The iCity Ontology: Towards a Data Standard for Transportation Planning

iCity-ORF Research Days Webinar Series

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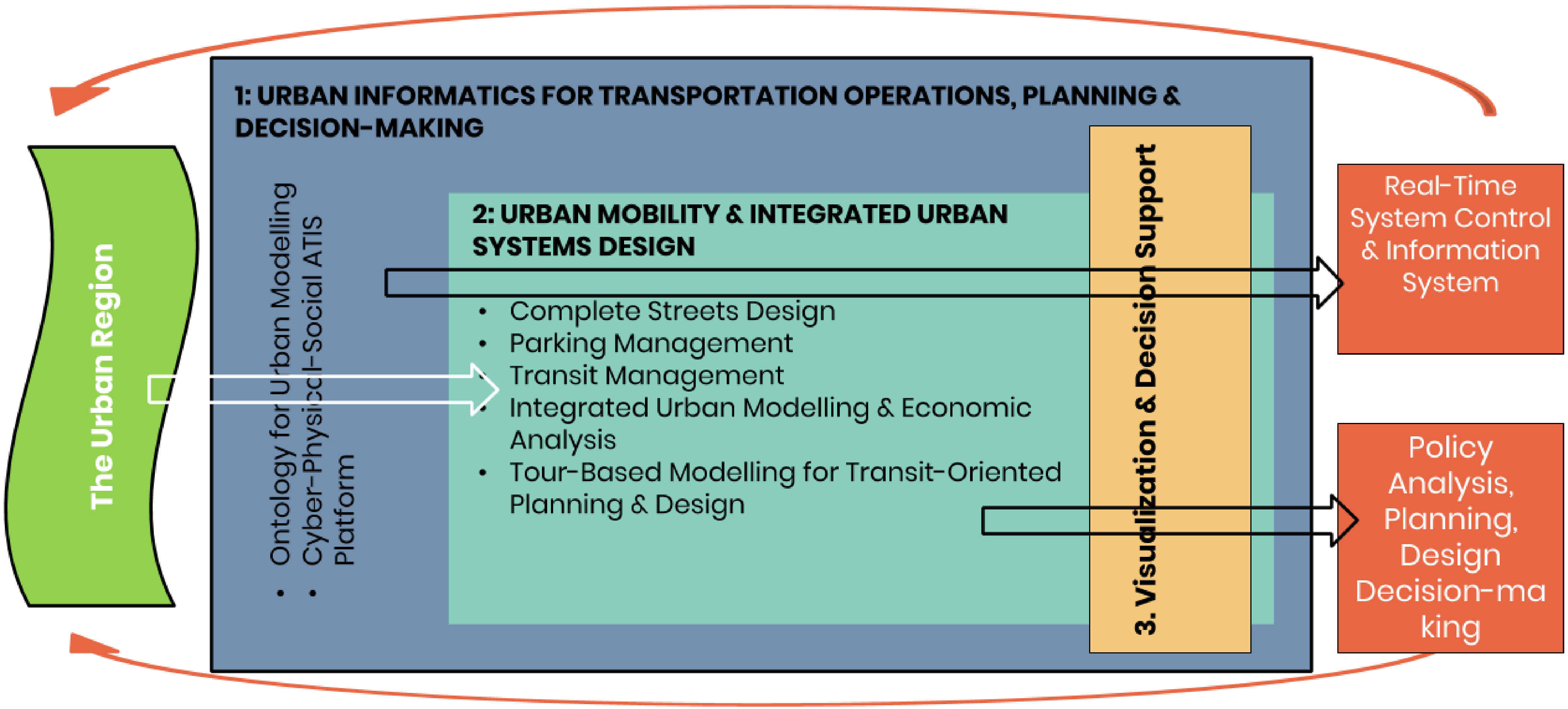


iCity Ontology

Our Focus:

- How is it all related?
- Can it be combined?
- How can it be shared?

Wait – what's an ontology?

- A specialized model
  - 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 these concepts?
- Provides a precise, formal representation that is machine-interpretable
  - More than a reference model (vocabulary) for a domain
  - Supports:
    - Data reuse
    - Data validation
    - Semantic integration
    - Inference

Example: Definition of a Route

- **Simulation Route**: a route represents a possible path of travel. It begins and ends at some distinct nodes in the transportation network and connects the start and end points by accessing some set of arcs.

$$SimulationRoute \sqsubseteq \exists hasStart.Node \sqcap \exists hasEnd.Node \sqcap \exists accesses.Arc$$

- **Wayfinding Service Route**: a route represents a possible path of travel. It has a start and an end node and some associated geometry.

$$Wayfinding \sqsubseteq \exists hasStart.Node \sqcap \exists hasEnd.Node \sqcap \exists hasShape.Geometry$$

