



# iCity: Urban Informatics for Sustainable Metropolitan Growth

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- A collaboration among researchers at UofT, OCAD-U and U of Waterloo, partnered with City of Toronto and Waterfront Toronto Esri Canada, IBM Canada, Cellint, and Maximum City
- This research is supported by the Ontario Ministry of Research, Innovation and Science through the Ontario Research Fund-Research Excellence Program, ORF-RE7.



# The iCity Ontology:

## *Transportation Data to Transportation Knowledge*

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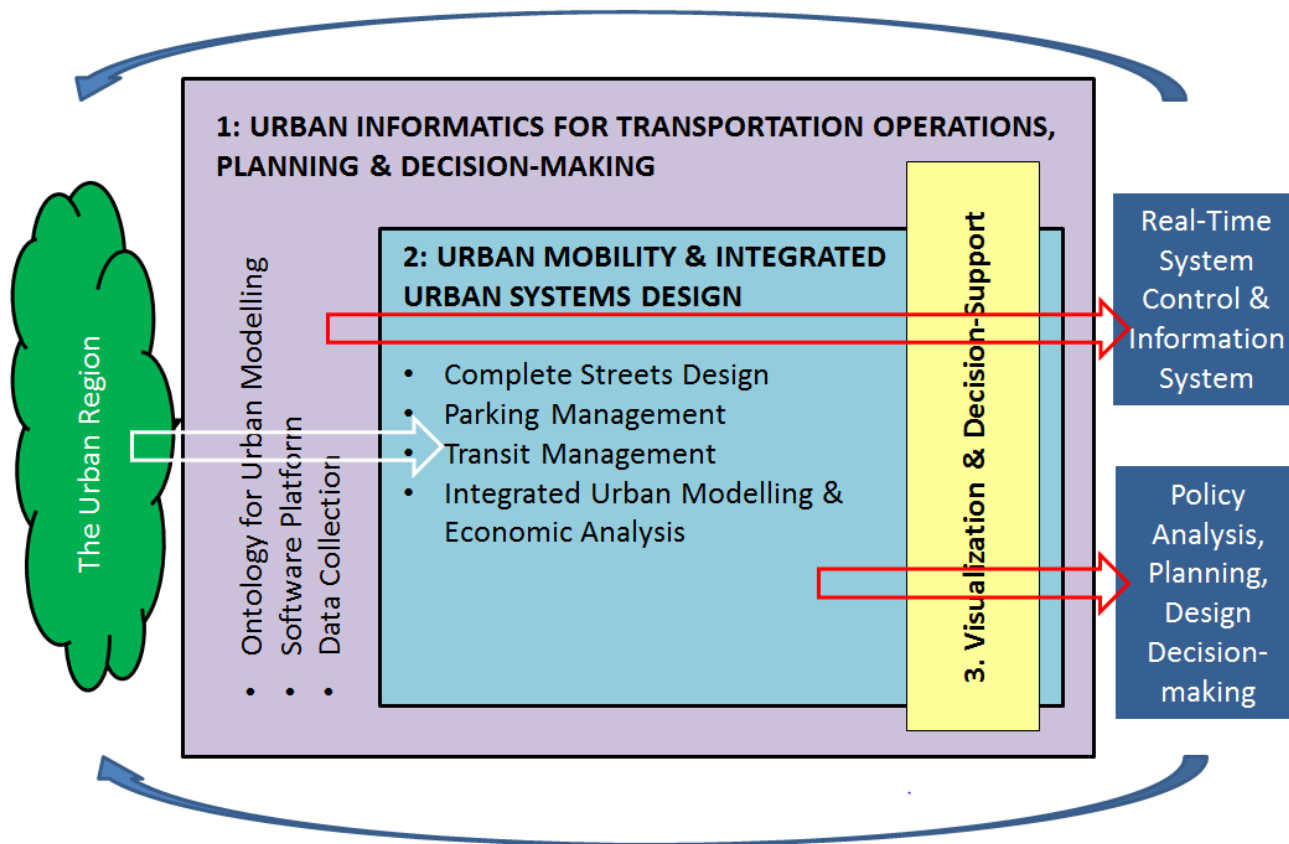
**Megan Katsumi & Mark S. Fox**

