25TH ITS WORLD CONGRESS
COPENHAGEN
17 – 21 SEPTEMBER 2018
Quality of life

INTEGRATION IN A DATA RICH WORLD:

STRUCTURING THE MORASS OF TRANSPORTATION DATA

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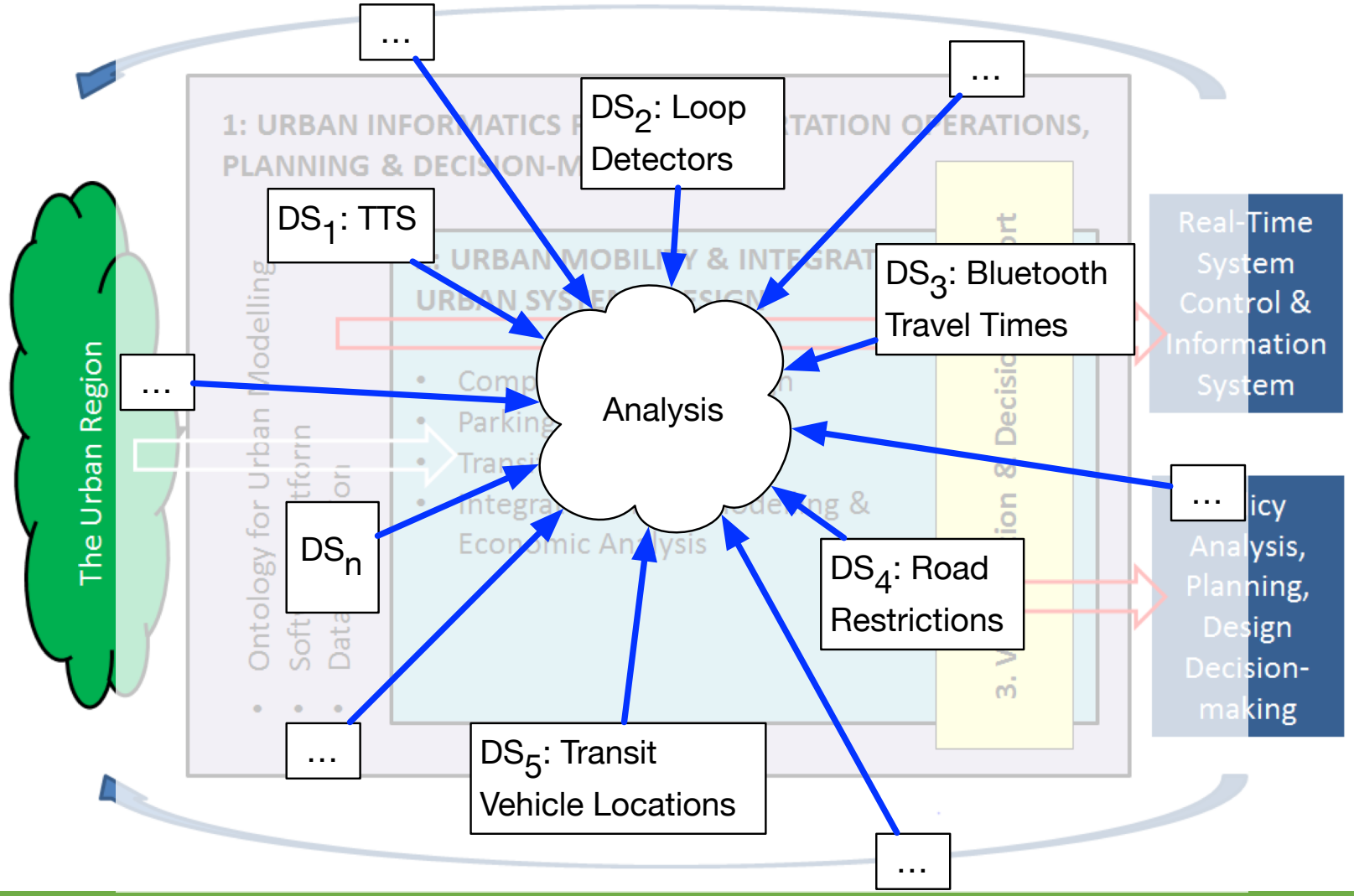
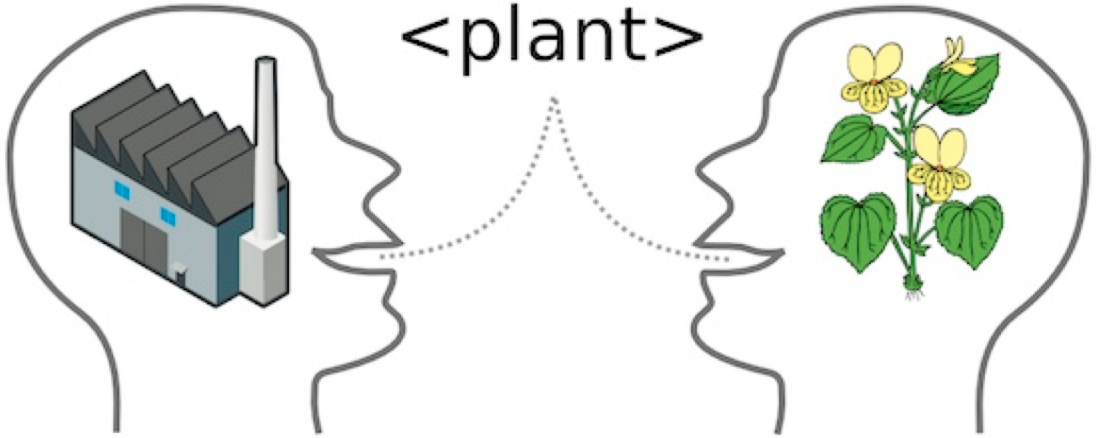
The iCity Project: A Morass of Data



