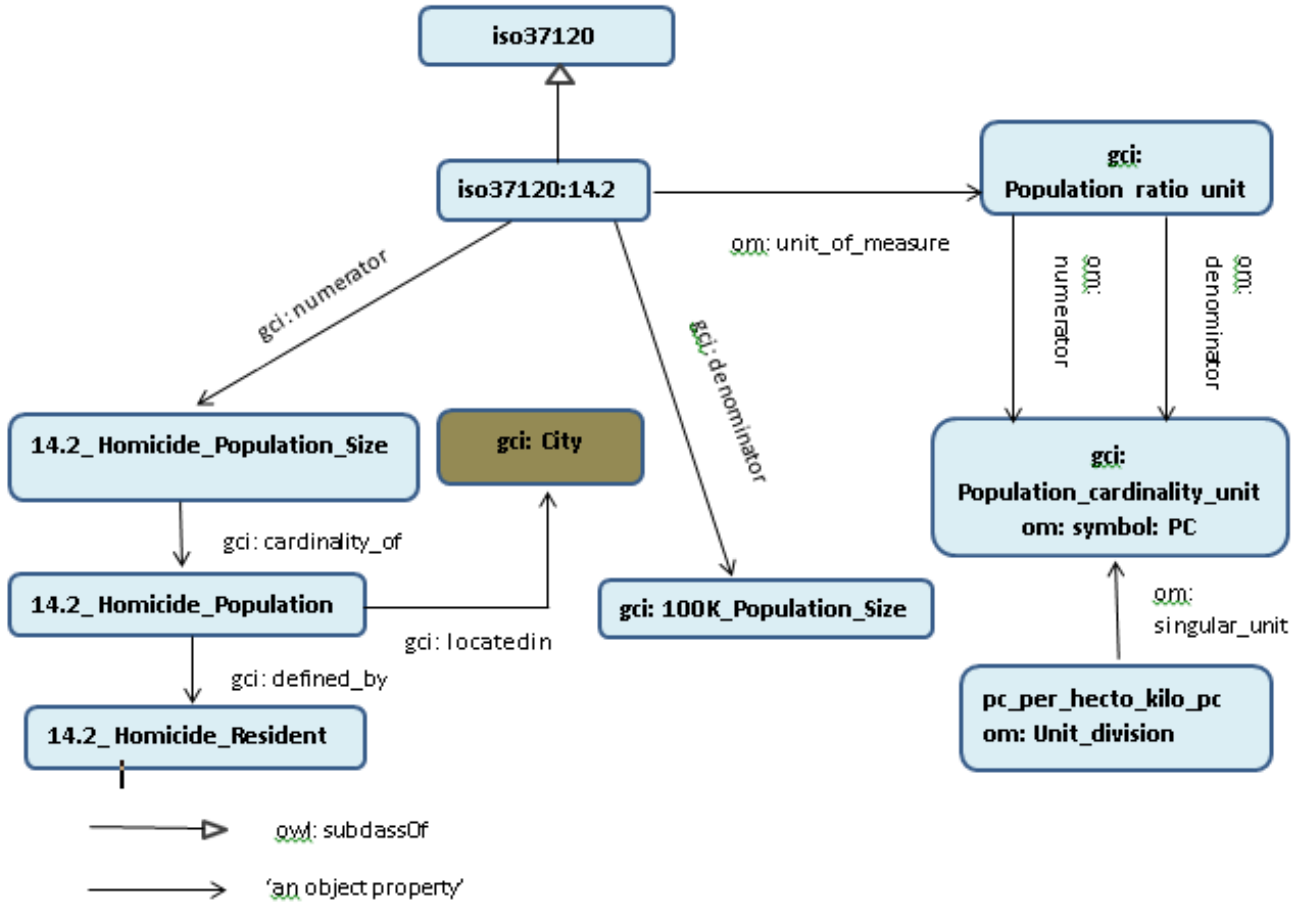


Figure 13: 14.2 Number of homicides per 100 000 population Ontology

What is unique to this indicator is the definition of the people making up the numerator population, namely 'Homicide Resident' with the following classes:

