



School of Cities
UNIVERSITY OF TORONTO



INFORMATION TECHNOLOGY STANDARDS

WG 11: Smart Cities



Ontology-based Standards for Smart Cities

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Motivation

- **Data Interoperability:** A common data model enables city software applications to share information, plan, coordinate, and execute city tasks, and support decision making within and across city services,
- An **Ontology** can provide a **precise, unambiguous representation and interpretation (semantics)** of information and knowledge commonly shared across city services.

What is an Ontology?

- Answers the questions:
 - What are the **core concepts and properties** that span the domain's data?
 - To what extent can we **generalize** them in a useful way?
 - What are the **key distinctions**?
 - Can we formally define **necessary and/or sufficient conditions** (using properties) for something to be an example (member) of a concept?
- More than a reference model (vocabulary) for a domain:
A precise, formal (logical language) representation of the meaning of concepts and properties

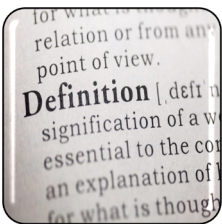
Ontology Components

Transportation Planning



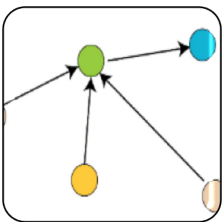
Micro-Theory

- Transportation Planning predicts transportation demand over a multi-decade horizon.
- In order to predict demand, it has to simulate how the city will change over those decades
- For example, how households and their members will change over time, and their changing transportation requirements as they age



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Knowledge Graph

- Classes, Properties, Instances
- (boosted with) Taxonomy and Inheritance

- Residents, Households, members
- Transportation Network
- Vehicles

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les in, owns
erates a business
of at least one
the same address

City Resident

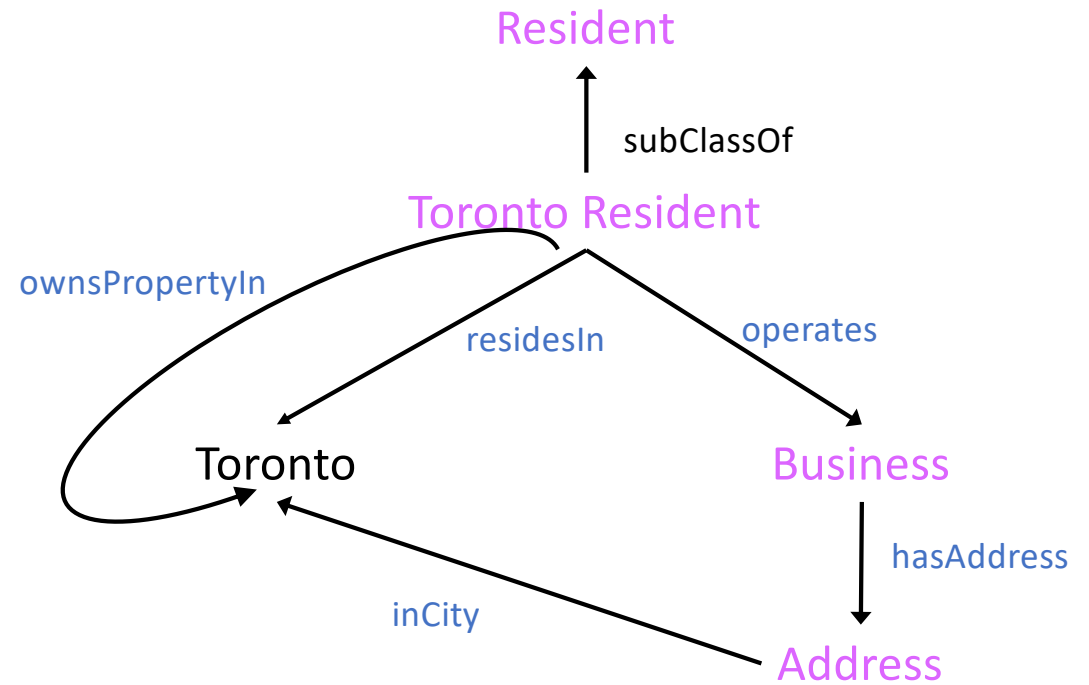
- Cities provide many services to their residents, but in order to receive those services, the validity of their residency must be determined.
 - For example, free transportation for senior residents
- Possible uses of an ontological description of a city resident include:
 - Verifying that a person who requests a service is a resident
 - Determining in a database of people what subset are residents of the city
 - Validating manually provided classifications of residency
- How would an ontology help?