**Enterprise Integration Lab ([eil.utoronto.ca](http://eil.utoronto.ca))**

**University of Toronto Transportation Research Institute ([uttri.ca](http://uttri.ca))**

**University of Toronto**

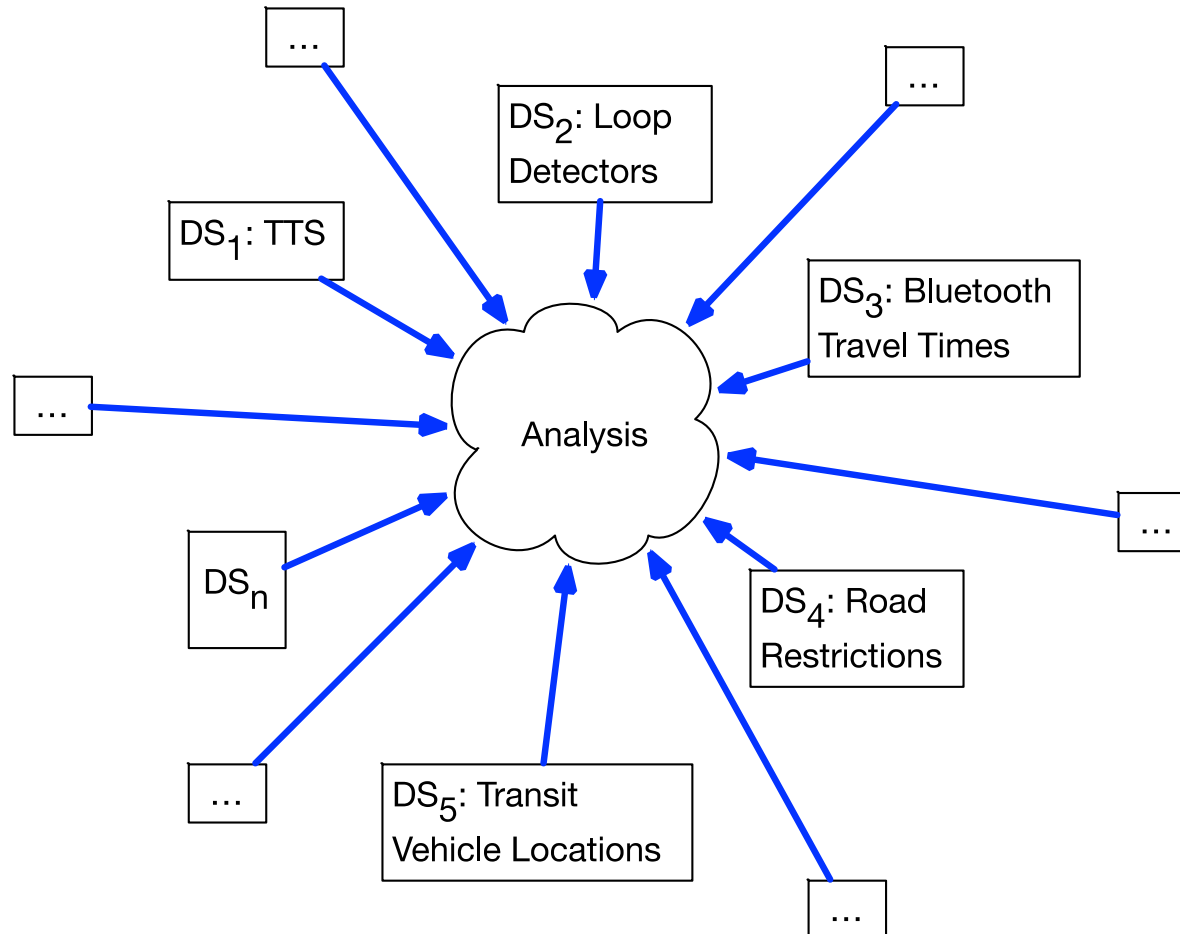
# iCity: Three themes and 10 projects



<http://uttri.utoronto.ca/research/projects/icity/>

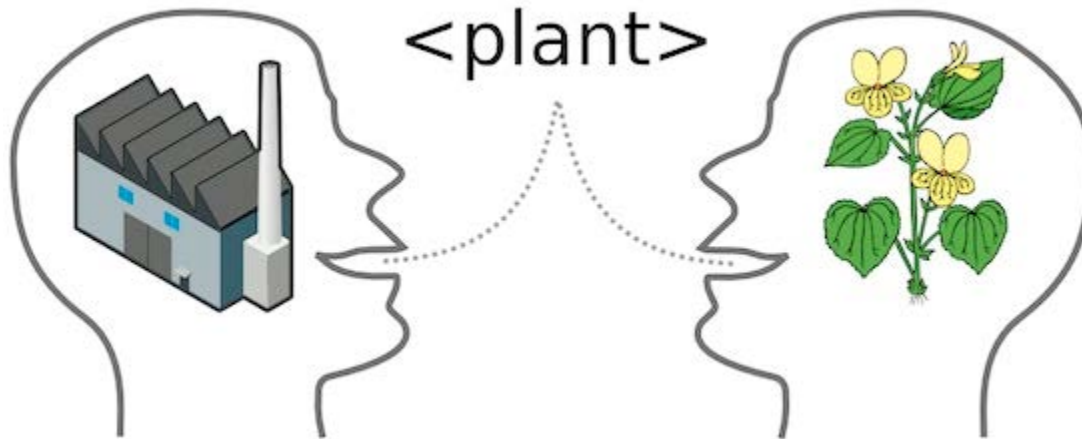
# A Morass of Data

- Sensors, studies, simulations,...