Data to Knowledge

Semantic Mapping to Ontology

{ID} → Simulation_Route

{Start} → Node

Simulation_Route hasStart {Start}

…

Route → Wayfinding_Service_Route

o → Node

…

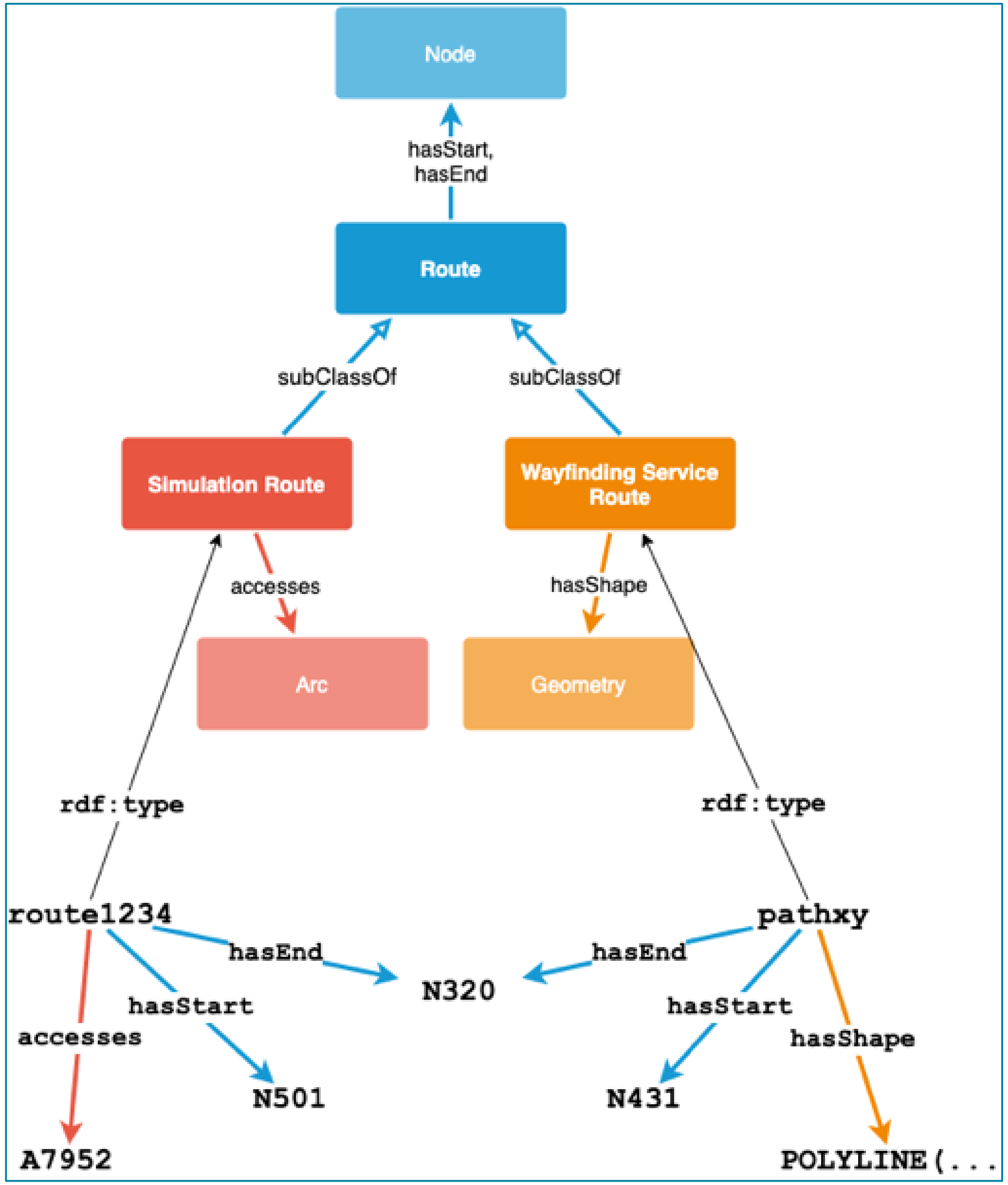
Travel simulation routes

ID	Start	End	Arc	Attr
route1234	N501	N320	A7952	…
…				

Wayfinding Route Records

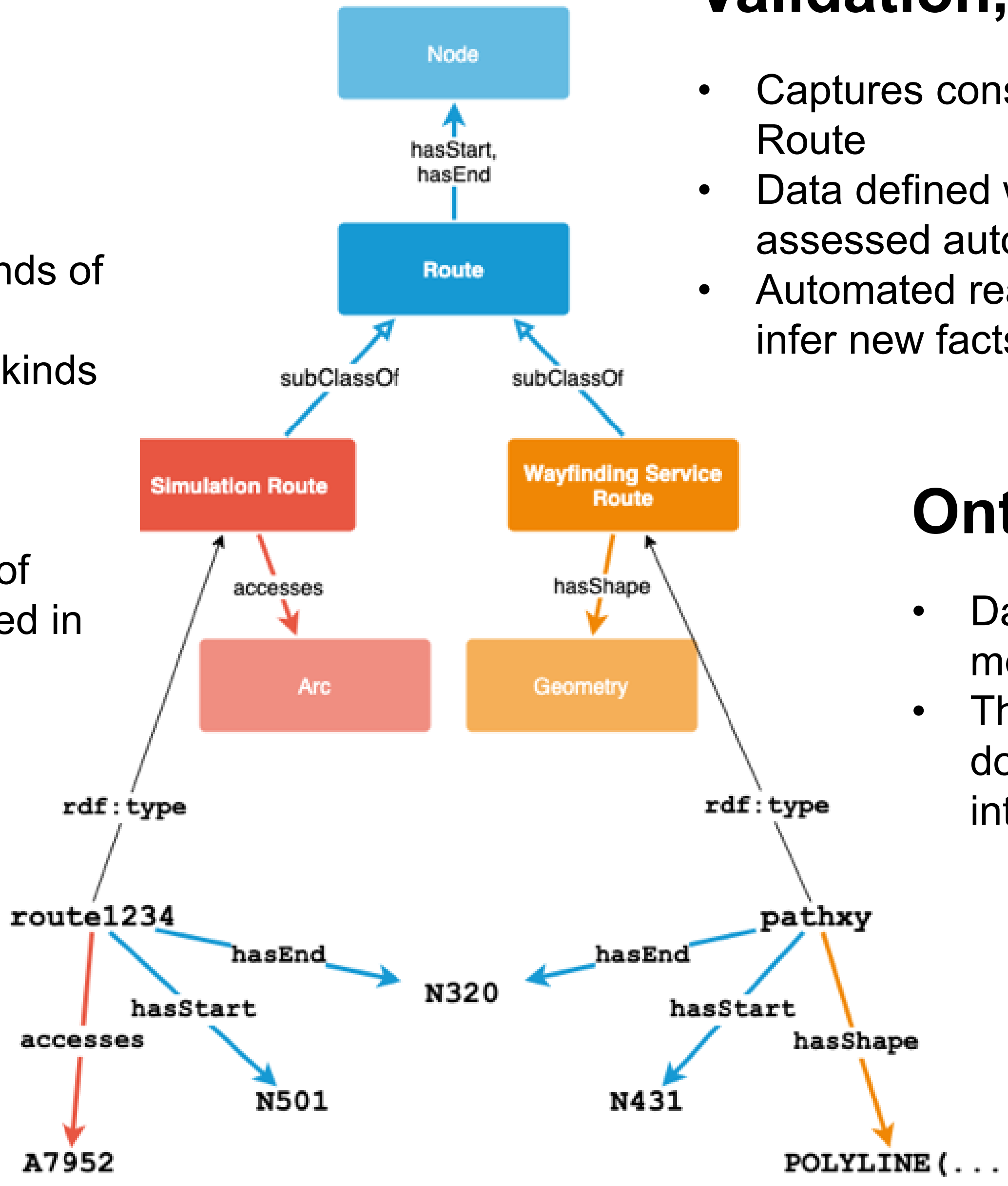
User	Route	o	d	Shape
jsmith	pathxy	N431	N320	POLYLINE(…
…				

Knowledge Graph



Ontology for Integration

- Supports the definition of multiple kinds of route
- Explicitly identifies how the different kinds of routes are related
  - What's common between them
  - What's different between them
- Data sources using either definition of route can be understood and captured in an integrated knowledge base