Challenge: Semantic Interoperability

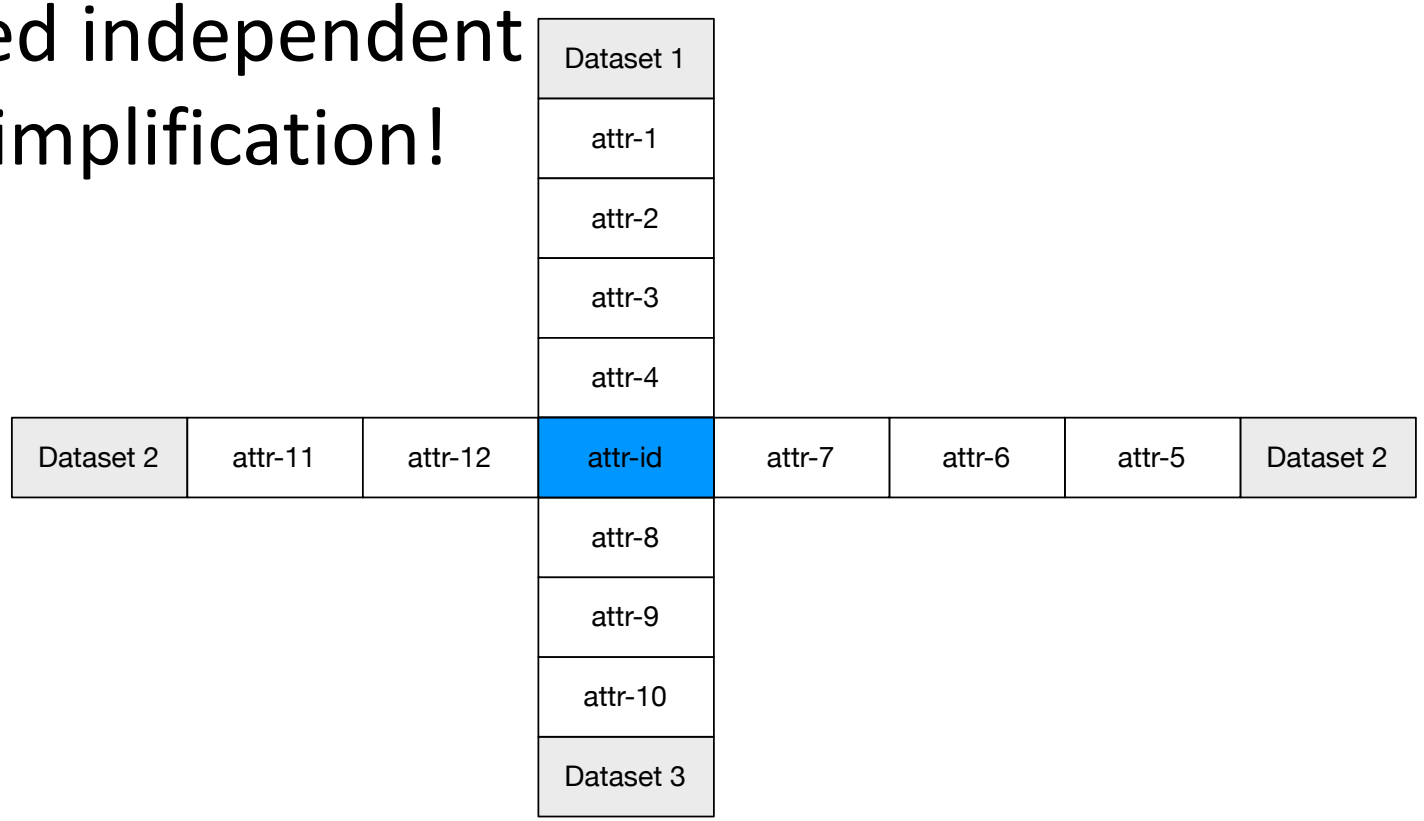
- Ability of computer systems to exchange data with unambiguous, shared meaning.