- 'internal change' and 'intentional process' from SUMO ontology to meet 'has_Homicide_Type' requirements including non-intentional (internal change) and willful (intentional process) Homicide types.
- 'infanticide' and 'Manslaughter' from SUMO ontology to meet 'has_ReasonForDeath'

Class	Property	Value Restriction
iso37120:14.2	gci:numerator	exactly 1 14.2_Homicide_Population_Size
	gci:denominator	exactly 1 gci:100K_Population_Size
	om:unit_of_measure	value pc_per_hecto_kilo_pc
14.2_Homicide_Population _Size	owl:subClassOf	gci:Population_Size
	gci: cardinality_of	exactly 1 14.2_Homicide_Population
	om:unit_of_measure	value gci:pc
14.2_Homicide Population	owl:subClassOf	gs:Population
	gci: defined_by	exactly 1 14.2_Homicide_Resident
	gci:located_in	exactly 1 sc:City
14.2_Homicide_Resident	owl:subClassOf	Victim

	has_Homicide_Type	exactly 1 (sumo:intentionalProcess or sumo:internalChange')
	has_ReasonForDeath	exactly 1 sumo:murder

The actual value measured is the cardinality of the population of '14.2 Homicide Population' and '14.2 City Population Size' has its unit of measure constrained to hecto_kilo_pc (100,000) in order to assure that when we take the ratio of number of 'Homicide' in the city to Total population of the city, it is to 100,000 of population.

6.3. Crimes against property per 100 000 population (14.3)

The complete definition of ISO37120:14.3 can be found in the OWL definition file and 14.3 has the same structure as 14.2 however different in the definition of the people making up the populations (Linked using defined_by), namely 'Property_Crime Resident' with the following classes:

- 'sumo: arson' from SUMO ontology to meet 'internal change' Crimes against property requirements for has_ReasonForPropertyCrime'
- 'sumo: Burglary' from SUMO ontology to meet 'intentional or willful' Crimes against property requirements for has_ReasonForPropertyCrime'
- 'sumo: Larceny_Theft' from SUMO ontology to meet 'internal change' Crimes against property requirements for has_ReasonForPropertyCrime'
- 'sumo: Motor_Vehicle_Theft' from SUMO ontology to meet 'internal change' Crimes against property requirements for has_ReasonForPropertyCrime'

Class	**Property**	**Value Restriction**
iso37120:14.3	gci:numerator	exactly 1 14.3_Property_Crime_Population_Size
	gci:denominator	exactly 1 gci:100K_Population_Size
	om:unit_of_measure	value occurrence_per_hecto_kilo_pc
14.3_Property_Crime_Population_Size	owl:subClassOf	gci:Population_Size
	gci: cardinality_of	exactly 1 14.3_Property_Crime_Population
14.3_Property_Crime_Population	owl:subClassOf	gs:Population
	gci:defined_by	exactly 1 14.3_Property_Crime_Resident
	gci: located_in	exactly 1 sc:City
14.3_Property_Crime_Resident	owl:subClassOf	Victim
	has_ReasonForProperty Crime	min 1 (sumo:arson or Burglary or Larceny_Theft or Motor_Vehicle_Theft)

The value measured is the cardinality of the population of '14.3 Property_Crime Population' and has its unit of measure constrained to hectokilopc (100,000) in order to assure that when we take the ratio of number of 'Property_Crime' in the city to Total population of the city, it is to 100,000 of population.

The definition of the numerator which depends upon the resident of the city who is '14.3 Property_Crime Resident' as follows:

- '14.3 Property_Crime Resident' is subClassOf 'Victim'
- 'has_ReasonForPropertyCrime' property has at least one of (sumo:arson or Burglary or Larceny_Theft or Motor_Vehicle_Theft) values.

6.4. Response time for police department from initial call (14.4)

Figure 14 below depicts the definition of 14.4.