Ontology for Data Validation, Inference

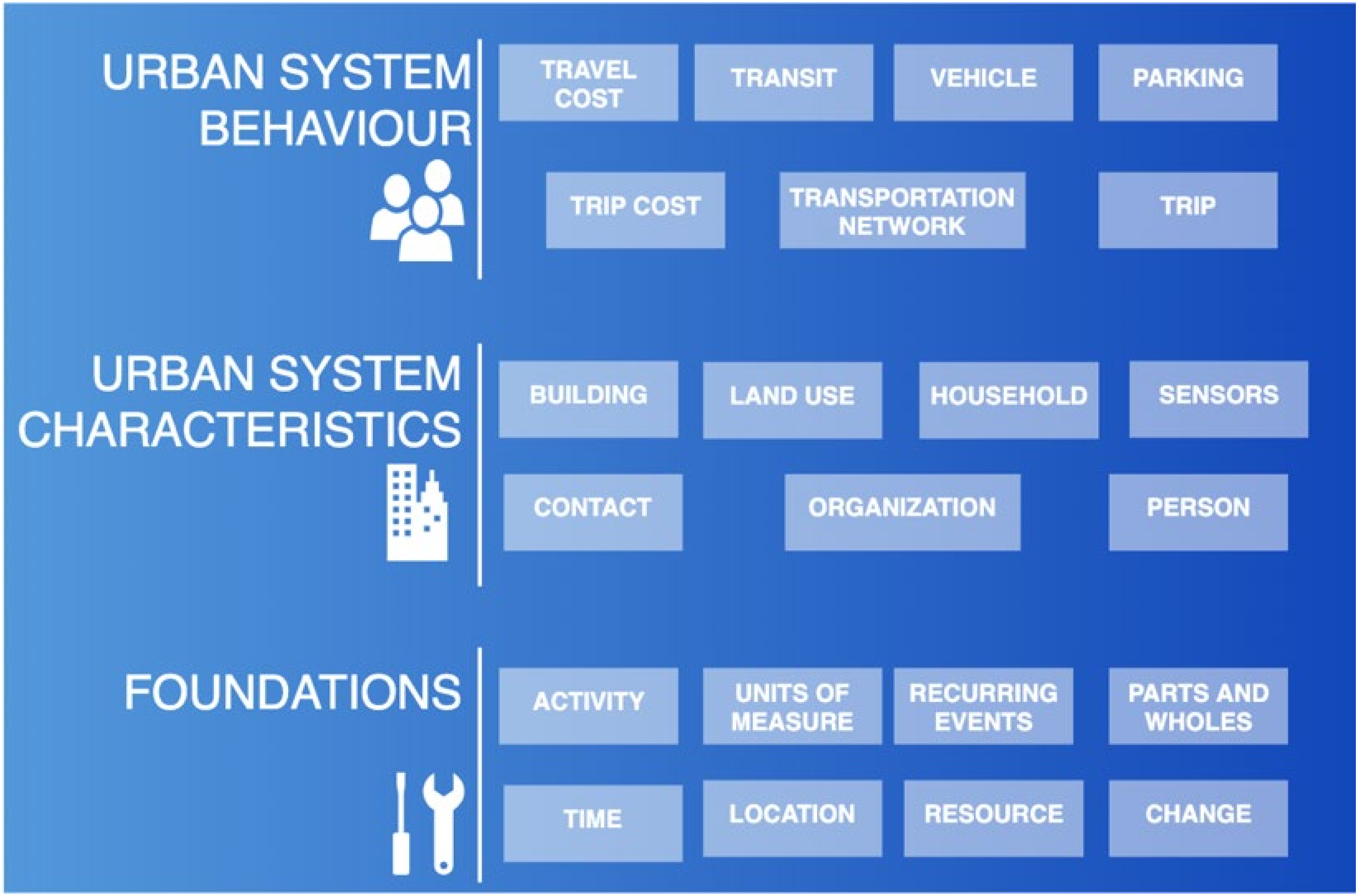
- Captures constraints on each type of Route
- Data defined with the ontology can be assessed automatically
- Automated reasoners can be applied to infer new facts about the data

Ontology for Data Reuse

- Data defined with the ontology has meaning embedded
- The representation serves as documentation for how it should be interpreted