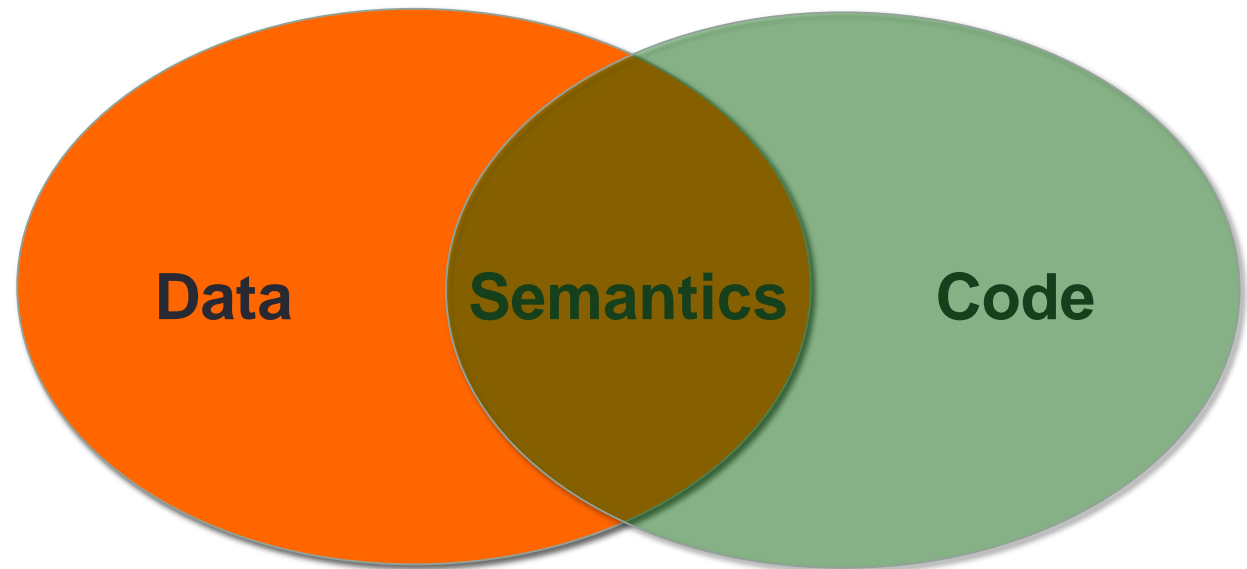
# Challenge: Semantic Interoperability

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



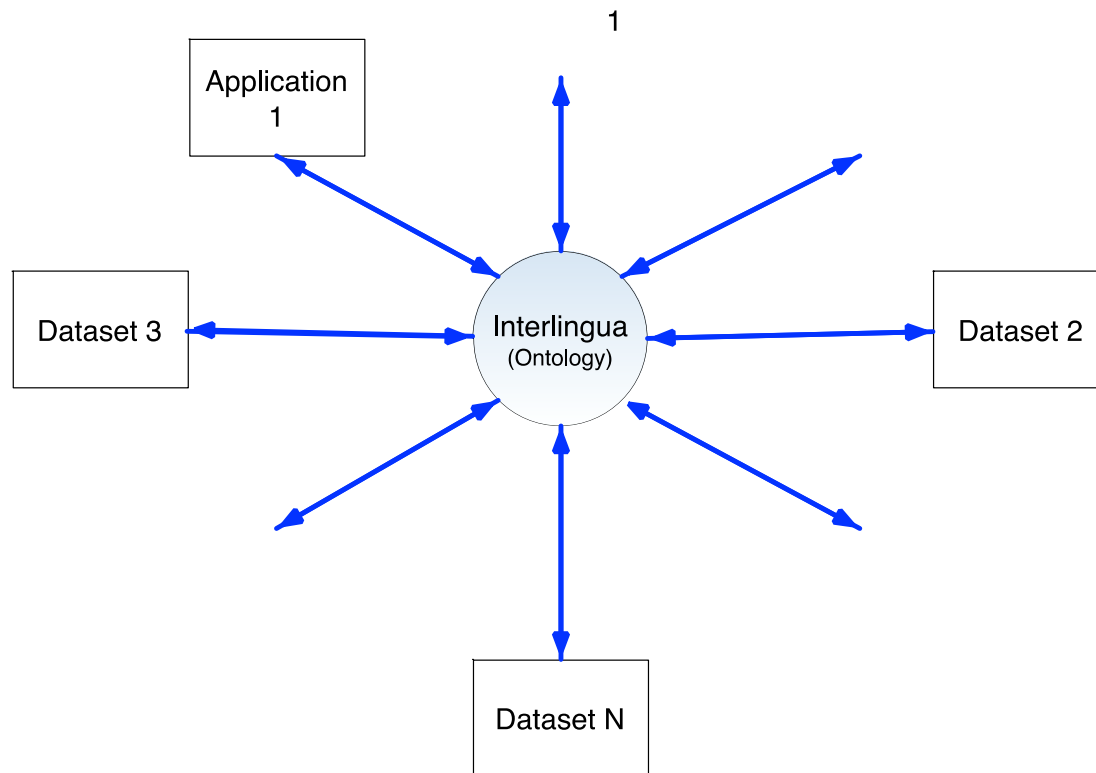
- A requirement for machine reasoning, knowledge discovery, and data federation across information systems.