- A requirement for machine reasoning, knowledge discovery, and data federation across information systems.

The Independence Fallacy

- Shared attribute(s) identified and used for merging
- Other attributes assumed independent
  - This if often an oversimplification!



Semantic Interoperability

Toronto

ID	Creation Date	Service Request Name
TO_Request1	01-02-2010 10:35:03	Missing/Damaged Signs

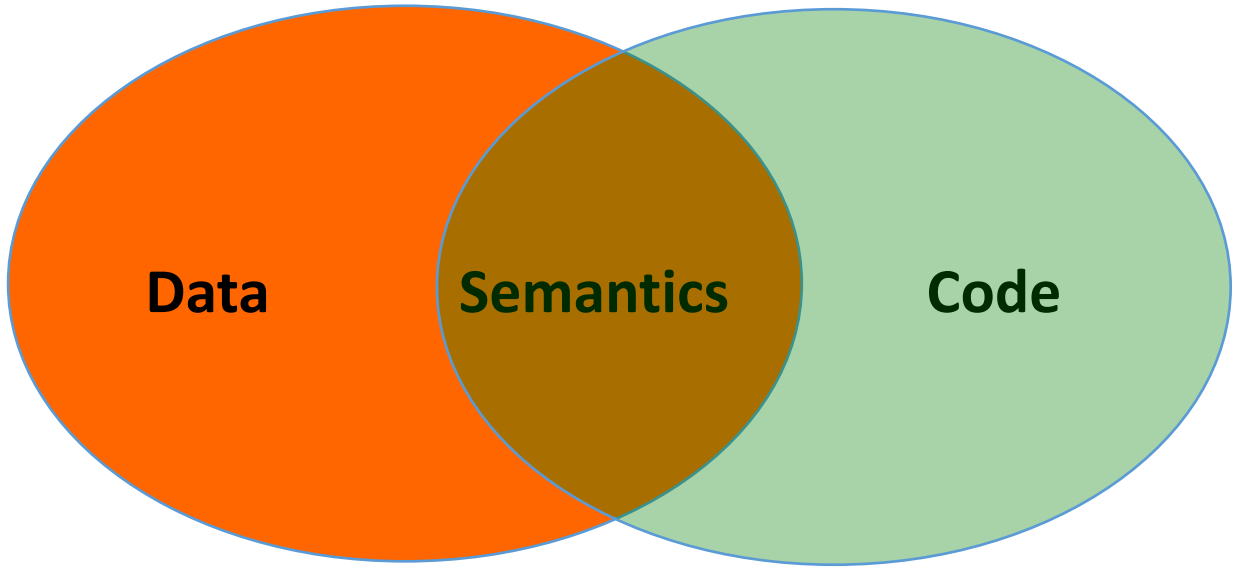
311

ID	Division	Section	Service Request Name	Problem Code
TO_Request1	Transportation Services	TMC – Signs & Markings	Missing/Damaged Signs	SAM-01