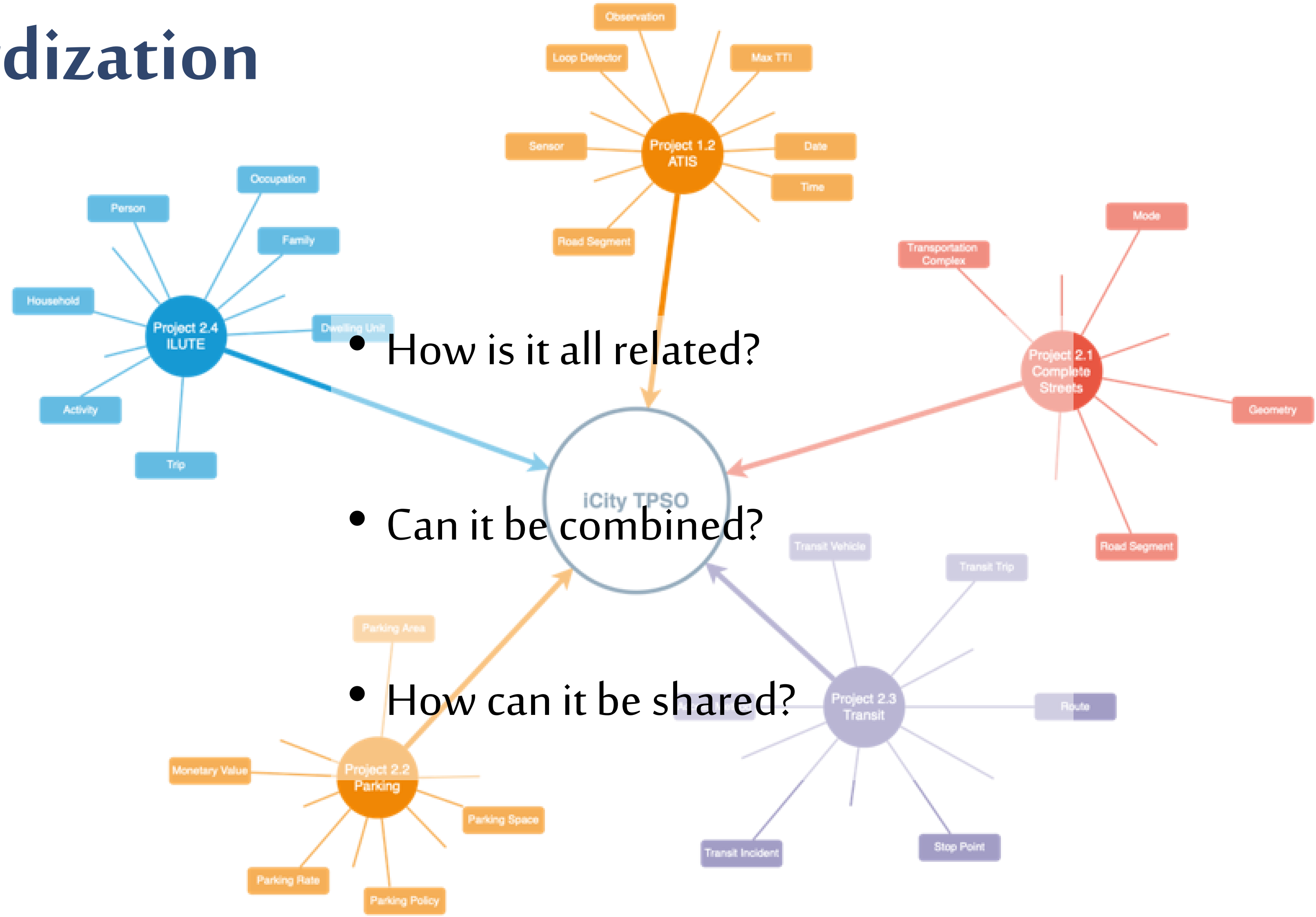
iCity TPSO

- iCity Transportation Planning Suite of Ontologies
- Developed & implemented for transportation planning activities in iCity-ORF project



iCity TPSO: Standardization

- **Observation**: this is a general challenge for transportation planning
- Led to the creation of multi-part ISO standards projects for a city data model



- How is it all related?
- Can it be combined?
- How can it be shared?

Transportation Planning: The Data Problem

- Data is siloed: acquired and generated data is expensive, but often not reused
- Multitude of transportation planning tools are in use by researchers and cities
- No easy way to compare results as each has their own unique data models

A standard for this data is needed!

What about existing standards?

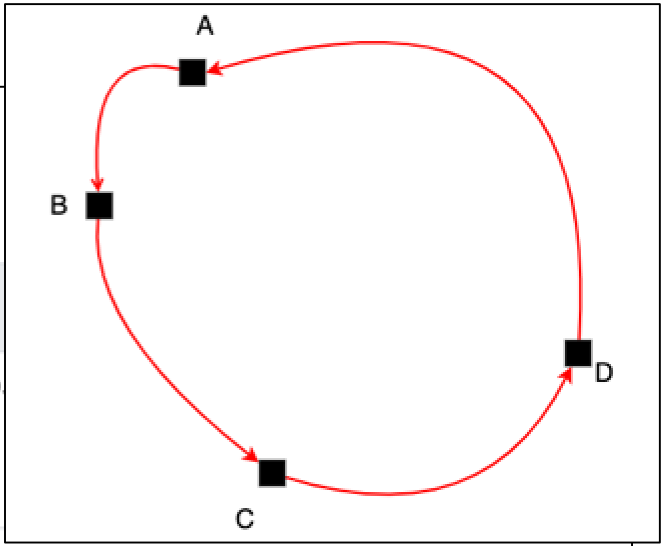
- Scope: existing standards overlap with, but **don't cover the domain of transportation planning**
- Encoding: traditional standards are **subject to ambiguity**, despite detailed definitions

Example: GTFS

stop_times.txt

File: **Required**

Field Name	Type	Required	Description
`trip_id`	ID referencing `trips.trip_id`	Required	Identifies a trip
`arrival`	Time	Conditionally	Arrival time at a specific stop for a specific trip on a route. If there



What about loop routes?

`stop_id`	ID referencing `stops.stop_id`	Required	Identifies the serviced stop. All stops serviced during a trip must have a record in stop_times.txt. Referenced locations must be stops, not stations or station entrances. A stop may be serviced multiple times in the same trip, and multiple trips and routes may service the same stop.
`stop_sequence`	Non-negative integer	Required	Order of stops for a particular trip. The values must increase along the trip but do not need to be consecutive. *Example: The first location on the trip could have a* `stop_sequence=1`*, the second location on the trip could have a* `stop_sequence=23`*, the third location could have a* `stop_sequence=40`*, and so on.*

- GTFS: General Transit Feed Specification[1]
- Common format for public transit data (schedules, locations,…)
- Highly successful, widely adopted

[1] https://developers.google.com/transit/gtfs

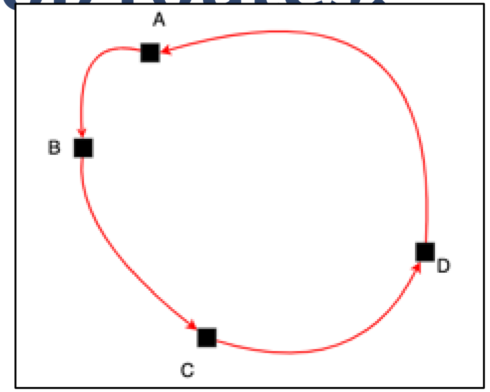
Example: How to define stop times for loop routes?

Option A:

Trip_id	arrival_time	departure_time	stop_id	stop_sequence	stop_headsign
trip_1	06:10:00	06:10:00	stop_A	1	"outbound"
trip_1	06:15:00	06:15:00	stop_B	2	"outbound"
trip_1	06:20:00	06:20:00	stop_C	3	”inbound"
trip_1	06:25:00	06:25:00	stop_D	4	"inbound"

Option B:

Trip_id	arrival_time	departure_time	stop_id	stop_sequence	stop_headsign
trip_1	06:10:00	06:10:00	stop_A	1	"outbound"
trip_1	06:15:00	06:15:00	stop_B	2	"outbound"
trip_1	06:20:00	06:20:00	stop_C	3	”inbound"
trip_1	06:25:00	06:25:00	stop_D	4	"inbound"
trip_1	06:30:00	06:30:00	Stop_A	5	“”



- Not explicitly addressed in the reference
- Identified as a special case in the GTFS best practices document
- *Recommendation*: Option B

Ambiguity in Standards Specifications

Traditional approach

- Detailed documentation
- Modelling languages that focus on the data's structure but not its semantics
- Meaning is grounded in natural language

LEADS TO

Challenges

- Natural language inherently ambiguous
- Need for supplementary material to resolve individual issues
  - Examples, best practices,…
  - But can't predict or detect everything
- Differences in interpretation lead to differences in adoption
  - Impacts the standard's effectiveness