# The Source Of Problem



# Solution: an Ontology for Urban Informatics

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

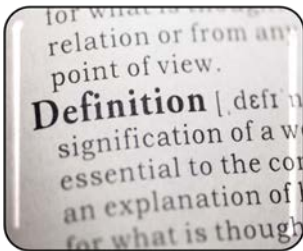


# The Ontology Approach



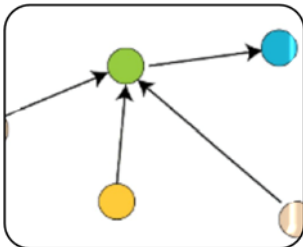
## Micro-Theory

- Axioms/Rules
- Deduction – answering questions



## Definitions and Constraints

- Class Definitions (in Logic)
- Automated classification

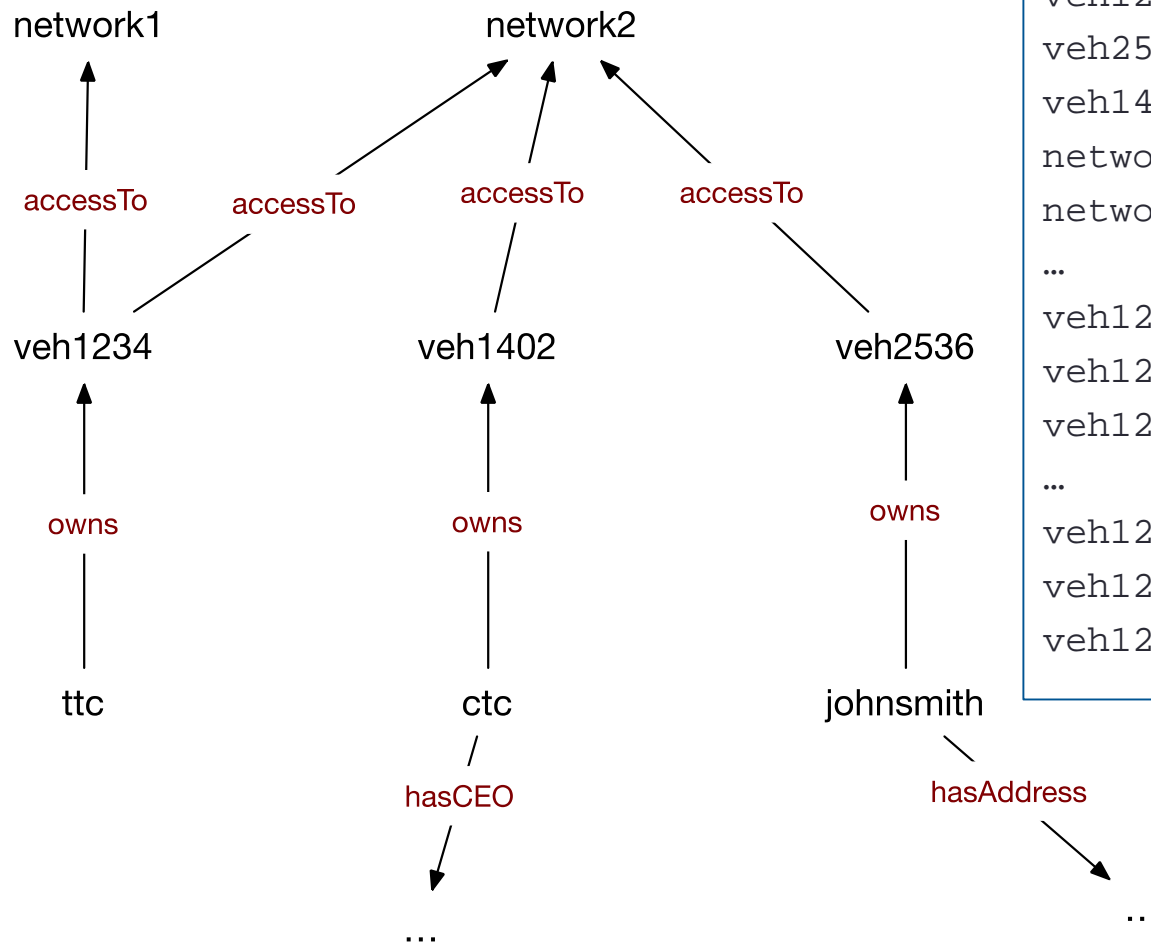


## Knowledge Graph

- Classes and Properties
- Taxonomy and Inheritance



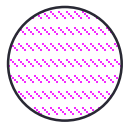
# Example Knowledge Graph



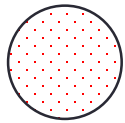
```

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.
  
```

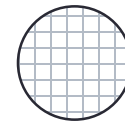
# An Example: Definitions and Constraints



**Vehicle**



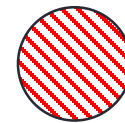
$\exists$  accessTo.RoadSystem



**TransitVehicle:**

TransitVehicle  $\equiv$  Vehicle  $\sqcap$   
 $\exists$  accessTo.TransitSystem

TransitVehicle  $\sqsubseteq$   
 $\neg$ (HouseholdVehicle)