Definition Example: City Resident

- **Toronto:** “you are identified as a resident if you reside in, own property, or own or operate a business in Toronto” (311 Toronto).
- **Beijing:** “all individuals holding the nationality of the People’s Republic of China who [have] a domicile in Beijing and nowhere else. If the individual maintains a regular dwelling somewhere else, the more regular dwelling is considered their place of residence” (Li, 1991).
- **New York:** “the place which an individual intends to be his permanent home – the place to which he intends to return. It is the home with range of sentiment, feeling and permanent association. One must be domiciled in New York and maintain a home in New York, the time spent in the State is irrelevant” (McGladrey, 2009).
- **Germany:** “a resident of Germany generally refers to an individual who has a domicile in Germany or spends more than six consecutive months in Germany (habitual place of abode)” (Seidel, 2011).

Knowledge Graph

“you are identified as a resident if you reside in, own property, or own or operate a business in Toronto”



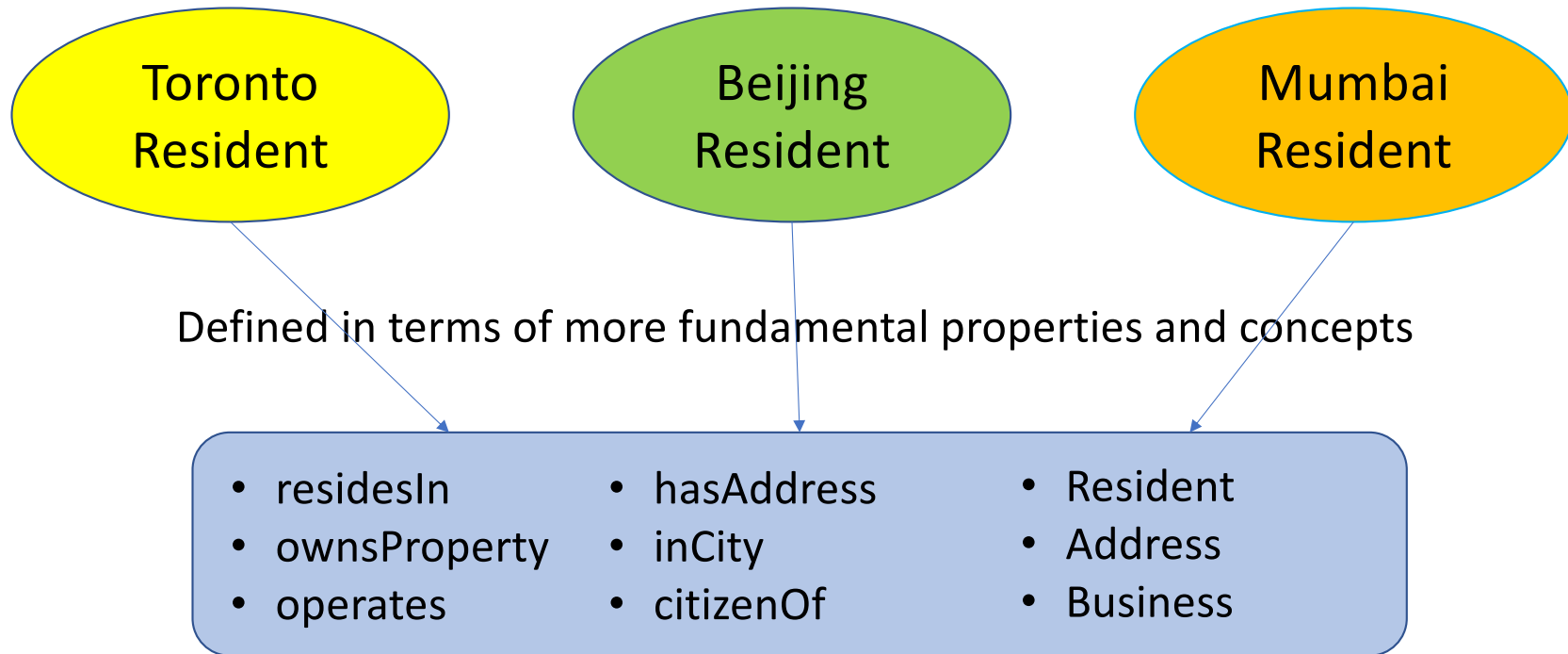
Definitions and Constraints

Semantics of Toronto Resident

“you are identified as a resident if you reside in, own property, or own or operate a business in Toronto”

```