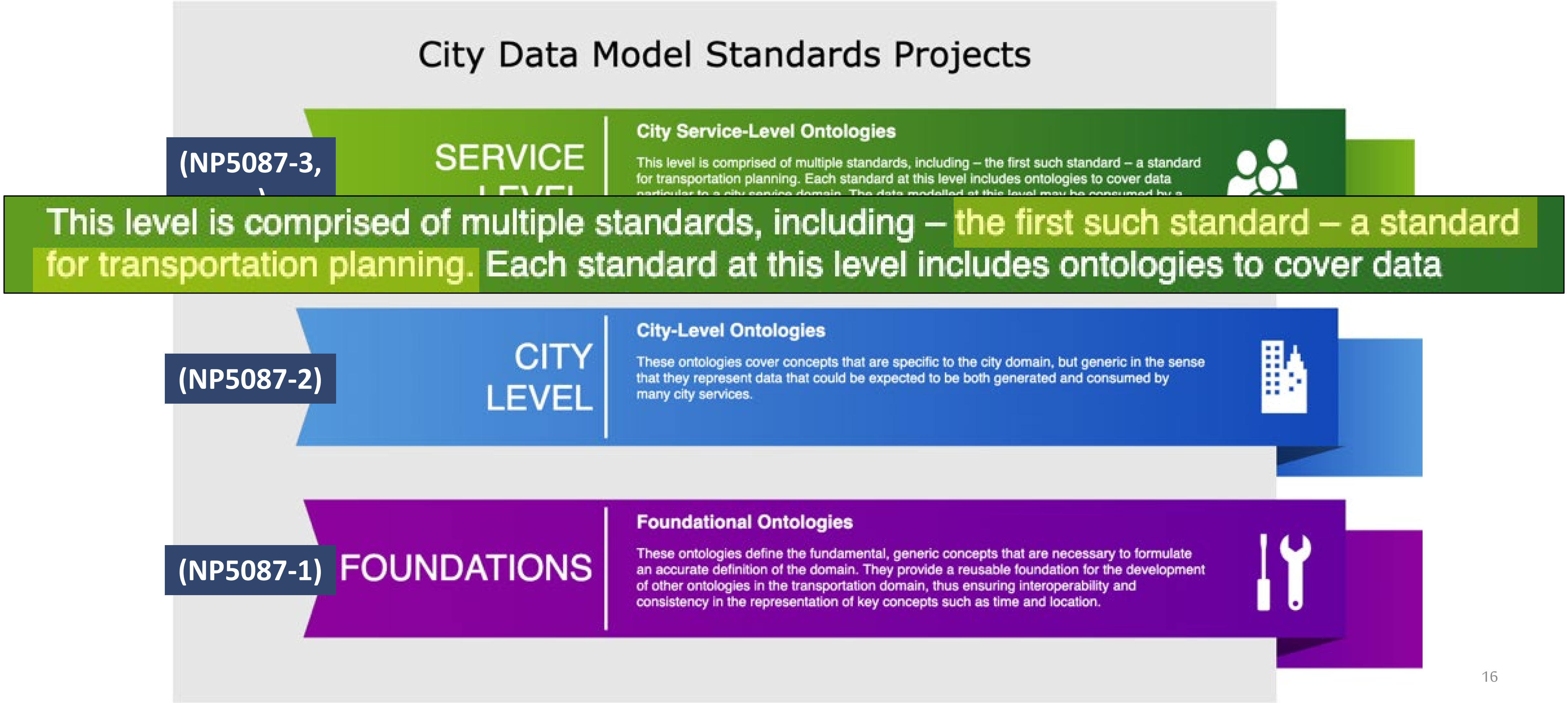
An ontology-based standard for transportation planning

Our proposal: Ontologies (the iCity TPSO in particular) provide a way to address:

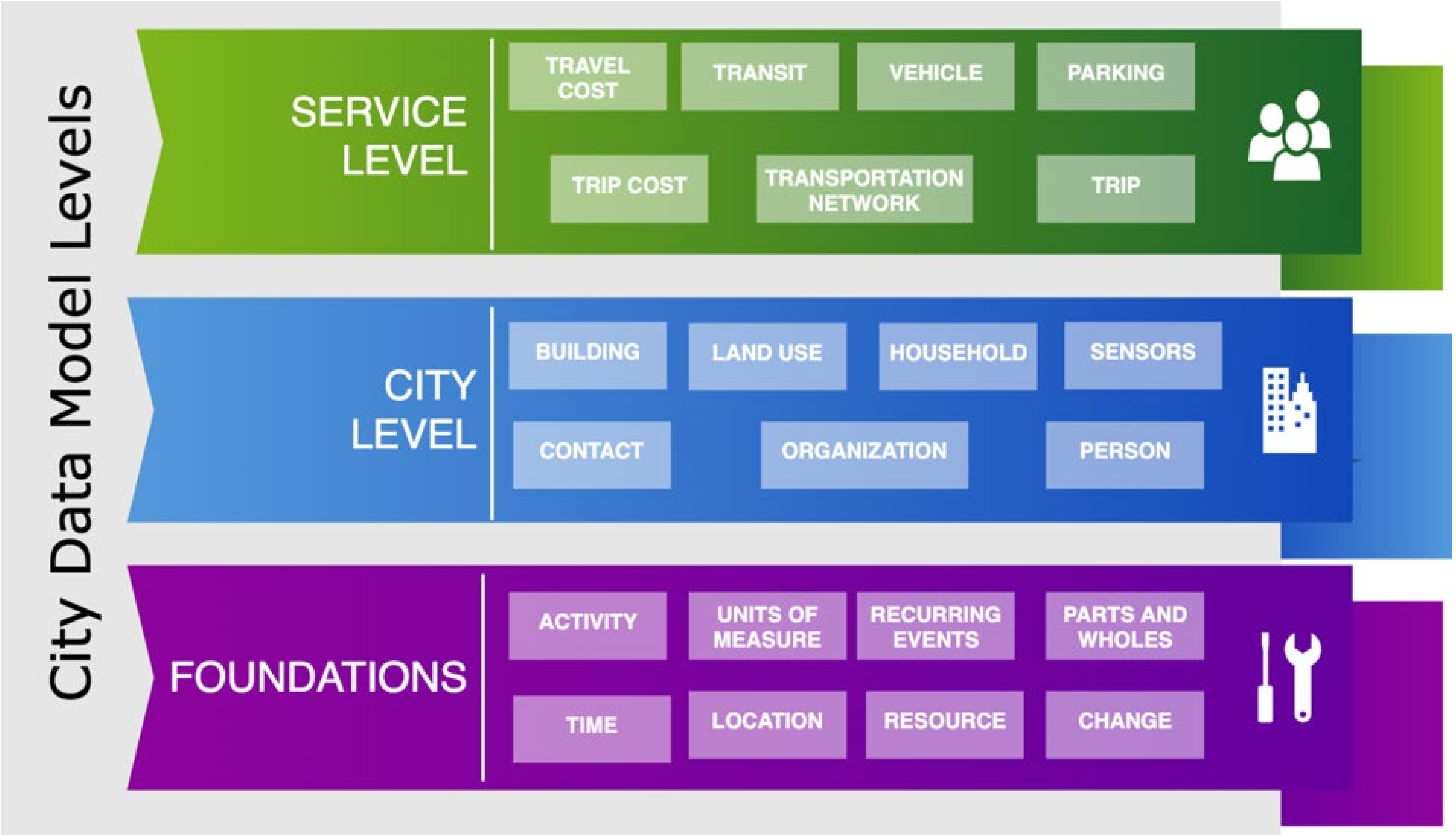
- a major challenge for transportation planning,
  and
- a limitation of traditional approaches to standards specification

