The **Ontario Road Network (ORN)** data represents the provincial road infrastructure and is segmented at real-world intersections or junctions. Each road net element in the ORN corresponds to a continuous stretch of roadway bounded by two junctions, meaning it begins and ends at **TransportNodes** such as intersections or dead ends.

In the **ISO/IEC 5087-3 ontology**, these segments are best modeled as **RoadLink** entities, which are a subclass of **TravelledWayLink**. Since **RoadLinks** connect junctions, and each ORN segment is defined by start and end junctions, this alignment is semantically accurate. A **Road** is a collection of **RoadLinks**.

Thus, **ORN** road net elements → **RoadLinks**, and **TransportNodes** → **Junctions**, consistent with ISO's transportation network modeling approach.

Namespaces Used:

- **GEO**: Geospatial ontology from GeoSPARQL — used for spatial concepts like Geometry, WKT literals TRANSPORT: Transportation Network pattern from ISO/IEC 5087-3 — includes core classes like Road, RoadLink, Junction, etc.
- **INFRAS**: Transportation Infrastructure pattern from ISO/IEC 5087-2 — specialized types of infrastructure (e.g., RoadLink, RoadSegment)
- **GEO_LOC**: Spatial Location pattern from ISO/IEC 5087-1 — used to define spatial positions (e.g., hasLocation, asWKT)
- **PARTWHOLE**: Mereology (part-whole relationships) from ISO/IEC 5087-1 — defines hasProperPart / properPartOf relationships
- **CITYUNITS**: City Units pattern from ISO/IEC 5087-1 — used for physical measures (e.g., speed, length) with measurementValue + unitOfMeasure
- **CDT**: City Digital Twin namespace — used to define custom/extended properties not in the ISO standard
- **RDFS**: RDF Schema vocabulary — used to define class hierarchies and metadata (e.g., subClassOf, label, comment)
- **I72**: # ISO 21972-based ontology for standardized quantity/value modeling (e.g., Length, Speed, Weight)
- **GEN**: # ISO 5087-1 Generic Properties — used for linking general metadata like identifiers
- **RDF**: # RDF standard namespace for core RDF types and structures (e.g., rdf:type)

Toronto Bound Filter:

lat_min: 43.5810, lat_max: 43.8555, lon_min: -79.6393, lon_max: -79.1152,

Data Provided by ORN Shapefile:

ORN Data Tag	ORN Data Description	Type	Equivalence
OGF_ID	A unique numeric provincial identifier assigned to each object.	Int	N/A
FROM_JCT	The beginning junction for a road element or ferry connection.	Int	trans:from
TO_JCT	A statement that identifies the positional accuracy of the ORN road geometry in metres.	Int	trans:to
ACCURACY	A statement that identifies the positional accuracy of the ORN road geometry, in metres.	Int	cdt:roadAbsoluteAccuracy
NID	A unique national identifier assigned to a road net element, junction and selected event data such as Toll Point, Blocked Passage and Structure which are required to support the National Road Network (NRN).	String	cdt:nationUUID
LENGTH	The measured planimetric length of a road net element in meters.	Int	cdt:length
DIRECTION	The direction(s) of vehicular or motor traffic flow. All road elements must have a direction of traffic flow assigned.	String	cdt:trafficFlow
EXIT_NUM	The number of an exit on or off a freeway, expressway or highway, assigned by an administrating body and is represented by a valid number or character.	String	cdt:exitNumber
ELEM_TYPE	An attribute describing the type of road net element.	String	cdt:roadElementType
TOLL_ROAD	Indicates if the road net element is a toll road.	String	cdt:tollRoadIND

ACQTECH	The type of data source or technique used to create or revise the road net element.	String	cdt:aquisitionTechnique
CREDATE	The date the road net element was originally created.	Date	cdt:creationDate
REVDATE	The date the road net element was last revised or updated.	Date	cdt:revisionDate
GEO_UPD_DT	Date/time the geometry was created or last modified in the source database.	Date	cdt:geoUpdateDate
EFF_DATE	Date/time the record was created or last modified in the source database.	Date	cdt:effectiveDate

Data Provided by ORN csv Files:

Note: All the following CSV files had a data tag ORN_ROAD_NET_ELEMENT_ID, an Integer representing a system-generated identifier unique at the application level.