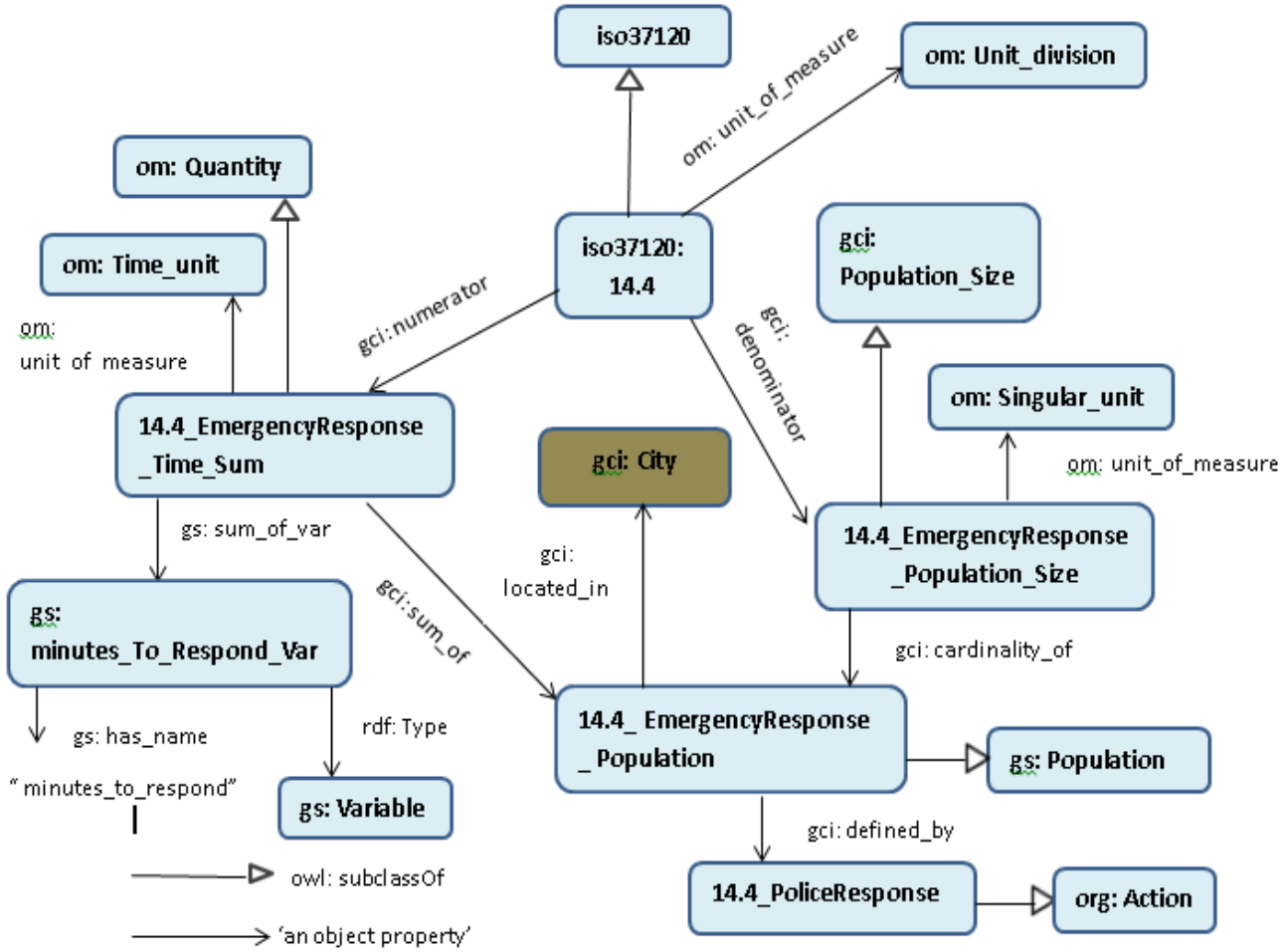


Figure 14: 14.4 Response time for police department from initial call Ontology

Indicator 14.4 is defined as:

Class	Property	Value Restriction
iso37120:14.4	gci:numerator	exactly 1 14.4_EmergencyResponse_Time_Sum
	gci:denominator	exactly 1 14.4_EmergencyResponse_Population_Size
	om:unit_of_measure	value minute_time_per_occurrence

The numerator is '14.4 Emergency Resonse_Time_Sum' which sums over the value of the property 'minutes_to_respond' found in the 'PoliceResponse' individuals that make up the

population 'EmergencyResponse_Population' and is measured in minutes (using the property ‘om: unit_of_measure’ with a value ‘ot:minute-time’):

Class	Property	Value Restriction
14.4_EmergencyResponse_Time_Sum	owl:subClassOf	om: Quantity
	om:unit_of_measure	om:minute_time
	gci: sum_of	exactly 1 14.4_EmergencyResponse_Population
	gs: sum_of_var	exactly 1 minutes_To_Respond_Var
14.4_EmergencyRespons_Population	owl:subClassOf	gs: Population
	gci defined by	exactly 1 PoliceResponse
	gci located_in	exactly 1 sc:City

The denominator is the number of EmergencyResponse activities in the EmergencyResponse Population (defined above) measured as occurrence's

Class	Property	Value Restriction
14.4_EmergencyResponse_Population_Size	owl:subClassOf	gci: ‘Population Size’
	gci:cardinality_of	exactly 1 14.4_EmergencyResponse_Population
	om:unit_of_measure	value gci:occurrence

The following axioms are defined to complete the indicator requirements:

1. ‘distress call date’ has to be on the year of indicator.
2. ‘distress call date and time’ has to be before the ‘arrival date and time’.
3. ‘Emergency Response’ should be on the year of indicator.
4. The city responded to Emergency is the same as city for indicator.

6.5. Violent crime rate per 100 000 population (14.5)

The complete subClassOf links for ISO37120:14.5 can be found in the OWL definition file and the basic definition will be explained in the following:

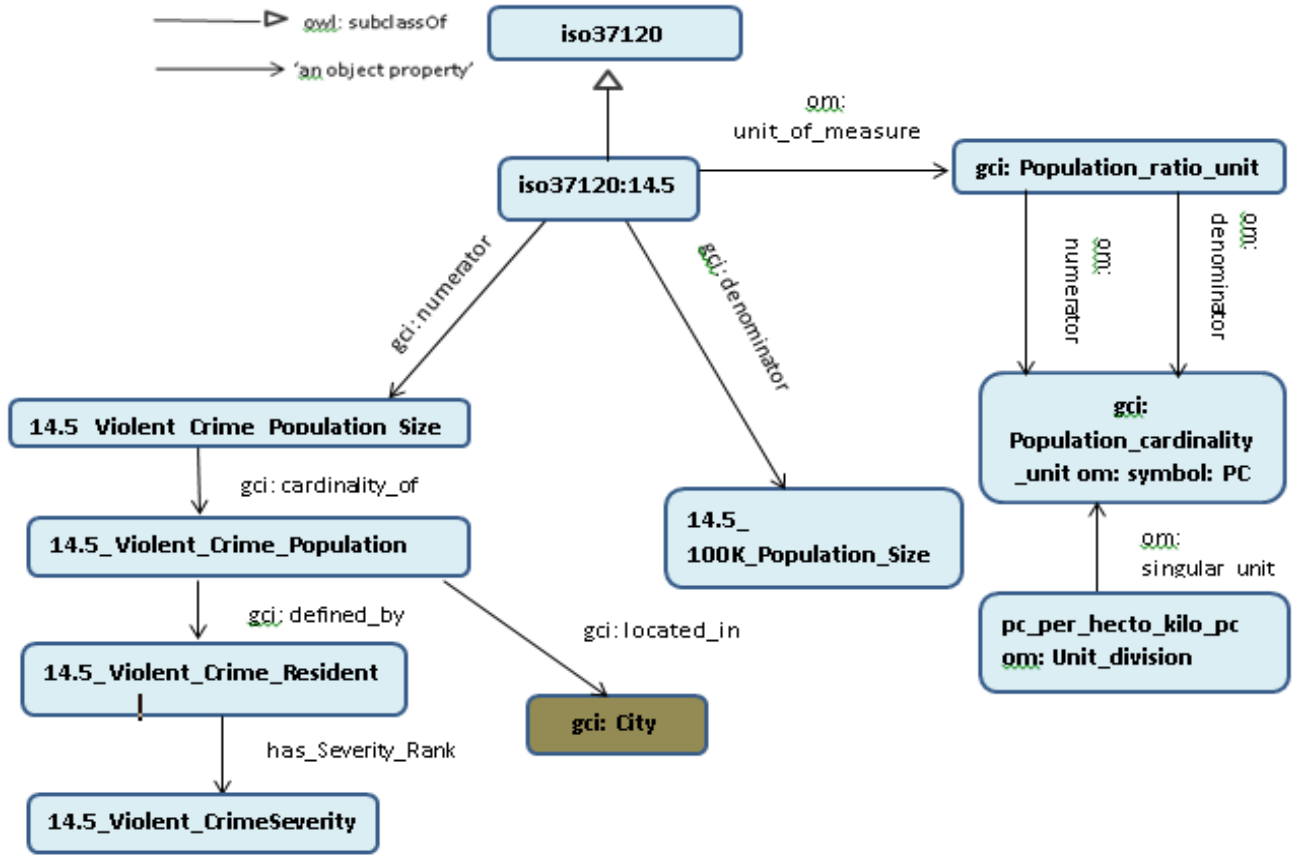


Figure 15: 14.5 Violent crime rate per 100 000 population Ontology

We define the numerator and denominator of 14.5 as follows:

iso37120:14.5	gci:numerator	exactly 1 14.5_Violent_Crime_Population_Size
	gci:denominator	exactly 1 gci:100K_Population_Size
	om:unit_of_measure	value occurrence_per_hecto_kilo_pc

What is unique to this indicator is the definition of the people making up the populations (Linked using defined_by), namely 'Violent_Crime Resident' with the following classes and properties that indicated the Severity of the violent crime in the population through 'has_Violent_Crime_Severity' property and also the reason for violent crime that should be minimum one of (raping or robbing or Aggravated Assault or Manslaughter) through 'has_ReasonForViolentCrime' property :

Class	Property	Value Restriction
14.5_Violent_Crime_ Population_Size	owl:subClassOf	gci: Population_Size
	gci: cardinality_of	exactly 1 14.5_Violent_Crime_Population
	om:unit_of_measure	value gci:occurrence
14.5_Violent_Crime_ Population	owl:subClassOf	gs:Population

	gci: defined_by	exactly 1 14.5_Violent_Crime_Resident
	gci: located_in	exactly 1 sc: City
14.5 Violent_Crime_Resident	owl:subClassOf	Victim
	has_ReasonForViolentCrime	min 1 (sumo:raping or sumo:robbing or Aggravated_Assault or Manslaughter)
	has_Violent_Crime_Severity	exactly 1 14.5_Violent_CrimeSeverity

Additional class needs to be created to support the Severity of Violent Crime in the indicator 14.5 definition. The property 'has_Severity_Rank' indicates the severity of the Violent Crime to make sure the most severe has been counted in case of multiple-offence and integer values 1 to 4 used for the ranking as follows:

1: 'murder and non-negligent manslaughter'; 2: 'rape'; 3: 'robbery', 4: 'aggravated assault'.

Class	Property	Value Restriction
14.5_ Violent_CrimeSeverity	owl:subClassOf	Violent_CrimeSeverity
	has_Severity_Rank	exactly1 rdfs:Literal

The following axioms are defined to satisfy the indicator definition:

1. The 'Violent Crime Severity' definition is restricted to those defined by the city.
2. The 'Violent Crime Type' definition is restricted to those defined by the city.
3. The year of the 'Violent Crime' is the same as the year for '14.5' indicator.
4. The 'Violent Crime' counted in each category, resides in the population's city.