- Has a **unique** interpretation:
  - Explicit, unambiguous encoding
  - Incorrect and correct interpretations may be automatically identified
- Added benefits:
  - Works with different tools and data formats
  - Supports a dynamic domain: core concepts are easily extended
  - May be implemented for other applications (e.g. reasoning)

ISO/IEC JTC1 WG11 Smart Cities
City Data Model NP5087



City Data Model: Transportation Planning (NP5087-3)



Standards Collaboration

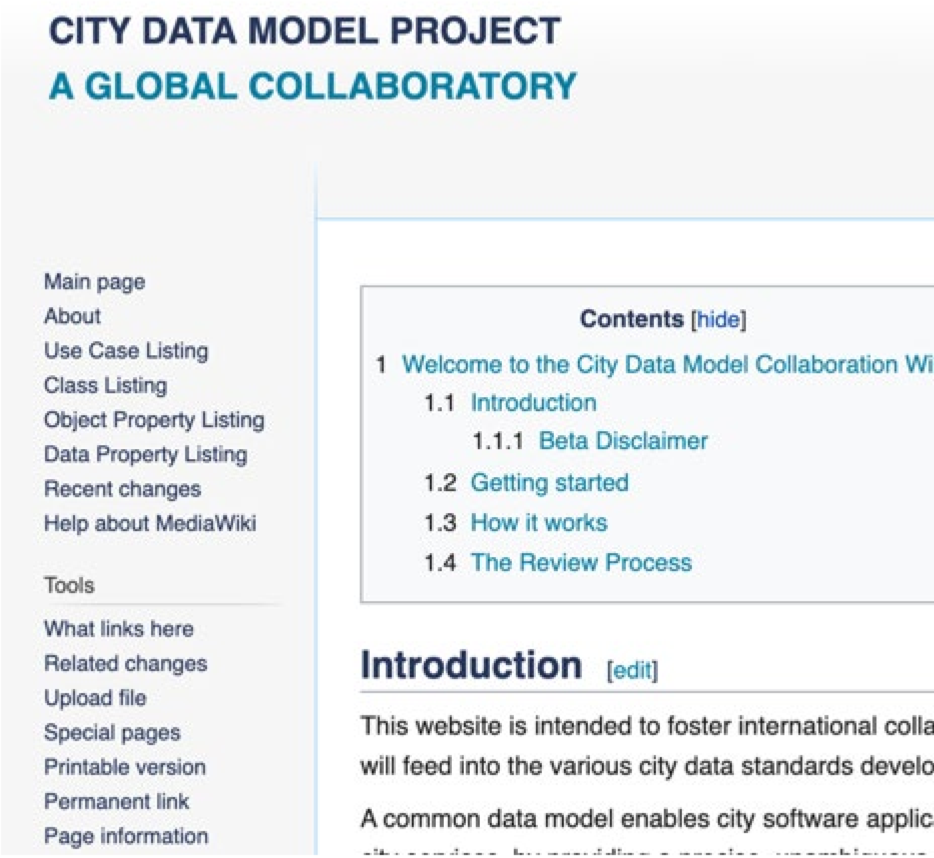
- Another standard, another silo?
  - How can we avoid this?
- There is a need to collaborate with other groups in order to understand how definitions of overlapping concepts are related
- We created a **Global Collaboratory** to support the alignment of the city data model standards with other standards efforts

The City Data Model Global Collaboratory

http://citydata.utoronto.ca [2]

- Develop a global consensus on the City Data Model
  - Identify concepts and definitions to be included
  - Align related concepts across standards

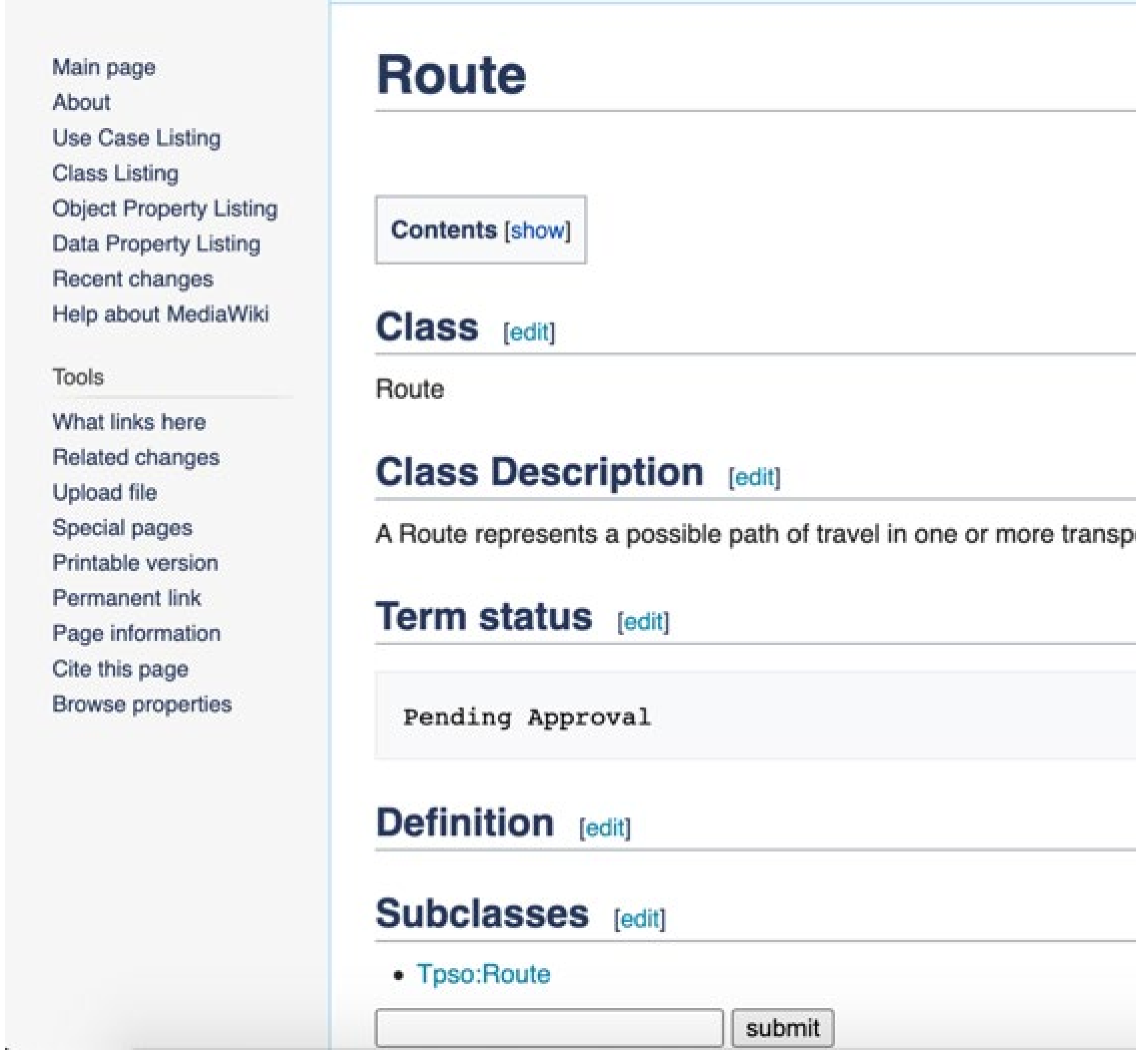
- Tasks supported:
  - Browse and review content
  - Comment on existing content and suggest changes or revisions
  - Propose terms and definitions
  - Submit use cases to explain/justify terms and definitions