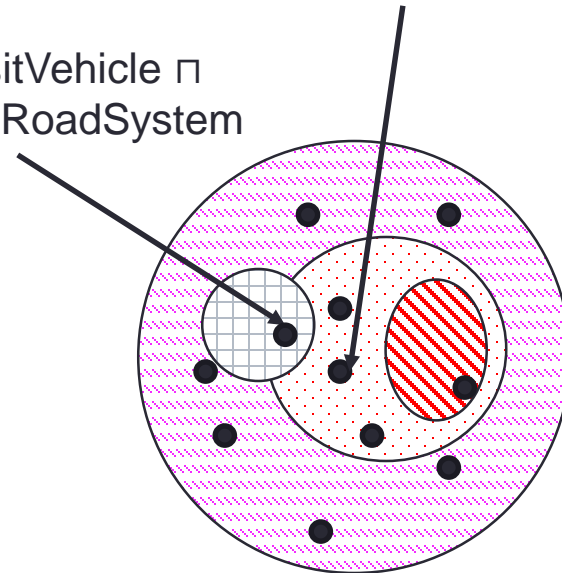
**HouseholdVehicle:**

HouseholdVehicle  $\equiv$  Vehicle  
 $\sqcap$   $\exists$  ownedBy.Person

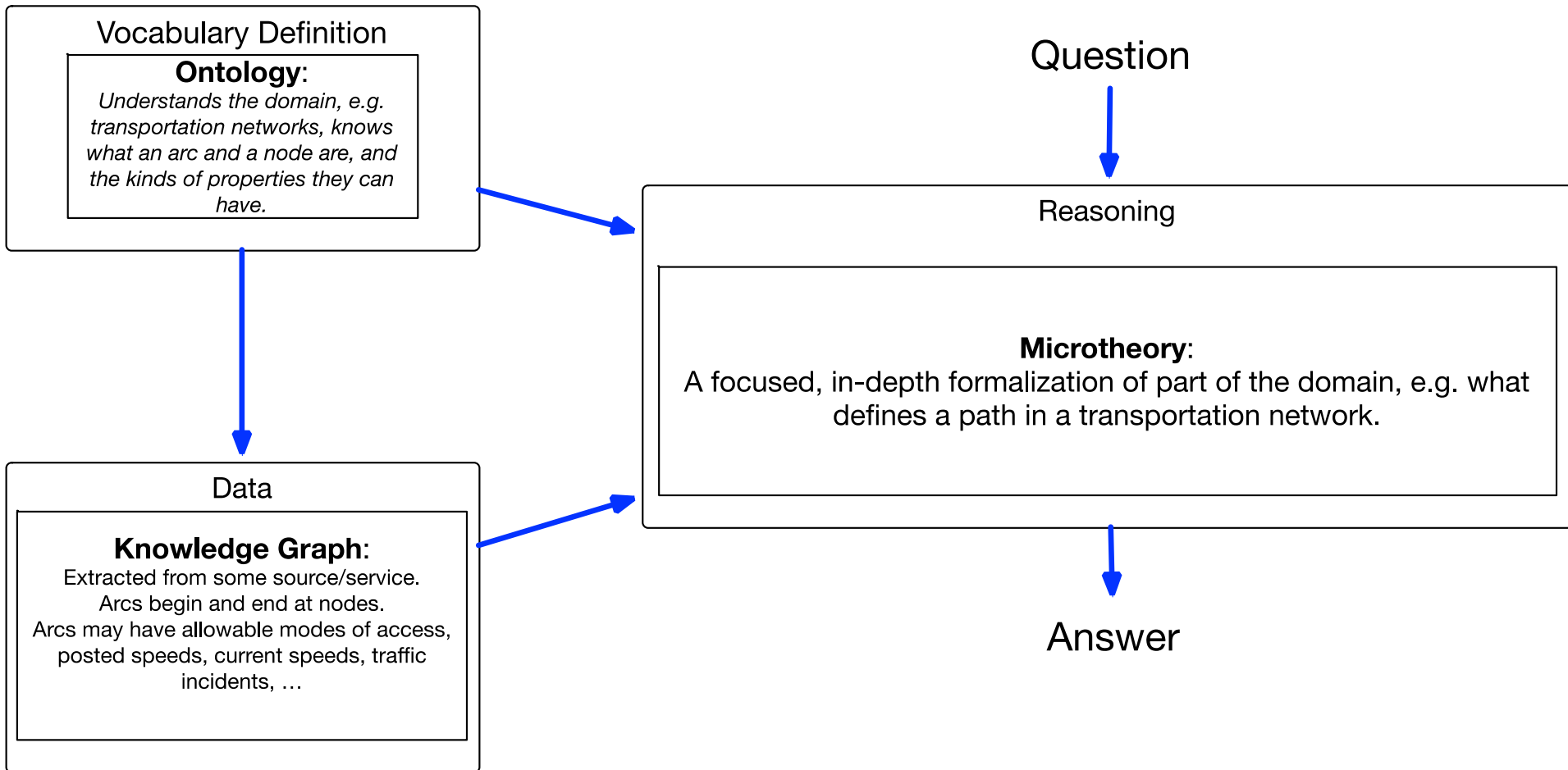
HouseholdVehicle  $\sqsubseteq$   $\neg$ (TransitVehicle)

CommercialVehicle  $\equiv$  Vehicle  $\sqcap$   
 $\exists$  accessTo.RoadSystem  $\sqcap$   $\neg$ (TransitVehicle)  
 $\sqcap$   $\neg$ (HouseholdVehicle)

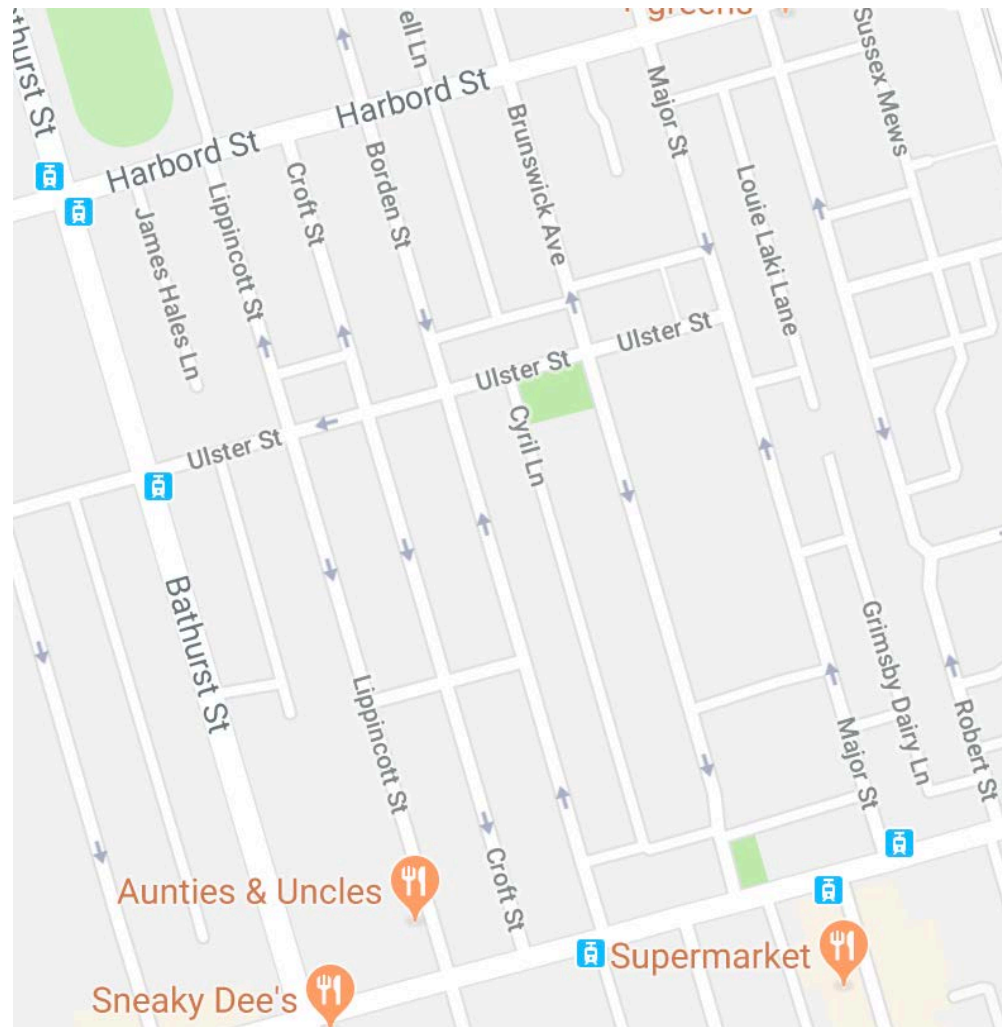
Bus  $\equiv$  TransitVehicle  $\sqcap$   
 $\exists$  accessTo.RoadSystem