TorontoResident subClassOf Resident
  and (residesIn.Toronto
       or ownsPropertyIn.Toronto
       or operates.(Business
                    and hasAddress.(Address and inCity.Toronto)))
```


Different Definitions of City Resident



Micro-Theory

- For each year above the age of 14, a member of a household will leave with a probability $p(\text{Age})$

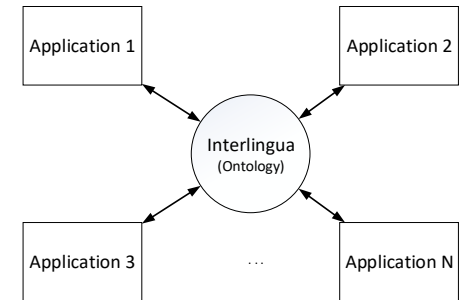
Person(?x) and Household(?y) and memberOf(?x, ?y)
and age(?x, ?z) and greaterThan(?z, 14)
and probleave(?z, ?pl)

----->

leave (?x, ?y, ?pl)

How are Ontologies Used?

- Data Integration:
 - Ontology to serve as an *interlingua*
 - Data and systems may be mapped into the ontology to support exchange of information
- Automated Classification
 - Definition-based classification of data
- Automated Deduction
 - New information may be inferred based on the data and knowledge of the domain formalized with the ontology.
- Model Checking:
 - Data may be automatically validated against the ontology to check whether it conforms to the definitions.

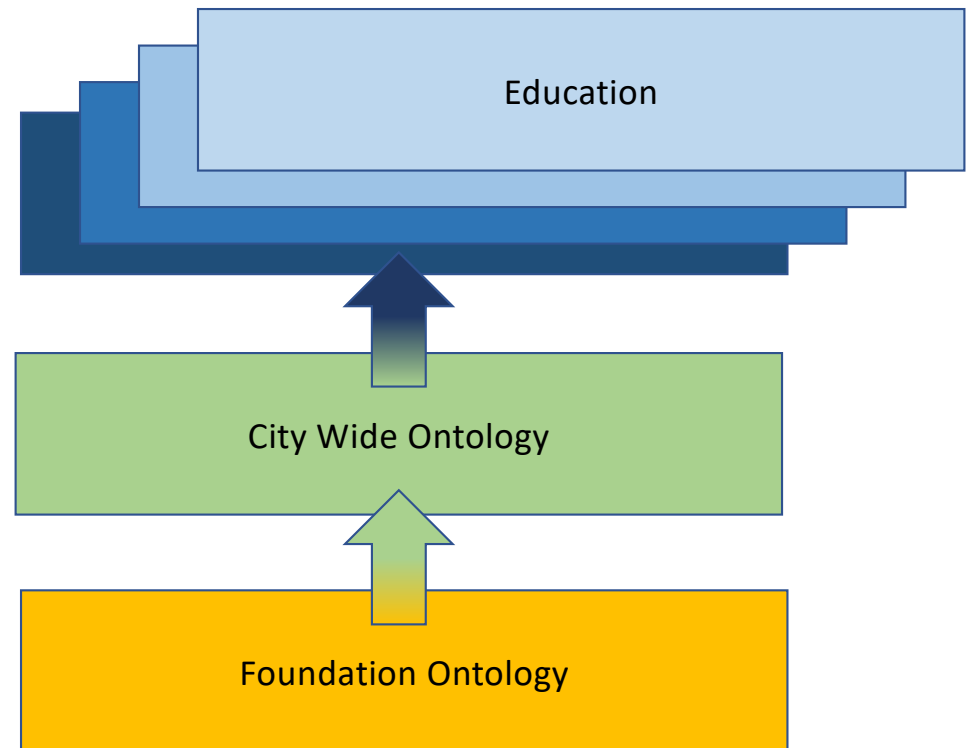


ISO/IEC 5087 Framework

Service Level (5087-n) spans concepts commonly associated with a particular service but still shared with other services, such as Vehicles and Transportation network. *Can be read by multiple services, but updated only by one service.*