[2] To be: citydatastandard.org

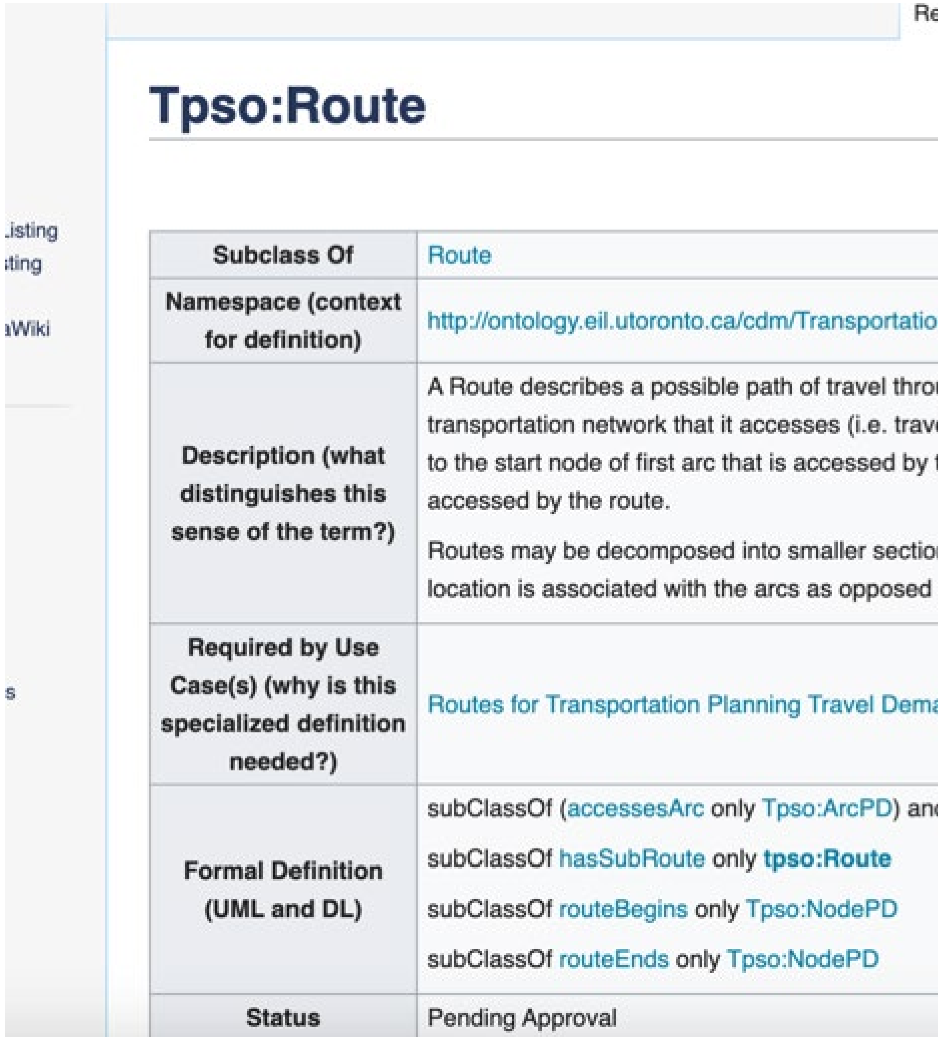
The Proposal Process: New terms

- Anyone can propose a new term.
- Once a term has been proposed, it becomes open for the specification of definitions from the community.
- Terms may be independent, or proposed as specializations of existing terms (i.e. sub-classes or sub-properties)



The Proposal Process: New definitions

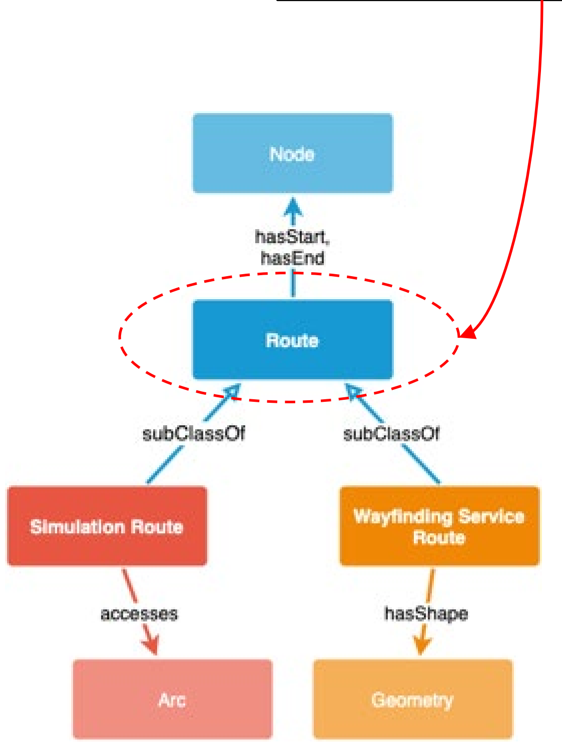
- Proposed definitions for a term must be specified in a *formal* language (Description Logic or UML)
- Proposed definitions must be accompanied by a use case
- Subject to community review
- Multiple definitions allowed and expected
  - Do not need to agree on one
  - Once discussion of definitions has settled, administrators will review all proposed definitions and identify the **minimum viable definition** for the term.