New York

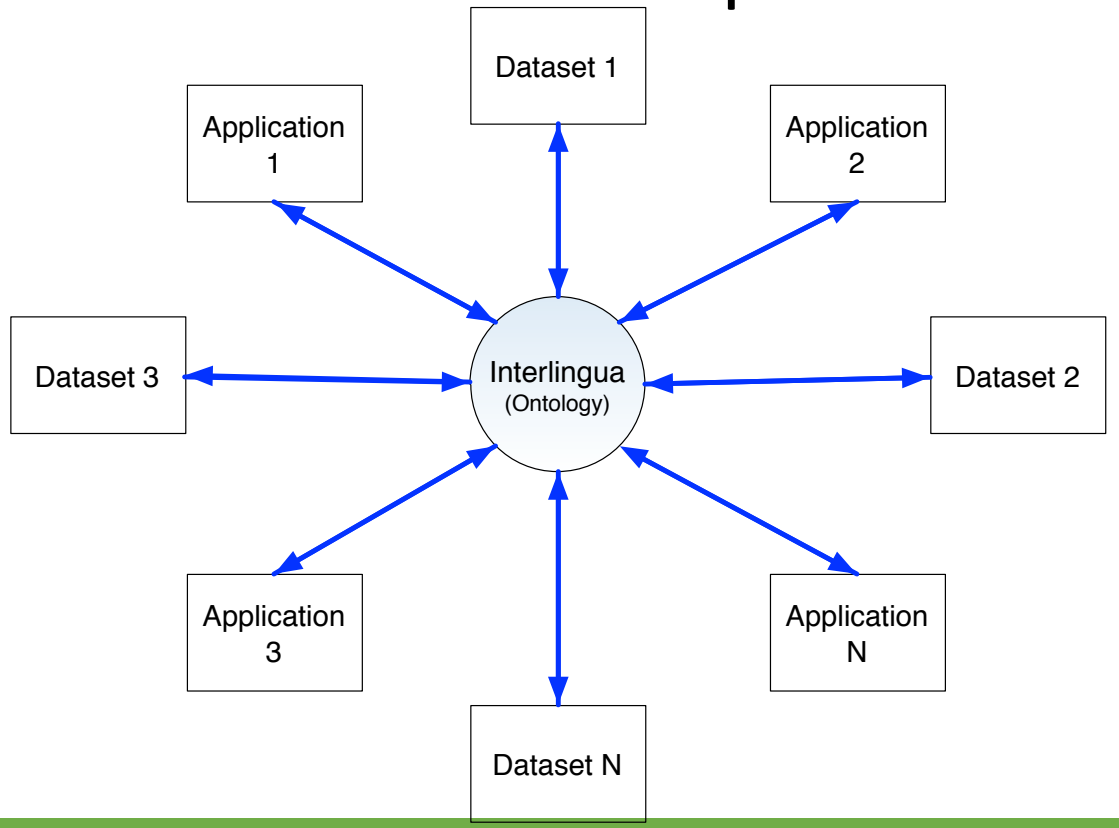
ID	Date	Agency	Complaint Type	Descriptor
NYC-Request1	4/30/2013 12:00:00AM	DOT	Street Sign – Damaged	Stop

Source of the Problem



Solution:
an ontology for urban informatics

- The iCity project addresses this challenge by designing a formal representation of the transportation domain: **an ontology**.

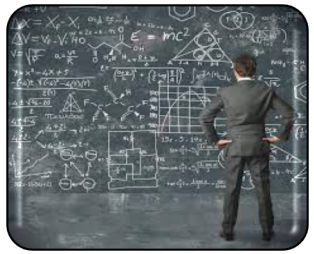


What is an Ontology?

- (More than) a reference model for the domain, it answers the questions:
  - What are the core concepts and properties that span the city'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?