City Level (5087-2) covers concepts that are general to cities and span all services such as Households, Services, Residents. *Can be read and updated by multiple services.*

Foundation Level (5087-1) covers very general concepts such as Time, Location, and Activity, upon which other levels are based.



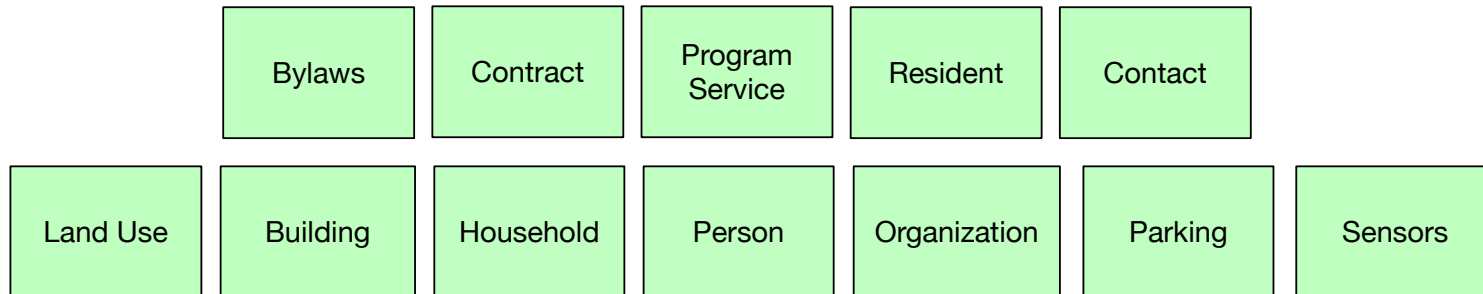
The process of development of this standard is to iteratively select a city service and apply the ontology engineering development process to create, extend and/or modify each level of the standard.