The Proposal Process: Minimum Viable Definitions

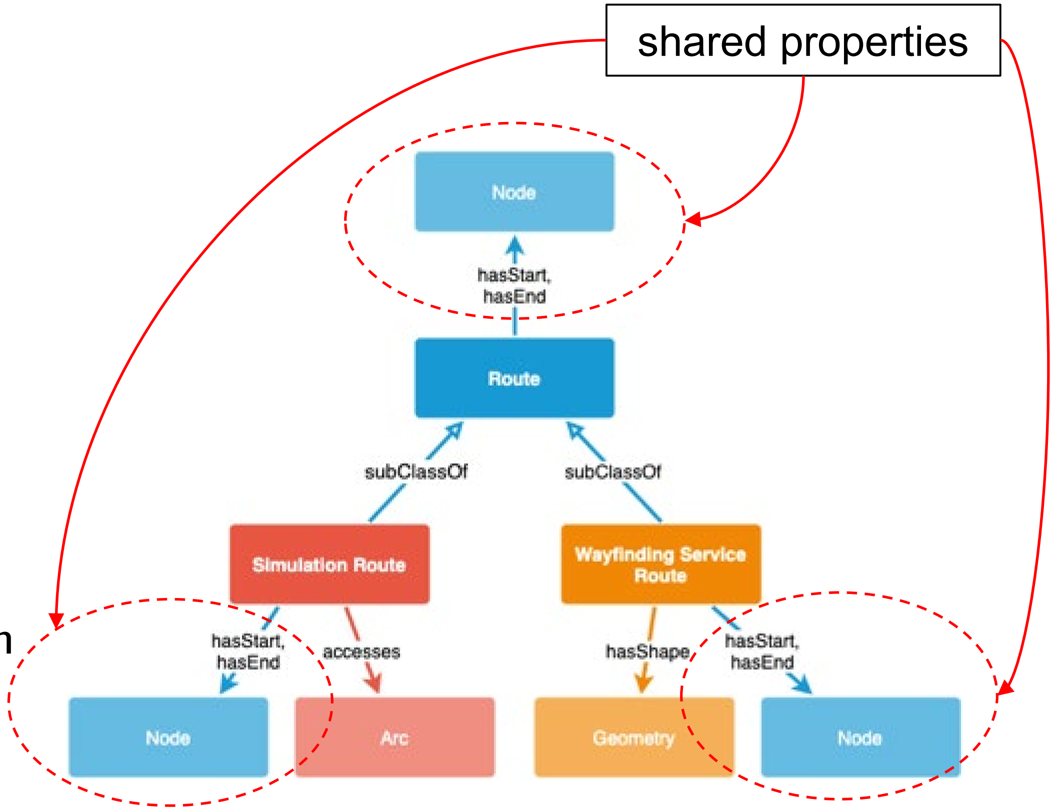
- Identified relative to a set of definitions for the same term
- The *minimum* semantics required for a term
  - Shown to be shared between each definition in the set

minimum viable definition



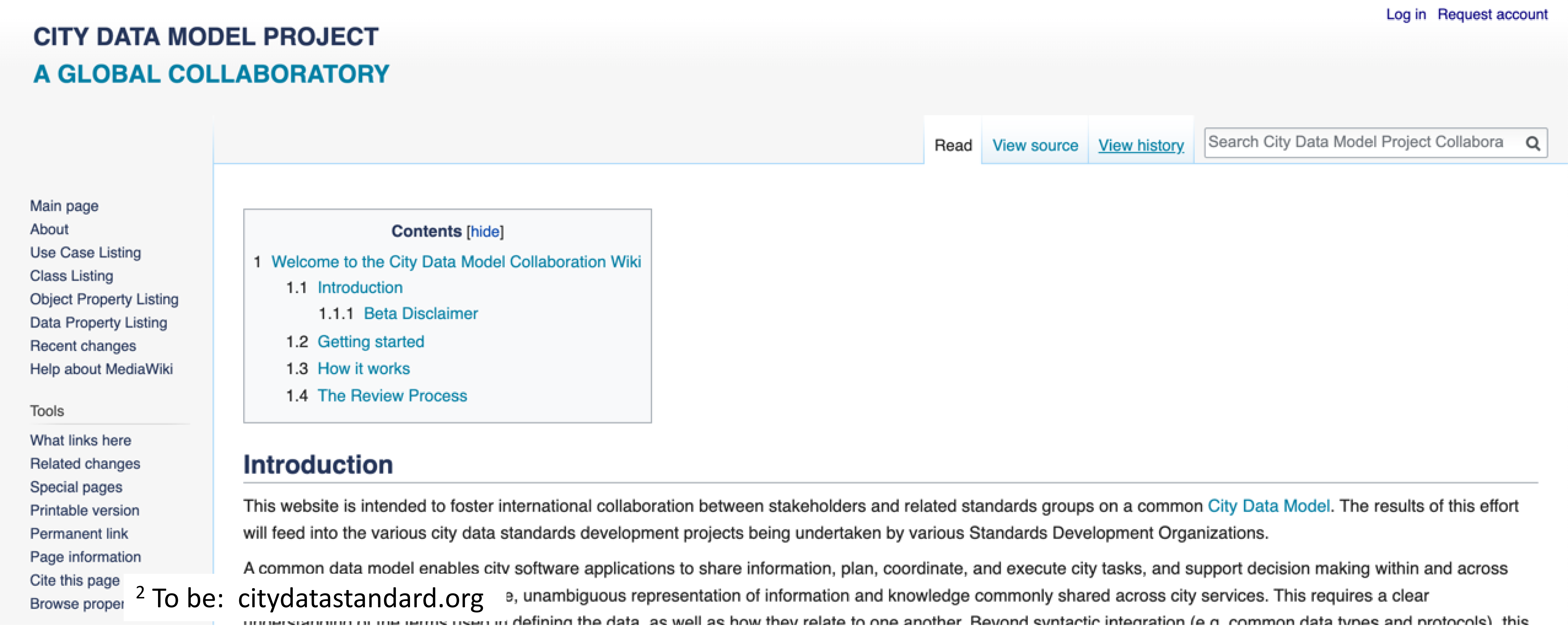
Minimum Viable Definitions

- Clearly identifies the shared meaning that all stakeholders have in common regarding a particular term
  - Definition identifies the set of properties shared amongst distinct definitions
    - Subset of shared terminology
  - Distinct definitions identified as subclasses of the minimum viable definition



Participants welcome!

http://citydata.utoronto.ca[2]



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