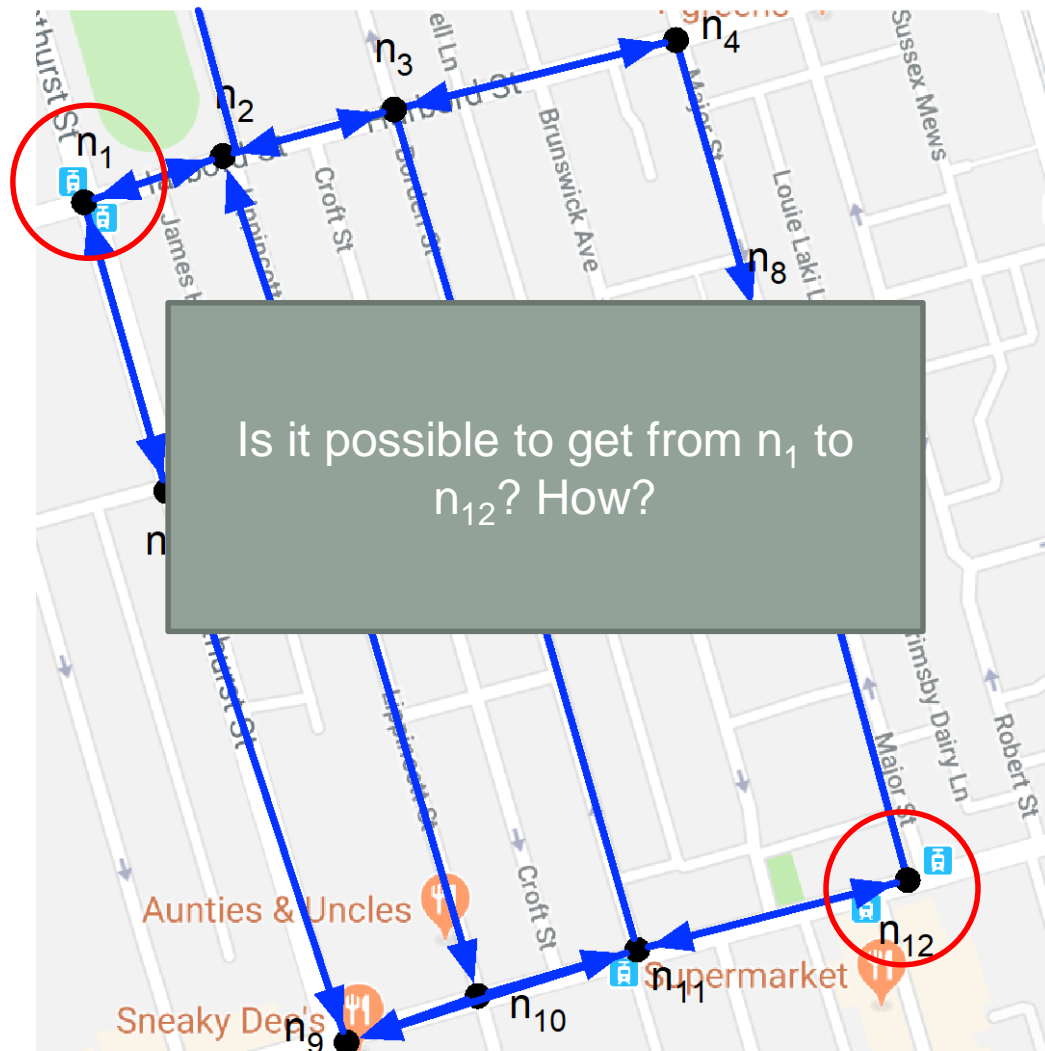
# Inference



# Example Road Network



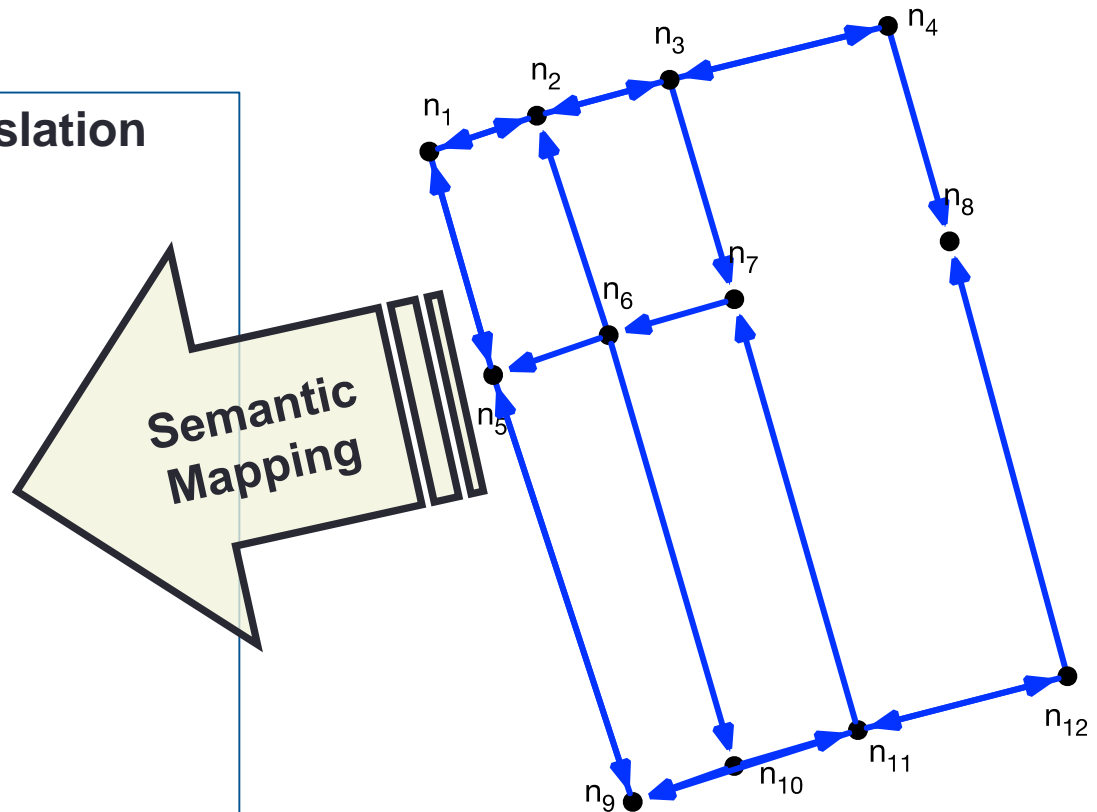
# Example Road Network



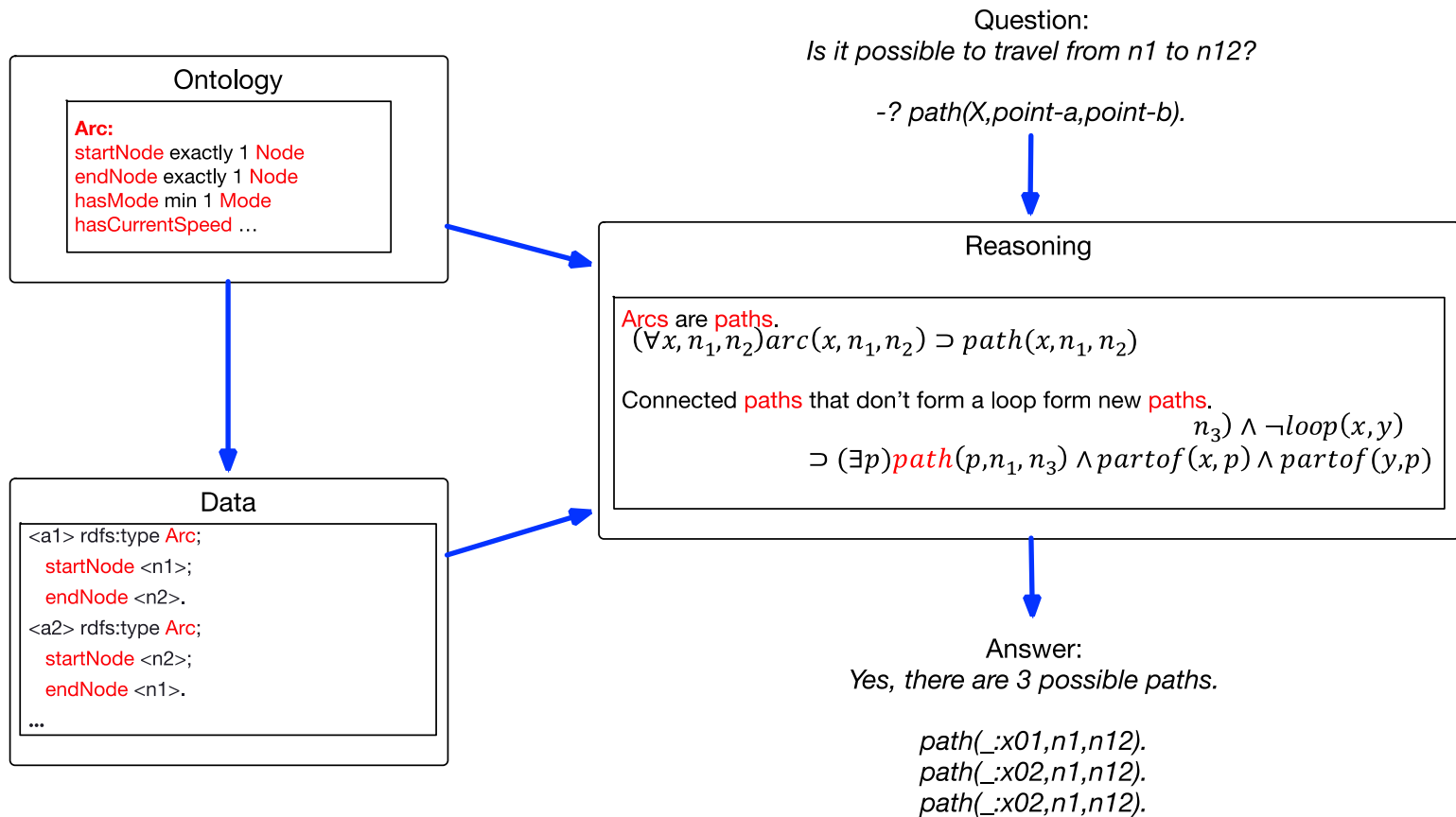
# Formalization

## Knowledge Graph Translation

```
<a1> rdfs:type Arc;  
  startNode <n1>;  
  endNode <n2>.  
<a2> rdfs:type Arc;  
  startNode <n2>;  
  endNode <n1>.  
<a3> rdfs:type Arc;  
  startNode <n6>;  
  endNode <n2>.  
...