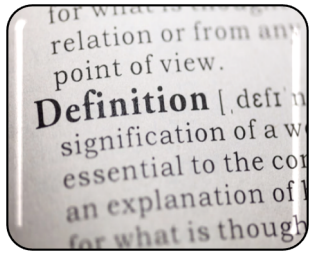
- A precise, formal (logical language) representation that supports:
  - Reuse
  - Integration
  - Automated deduction

The Ontology Approach



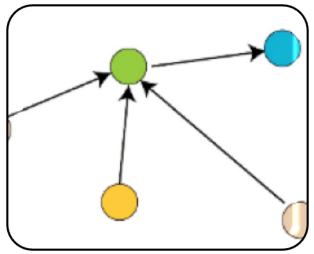
Micro-Theory

- Axioms/Rules
- Deduction – answering questions



Definitions and Constraints

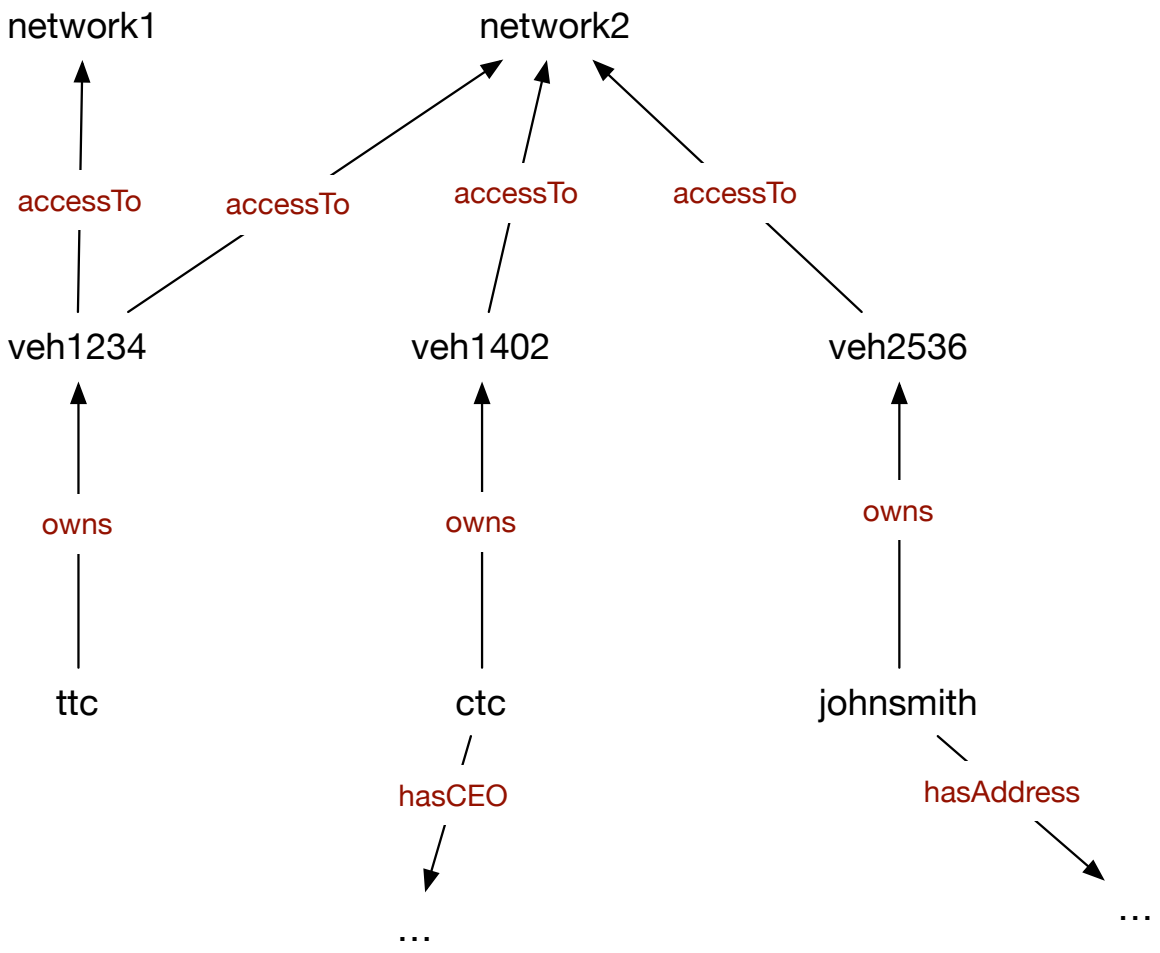
- Class Definitions (in Logic)
- Automated classification



Knowledge Graph

- Classes and Properties
- Taxonomy and Inheritance

Example Knowledge Graph




```
veh1234 rdfs:type Vehicle.
veh2536 rdfs:type Vehicle.
veh1402 rdfs:type Vehicle.
network1 rdfs:type RoadSystem.
network2 rdfs:type TransitSystem.
…
veh1234 accessTo network1.
veh1234 accessTo network2.
veh1234 accessTo network1.
…
veh1234 ownedBy ttc.
veh1234 ownedBy ctc.
veh1234 ownedBy johnsmith.
```