ISO JTC1/WG 11 Smart Cities: 5087

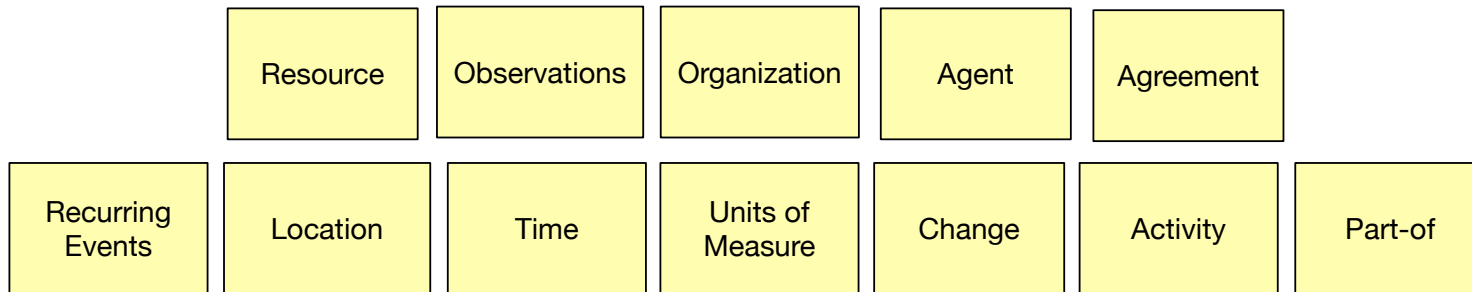
Part 3



Part 2

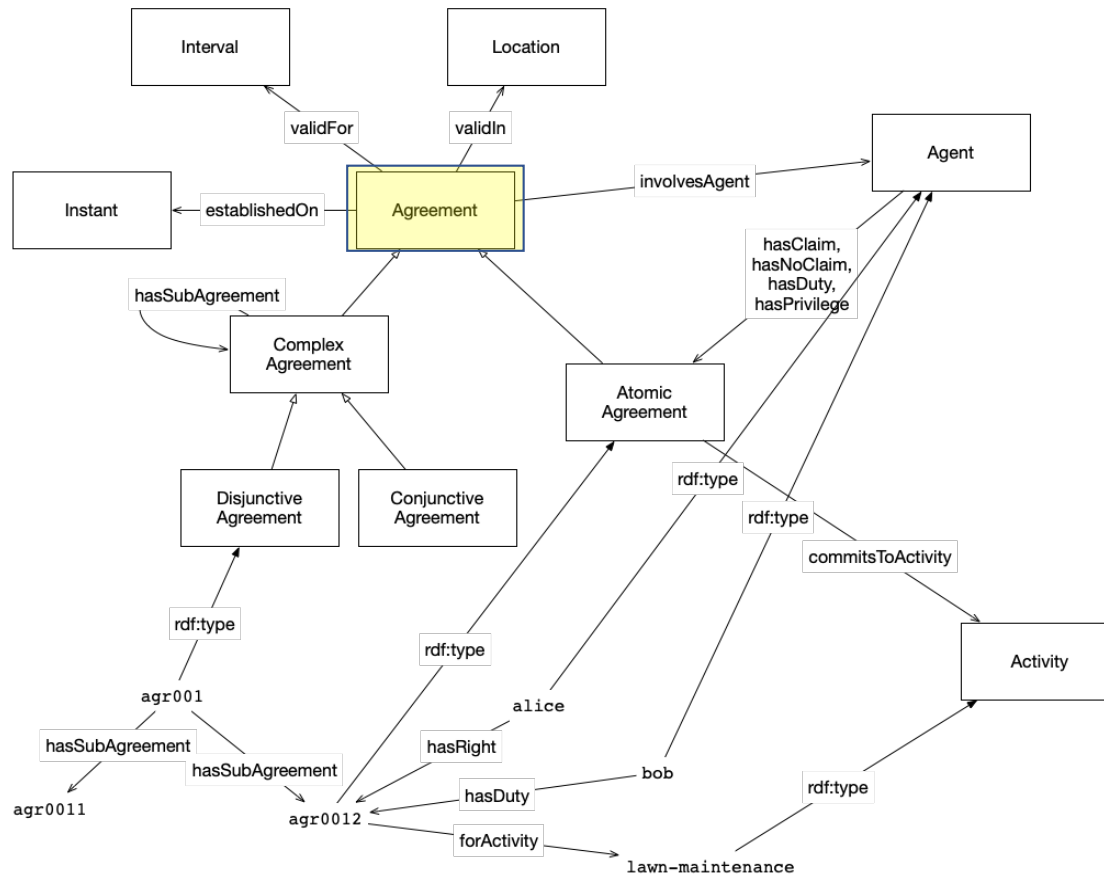


Part 1



Example Classes/Concepts

5087-1: Agreement Pattern



21972/5087-2: Indicator Pattern

Vocabulary

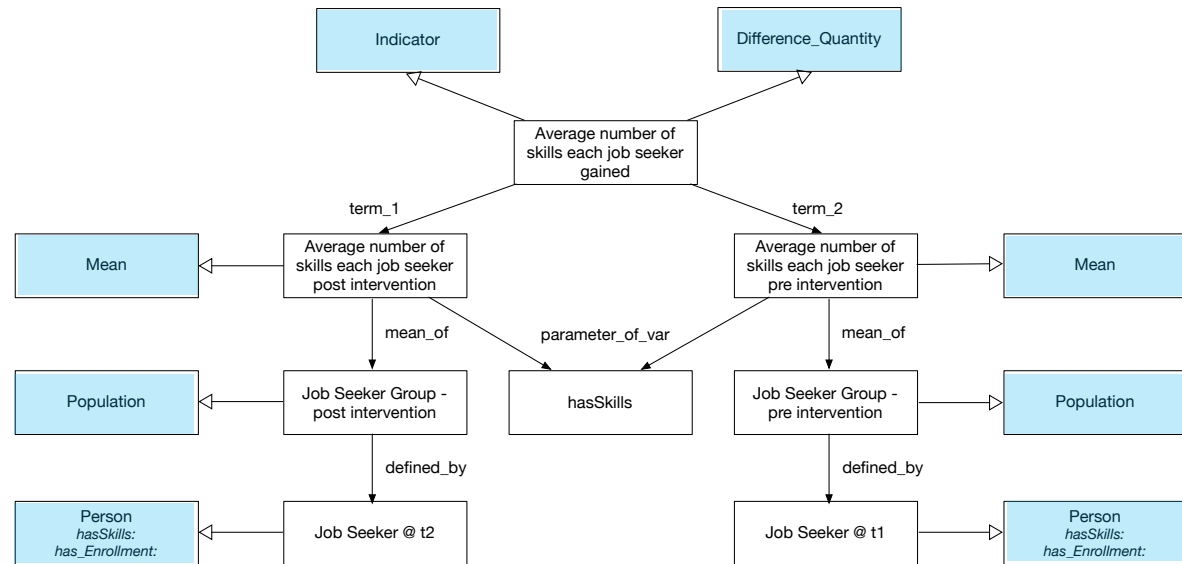
Class	Property	Value Restriction
Indicator	sch:identifier	exactly 1 xsd:string (begins with IND)
	sch:name	exactly 1 xsd:string
	sch:description	"Average Number of Skills each Job Seeker gained"
	definedBy	exactly 1 xsd:string (begins with ORG)
	forOutcome	only xsd:string (begins with OUT)
	hasSimilarIndicator	only xsd:string (begins with SI)
	hasThreshold	exactly 1 xsd:string
	sch:dateCreated	exactly 1 "yyyy-mm-dd"
	sch:provider	max 1 xsd:string

sch:description: "Average Number of Skills each Job Seeker gained"