7. Evaluation

In this section, the City of Toronto in the Province of Ontario, Canada will be used to answer the 14.1 Public Safety indicator's competency questions. The following table defines the instances for the Toronto 14.1 indicator:

Instance	Property	Value
ex (instance of 14.1)	rdfs:type	iso:14.1
	gci: numerator	ex_num
	gci: denominator	ex_den
	gci: for_city	gn:6167865 (Toronto)
	ot: hasDateTimeDescription	cy2013
	om: value	ex_value
cy2013	rdfs:type	ot:datetimedescription

	ot:year	2013
ex_value (value of 14.1)	rdfs:type	om: Measure
	om: numerical_value	240
	om: unit_of_measure	gci: Population_Ratio_Unit (instance)
ex_num (numerator of 14.1)	rdfs:type	isops: 14.1_SwornPoliceOfficerPopulation_size
	gci: cardinality_of	isops:ex_SPO_pop
	om: value	isops:ex_num_value
ex_num_value (value of the numerator of 14.1)	rdfs:type	om: Measure
	om: numerical_value	7200
ex_SPO_pop (Numerator Population)	rdfs:type	isops: 14.1_SwornPoliceOfficer_Population
	gci: located_in	gn:6167865
	gci: defined_by	isops: 14.1_SwornPoliceOfficer_Resident
ex_den (14.1 denominator)	rdfs: type	gci:100K_Population_Size.
	om:value	ex_den_value
ex_den_value (value of the Denominator of 14.1)	rdfs:type	om: Measure
	om: numerical_value	30

The following illustrates how the competency questions for ISO37120:14.1are implemented in SPARQL:

```
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 gcips: <http://www.semanticweb.org/kourosh/ontologies/2016/4/GCI-PublicSafety#>
PREFIX gci: <http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl#>
PREFIX ic: <http://ontology.eil.utoronto.ca/icontact.owl#>
PREFIX isops: <http://www.semanticweb.org/kourosh/ontologies/2016/6/PublicSafety.owl#>
PREFIX  org:<http://ontology.eil.utoronto.ca/organization.owl#>
```

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

```
SELECT distinct  ?city  where {ex  gci:for_city ?city}
```

2. (F) What types of police officers does a city have?

```
SELECT ?PoliceOfficerType
WHERE {
        ex gci:numerator ?spo_size.
        ?spo_size gci:cardinality_of ?spo_pop.
        ?spo_pop gci:defined_by ?spo_res.
        ?PoliceOfficerType owl:subClassOf ?spo_res }
```

3. (F) Who is the police officer's employer?

```
SELECT ?PoliceOfficerEmployer
WHERE {
        ex gci:numerator ?spo_size.
        ?spo_size gci:cardinality_of ?spo_pop.
        ?spo_pop gci:defined_by ?spo_res.
        ?spo_res gcie:has_Placement.
        ?spo_pl gcips:source_of_payment ?PoliceOfficerEmployer.
}
```

4. (F) What is the employment type of police officers?

```
SELECT  ?Employment_Type
WHERE {
        ex gci:numerator ?spo_size.
        ?spo_size gci:cardinality_of ?spo_pop.
        ?spo_pop gci:defined_by ?spo_res.
        ?spo_res gcie:has_Placement.
        ?spo_pl gcips:employment_Type ?EmploymentType.
}
```

5. (D) Does police officer have full arrest power?

```
SELECT  distinct     ?Arrest_Power
WHERE {
        ex gci:numerator ?spo_size.
        ?spo_size gci:cardinality_of ?spo_pop.
        ?spo_pop gci:defined_by ?spo_res.
        ?spo_res org:has_Authority ?Arrest_Power.
        ?Arrest_Power rdfs:type gcips:FullArrestEmpowerment.
```

```
}
```

6. (D) Does the police officer carry identification at work?

```
SELECT  ?id
WHERE {
                ex gci:numerator ?spo_size.
                ?spo_size gci:cardinality_of ?spo_pop.
                ?spo_pop gci:defined_by ?spo_res.
                ?spo_res org:hasPolicy ?id.
                ?id rdfs:type gcips:CarryID.
}
```