Example Definitions and Constraints

Vehicle

∃ accessTo.RoadSystem

TransitVehicle:

TransitVehicle≡ Vehicle ⊓ ∃accessTo.TransitSystem

TransitVehicle ⊑
¬(HouseholdVehicle)

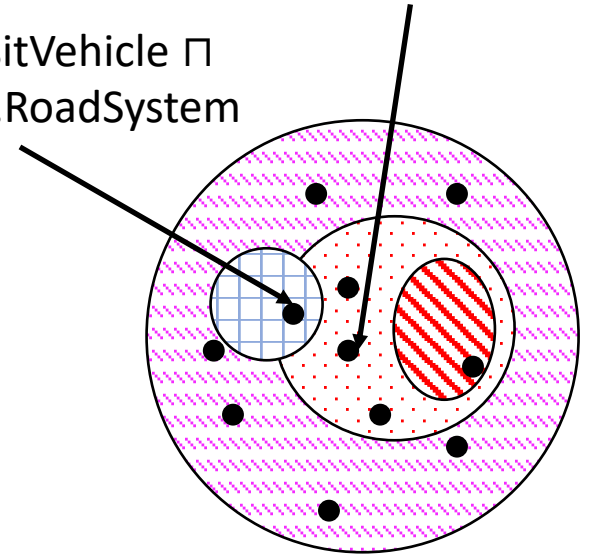
HouseholdVehicle:

HouseholdVechicle≡ Vehicle ⊓ ∃ownedBy.Person

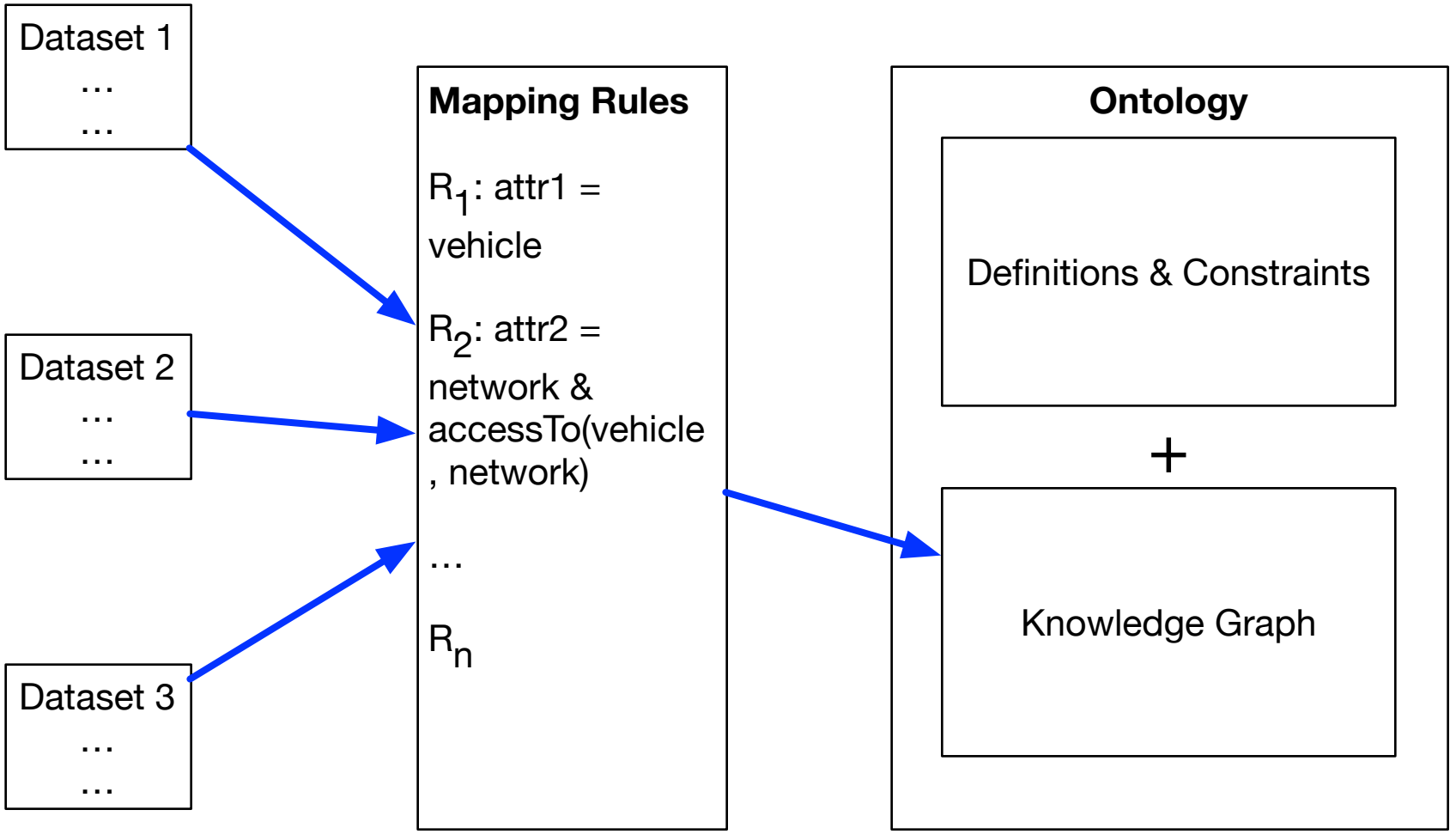
HouseholdVehicle ⊑ ¬(TransitVehicle)