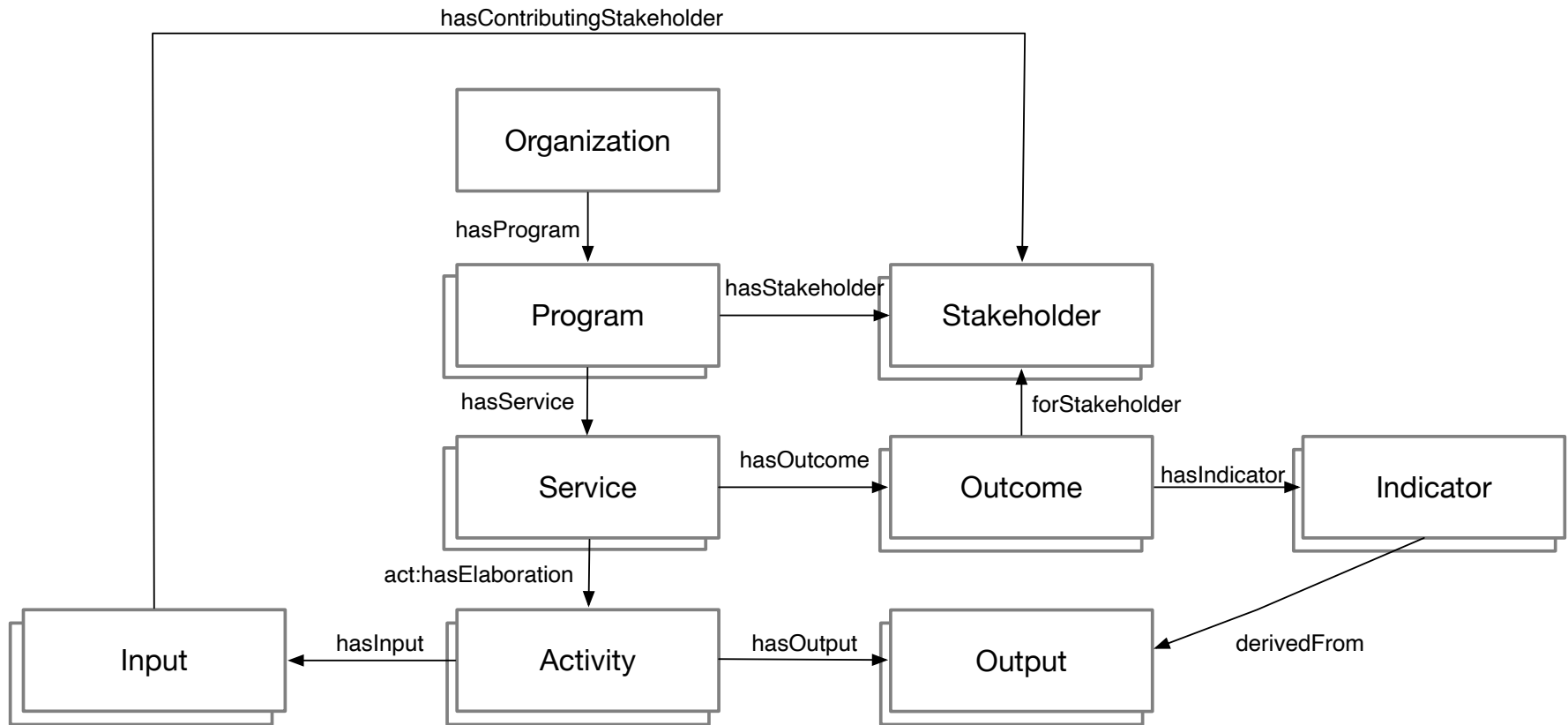


ISO/IEC 21972:2020:
Representing textual descriptions of Indicators using a semantically precise representation.

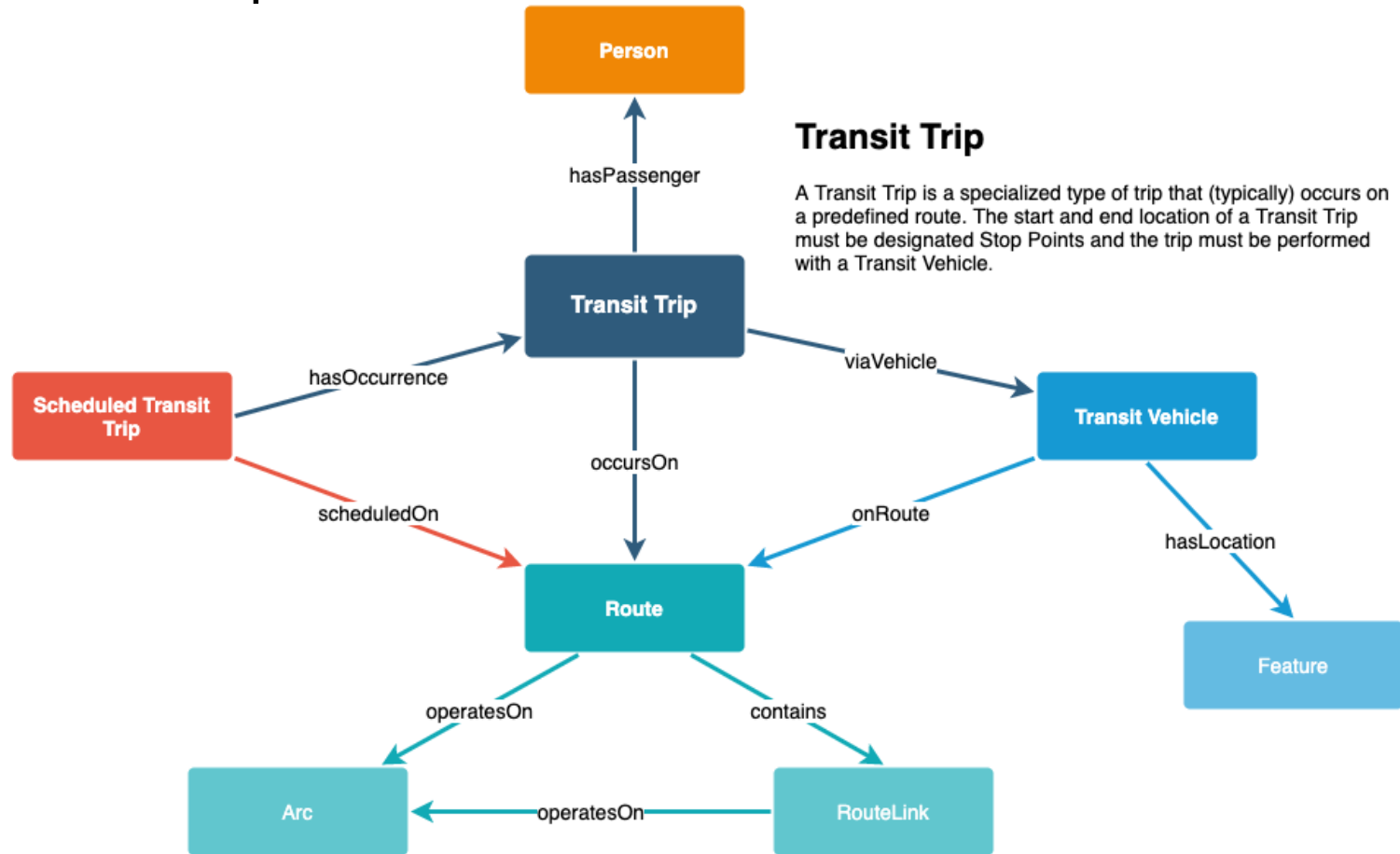
Enables automated comparison/analysis of Indicators.