7. (D) Is the police officer paid from governmental funds?

```
SELECT ?PoliceOfficerEmployer.
WHERE {
                ex gci:numerator ?spo_size.
                ?spo_size gci:cardinality_of ?spo_pop.
                ?spo_pop gci:defined_by ?spo_res.
                ?spo_res gcie:has_Placement.
                ?spo_pl gcips:source_of_payment ?PoliceOfficerEmployer.
}
```

8. (D) How many police officers does a city have?

```
SELECT  ?numPOs
        WHERE {
                ex gci:numerator ?spo_size.
                ?spo_size om:value ?spo_val.
                ?spo_val om:numerical_value ?NumPOs.
}
```

8. Conclusions

This research focused on defining ontology for the representation of ISO37120 Public Safety theme indicators definition and how deep Public Safety ontology would be required. Toward constructing this ontology; GCI Public Safety ontology was defined for making indicators representation straightforward including:

1. Representing Public Safety related concepts and supporting data published on the Semantic Web using a generic ontology,

2. Making GCI Public Safety ontology concepts such as Victim, Sworn Police Officer, Homicide, etc. reusable and also using this data to extract a city's specific Public Safety indicators value.

In summary, the generic Public Safety ontology is the foundation of ISO37120 indicators definition and the conclusive contributions of this research as follows:

1. Supporting the definition of ISO37120 Public Safety as a main goal.
2. Each ISO37120 Public Safety indicator defined based on GCI-Foundation and Public Safety ontologies.
3. Semantic Web used for ISO37120 Public Safety development which makes definition reasoning possible.
4. Instantiation of ISO37120 Public Safety indicators and supporting data which enables analysis by PolisGnosis.

9. Acknowledgements

This research is sponsored by the Natural Science and Engineering Research Council of Canada.

10. References

Graves, A., Integrating and Publishing Public Safety Data Using Semantic Technologies https://www.researchgate.net/publication/221584658_Integrating_and_publishing_public_safety_data_using_semantic_technologies

Dahleh, D., and, M.S., (2016), "An Environment Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto. http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/GCI-Environmental-Ontology-Final-17sep2016.pdf

Fiode, J., and Fox, M.S., (2016), "A Health Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto, to appear.

DBPedia ontology classes http://mappings.dbpedia.org/server/ontology/classes/

Forde, A., and Fox, M.S., (2015), "An Innovation Ontology for Global City Indicators (ISO 37120)",
Working Paper, Enterprise Integration Laboratory, University of Toronto,
http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/GCI-Innovation-Ontology-v15.pdf.

Fox, M.S., (2013), "A Foundation Ontology for Global City Indicators", Working Paper, Enterprise Integration Lab, University of Toronto, Revised: 31 January 2017.
http://www.eil.utoronto.ca/applications/smartcities/papers/
GCI-Foundation-Ontology-v9.pdf.

Fox, M.S., (2014), “An Education Ontology for Global City Indicators (ISO 37120)”, Working Paper,
Enterprise Integration Lab, University of Toronto, http://eil.utoronto.ca/wpcontent/uploads/smartcities/papers/GCI-Education.pdf.

Fox, M.S., (2017), “PolisGnosis Project: Enabling the Computational Analysis of City Performance”, *Proceedings of the 2017 Industrial and Systems Engineering Conference*, K. Coperich, E. Cudney, H. Nembhard, eds.
http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/IISE-2017-3349.pdf

Fox, M.S., and Grüninger, M., (1998), "Enterprise Modelling", AI *Magazine*, AAAI Press, Fall 1998, pp.109-121.

Fox, M.S., and Huang, J., (2005), “Knowledge Provenance in Enterprise Information”, International Journal of Production Research, Vol. 43, No. 20, pp. 4471-4492, http://www.eil.utoronto.ca/km/papers/fox-ijpr05.pdf.

Fox, M.S., and Pettit, C.J., (2015) “On the Completeness of Open City Data for Measuring City Indicators”, *Proceedings of the IEEE Conference on Smart Cities*, Guadalajara Mexico.