```

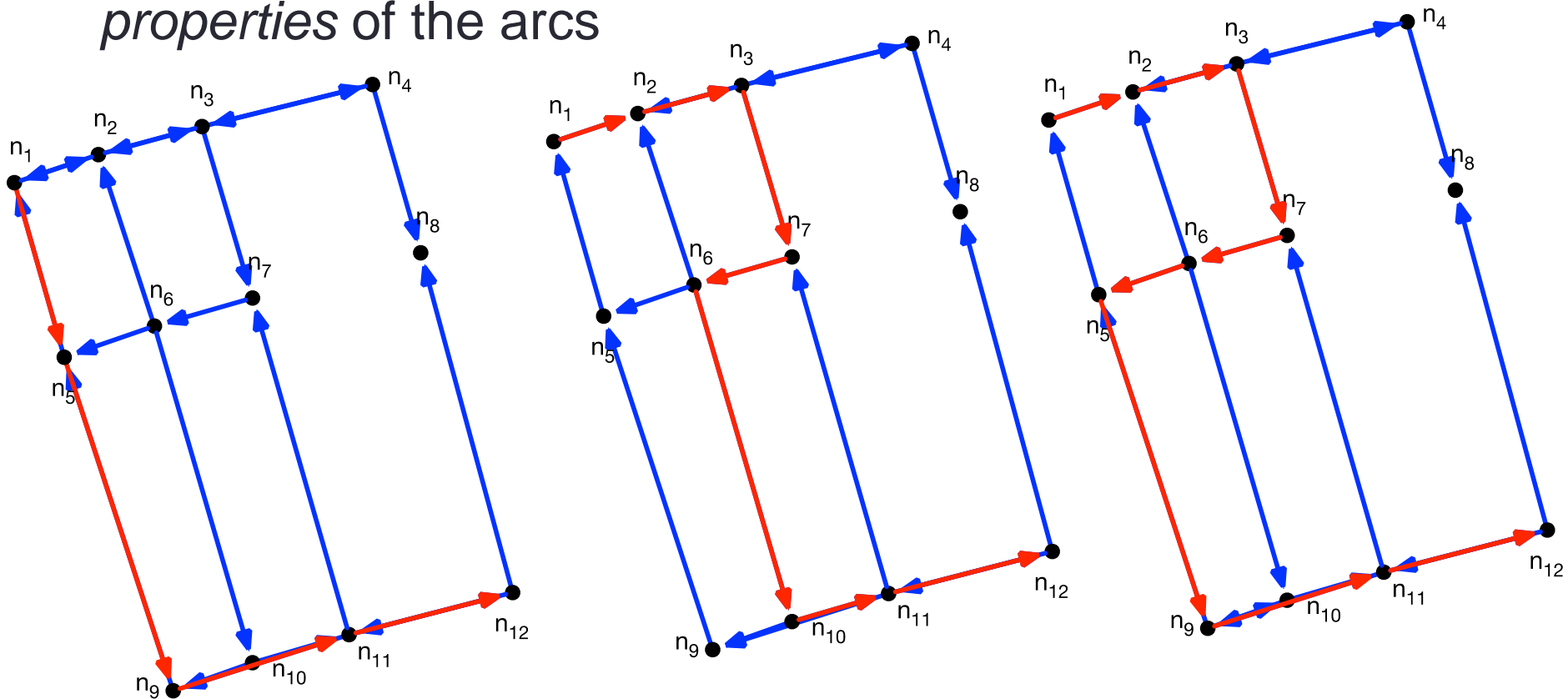


# Automated Reasoning



# New Knowledge

- Infer the existence of paths
- Infer additional knowledge about the paths based on *properties* of the arcs





# Final Thoughts

- Explicit specification of semantics supports:
  - Integration
  - Deduction of new knowledge
- Applications beyond the iCity project
- Ongoing Work
  - Implementation with IT-SoS
  - Development of microtheories: focused, detailed extensions to enable specialized reasoning
    - Deployment as web application(s)
  - Explore visualization solutions to support communication of the ontology and its instances.

# Thank you

- Questions?
- Contact me:
  - [katsumi@mie.utoronto.ca](mailto:katsumi@mie.utoronto.ca)
- More on the iCity Ontology and related work:
  - <http://uttri.utoronto.ca/research/projects/icity/papers/theme-one/>