CommercialVehicle ≡ Vehicle ⊓
∃accessTo.RoadSystem ⊓ ¬(TransitVehicle)
⊓ ¬(HouseholdVehicle)

Bus≡ TransitVehicle ⊓
∃accessTo.RoadSystem



Implementation: How does it work?



Semantic Mapping Example

Transit Agency Vehicle Location Feed

Vehicle_ID	Route	long	lat	Time
Veh1234	501	43.72053137	-79.52223983	01-Sep-2017 05:20:20
…				

Canadian Tire Fleet Records

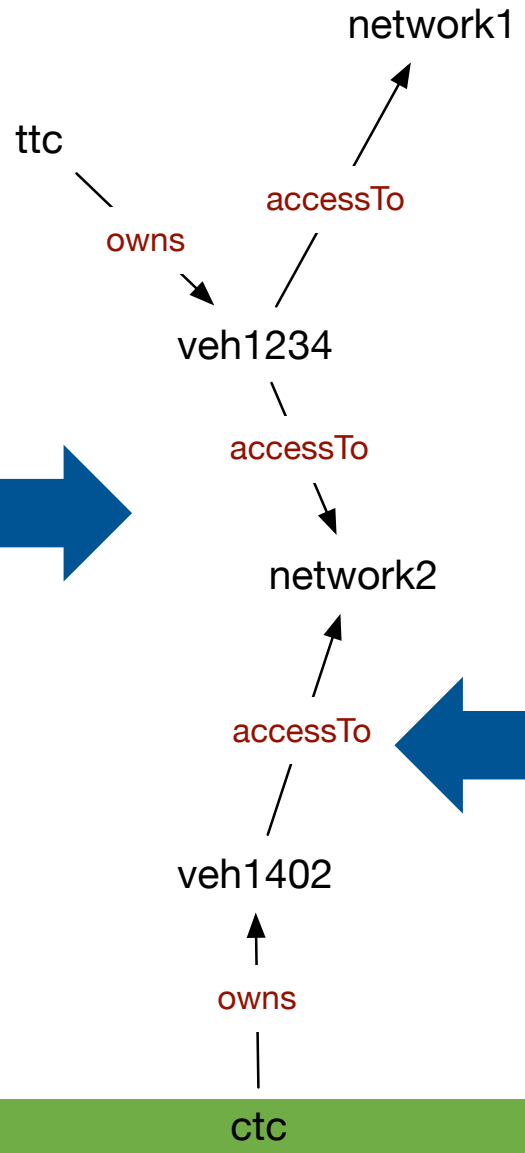
Carrier	location	Driver	recorded
Veh1402	44.72053137, -76.52223983	Al-cooper	01-Sep-2017
…			

Mappings:

Vehicle_ID → Vehicle

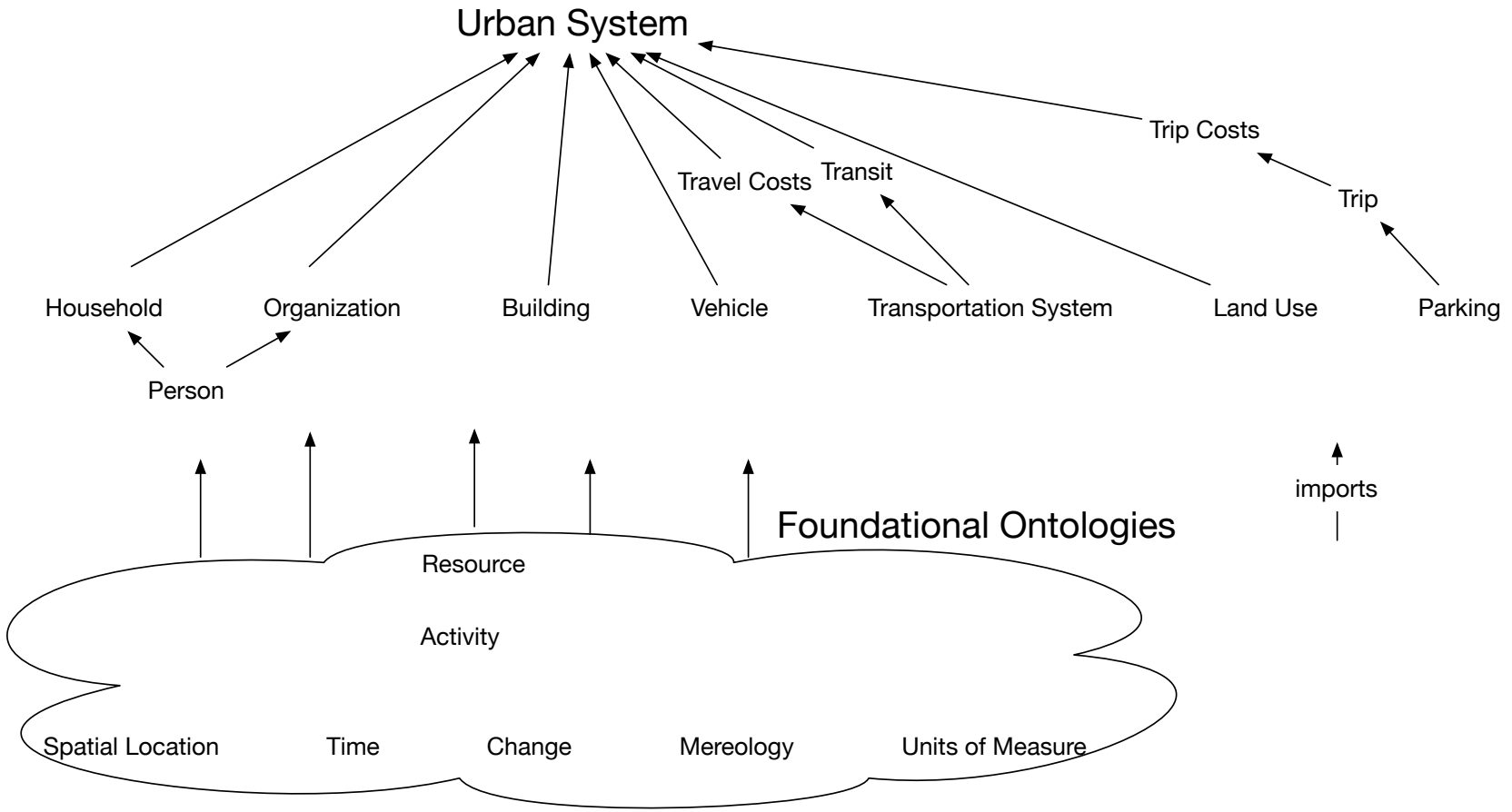
Carrier → Vehicle

…



Query:
What is the **location** of all of the **transit vehicles**?

iCity Ontology: Structure



Final Thoughts

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- A tool to better leverage data:
  - Semantic integration of transportation data from multiple sources.
- A tool to support (re-)use of data:
  - Ensures that the data is available to and understood by others.
    - Knowledge created from the data persists!
  - Consistency checking
  - Inference

- **Applications beyond iCity:** the ontology defines concepts generally applicable for ITS.