5087-2: Program/Service Pattern



5087-3: Trip Pattern



Methodology

Our goal is to identify, define, formalize and validate urban data concepts. In particular, our objectives are to:

1. Identify candidate concepts (and their properties) and their use cases through a detail analysis of existing urban vocabularies, ontologies and city enterprise software.
2. Reduce the candidate concepts from the different sources into a minimal set of core concepts.
3. Manage and curate an open process where Standards Development Organizations (SDOs) and other experts can comment on the core concepts (defined in step 2) and post modifications, use cases and new concepts.
4. Formalize and evaluate the resulting concepts from step 3.
5. Promulgate the results through the International Standards Organization.

City Data Model Project: A Global Collaboratory

citydata.utoronto.ca

The screenshot displays three browser windows from the City Data Model Project website. The left window shows the main site navigation and an introduction to the project. The middle window shows the 'Category:Class' page, which lists various classes and provides instructions on how to propose a new class. The right window shows the 'Toronto Resident' class page, which includes a table of class properties, a description, and a UML diagram.

Category:Class

- A **Class** is a term that is used to describe a group of objects that share common attributes and behaviour. They are defined by a set of attributes and behaviour.
- OWL: Classes correspond to **Classes** in OWL. Hence, classes essentially thinking, like the concept person or animal.
- RDF: Classes are similar to the **Classes** in RDF. They be members of a Class.
- UML: Classes correspond to **Classes** in UML. They have attributes and behaviour. They are defined by a set of attributes and behaviour.

Propose a New Class

See something missing below? There are two ways to propose a new class:

1. If you have a different definition for a class.
2. If you have a definition for a class that is missing.

Pages in category "Class"

The following 4 pages are in this category:

- C**
- [City Resident](#)
- S**
- [Service](#)

Toronto Resident

Name	Toronto Resident
Subclass Of	City Resident
Namespace (context for definition)	toronto
Description (what distinguishes this sense of the term?)	You are identified as a resident if you reside in, own property, or own or operate a business in Toronto.
Use Case (why is this specialized definition needed?)	This term is required to distinguish the definition of a Resident as used by the city of Toronto, with varying definitions of Resident used in other cities. It is used to calculate statistics about the city.
Formal Definition (UML and DL)	TorontoResident subClassOf Resident and (residesIn.Toronto or ownsPropertyIn.Toronto or operates.(Business and hasAddress.(Address and inCity.Toronto))) UML: see figure below
Status	Pending Approval
Has Subclass	<input type="text"/> submit

Sort by date Enable comment auto-refresher

You are not allowed to post comments.

Figure

```
classDiagram
    class Resident
    class TorontoResident
    Resident <|-- TorontoResident
```

Status

- Three virtual workshops on city data models held in the fall of 2019 with over 100 people registered
- 5087-1,2,3 under development by ISO/IEC JTC1
- Collaboratory in beta test, to be launched beginning of 2021
- Participation by other SDOs in the development of the city data model via the collaboratory
 - JTC1 WG11
 - W3C
 - OGC
 - TC204 WG1