Government of Canada, Canadian Communications Interoperability Plan
Departmental Performance Report 2013-2014
http://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/dprtmntl-prfrmnc-rprt-2013-14/index-eng.aspx#a32

Grüninger, M., and Fox, M. S., (1995), “Methodology for the Design and Evaluation of Ontologies.” *Proceedings of the Workshop on Basic Ontological Issues in Knowledge Sharing*, IJCAI-95, Montreal, Canada.

Hobbs, J.R., and Pan, F., (2006), “Time Ontology in OWL”, http://www.w3.org/TR/owl-time/.

Huang, J., and Fox, M.S, (2006), "An Ontology of Trust – Formal Semantics and Transitivity," *Proceedings of the International Conference on Electronic Commerce*, pp. 259-270, http://www.eil.utoronto.ca/km/papers/huang[ec06.pdf.

ISO37120, (2014), “ISO 37120: Sustainable Development of Communities – Indicators for City Services and Quality of Life”, International Organization for Standardization, First Edition, 2014-05-15, ISO37120:2014(E).

Schema.org Community Group https://schema.org/

Kanter, R. M., & Litow, S. S. (2009). “Informed and interconnected: A manifesto for smarter cities.” Harvard Business School General Management Unit Working Paper, 09-141. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1420236.

Komisar, A., and Fox, M.S., (2017), "An Energy Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto, to appear.

Lebo, T., Sahoo, S., and McGuinnes, D., (2013), “PROV-O: The PROV Ontology”,

https://www.w3.org/TR/prov-o/

Leitner, Michael (Ed.), Crime Modeling and Mapping Using Geospatial Technologies Crime Modeling and Mapping Using Geospatial Technologies 2013 - chapters 8 and 18 www.springer.com/us/book/9789400749962

Niles, I., and Pease, A., (2001), “Towards a Standard Upper Ontology”, In Proceedings of the 2nd International Conference on Formal Ontology in Information Systems FOIS-2001,Ogunquit, Maine. New York: ACM Press.

Pattuelli, M.C., (2003), “The GovStat Ontology: Technical Report”. The GovStat Project, Integration Design Laboratory, School of Information and Library Science, University of North Carolina at Chapel Hill.
http://ils.unc.edu/govstat/papers/govstatontology.doc.

Pease, A., Suggested Upper Merged Ontology (SUMO) http://www.adampease.org/OP/

Rauch, N., and Fox, M.S., (2017), "An Fire and Emergency Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto, to appear.

Rijgersberg, H., Wigham, M., and Top, J.L., (2011), “How Semantics can Improve Engineering Processes: A Case of Units of Measure and Quantities”, Advanced Engineering Informatics, Vol. 25, pp. 276-287.

Tham, D., Fox, M.S., and Gruninger, M., (1994), "A Cost Ontology for Enterprise Modelling", Proceedings of the Third Workshop on Enabling Technologies - Infrastructures for Collaborative Enterprises, West Virginia University.

Uceda-Sosa, R., Srivastava, B., and Schloss, B., (2012), “Building a Highly Consumable Semantic Model for Smarter Cities”, In Proceedings of the workshop on AI for an Intelligent Planet, ACM.

UK Government, Open data about crime and policing in England, Wales and Northern Ireland Time Period Covered: December 2010 to July 2016 https://data.police.uk/docs/

Wang, Y., and Fox, M.S., (2015), "A Shelter Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto, http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/GCI-Innovation-Ontology-v15.pdf.

Wang, I., and Fox, M.S., (2016a), "A Finance Ontology for Global City Indicators (ISO 37120)", Working Paper, Enterprise Integration Laboratory, University of Toronto, http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/GCI-Innovation-Ontology-v15.pdf.

Wang, Z., and Fox, M.S., (2016b), “Expenditure, Revenue and Taxes – Towards a Standard for Representing City Finance Open Data”, *Proceedings of the IEEE Smart Cities Conference*, Trento Italy, pp. 1-6.
http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/wang-ieeesc22016.pdf

Appendix

The Global City Indicator Foundation ontology can be found in:
http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation-v2.owl.

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

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

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