Data Provided by ORN_SPEED_LIMIT.csv:			
ORN Data Tag	ORN Data Description	Type	Equivalence
SPEED_LIMIT	The maximum speed limit assigned to a road element in kilometres per hour in accordance with Municipal By-Laws or Provincial Law.	Int	trans:speedLimit

ORN_SPEED_LIMIT.csv: The maximum speed limit assigned to a road element in kilometres per hour in accordance with Municipal By-Laws or Provincial Law. In cases where a road element has more than one speed limit value, the speed limit of the longest portion of the road element is supplied.

Data Provided by ORN_ROAD_CLASS.csv:			
ORN Data Tag	ORN Data Description	Type	Equivalence
ROAD_CLASS	The classification of a road.	String	cdt:roadClass

ORN_ROAD_CLASS.csv: A linear event identifying the class of road based on a functional classification schema.

Data Provided by ORN_OFFICIAL_STREET_NAME.csv:			
ORN Data Tag	ORN Data Description	Type	Equivalence
FULL_STREET_NAME	This attribute is derived from the individual street name components where present, namely directional prefix, street type prefix, street name body, street type suffix and directional suffix and is stored in upper case text.	String	cdt:roadName

ORN_OFFICIAL_STREET_NAME.csv: An event identifying an official street name and may be associated with a bilingual name. A language code shall be used to specify the applied language which resides in the Street_Name_Parsed Table.

Data Provided by ORN_BLOCKED_PASSAGE.csv:			
ORN Data Tag	ORN Data Description	Type	Equivalence
BLOCKED_PASSAGE_TYPE	A man-made or natural barrier or access restriction placed on a road net element to control or limit access to a road net element.	String	cdt:blockedPassage

ORN_BLOCKED_PASSAGE.csv: A point event on a road element identifying the existence of an access barrier or an obstruction, either man-made or natural, which controls or limits access to a road element

Data Provided by ORN_JURISDICTION.csv:			
ORN Data Tag	ORN Data Description	Type	Equivalence
JURISDICTION	An indication of who has the jurisdictional, or custodianship responsibility for a road net element. The custodian would have the responsibility to ensure maintenance occurs, but is not necessarily the one who undertakes the maintenance directly.	String	cdt:jurisdiction

STREET_SIDE	The side of the street for which the addressing applies.	String	cdt:streetSide

ORN_JURISDICTION.csv: Identifies jurisdictional, or custodianship responsibility of the road

Data Provided by ORN_ROAD_SURFACE.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
SURFACE_TYPE	A linear event indicating the surface type of a road element.	String	cdt:surfaceType
PAVEMENT_STATUS	The surface type of a road element.	String	cdt:pavementStatus

ORN_ROAD_SURFACE.csv: The surface type of a road element.

Data Provided by ORN_NUMBER_OF_LANES.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
NUMBER_OF_LANES	The number of lanes of a road.	Int	trans:numLanes

ORN_NUMBER_OF_LANES.csv: A linear event indicating the number of lanes.

Data Provided by ORN_ROUTE_NAME.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
ROUTE_NAME_ENGLISH	The English name that is attached to a road net element as defined by a Municipality, Provincial Ministry, or Federal Agency and is associated to an established and/or maintained route.	String	cdt:routeName

ORN_ROUTE_NAME.csv: The name attached to a road net element as defined by a Municipality, Provincial Ministry, or Federal Agency and is associated to an established and/or maintained route.

Data Provided by ORN_ROUTE_NAME.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
ROUTE_NUMBER	The route number assigned to a road typically associated with provincial highways, secondary highways, county roads and regional roads and is represented by a numeric and/or an alpha-numeric character. A road can be assigned multiple route numbers.	String	cdt:routeNumber

ORN_ROUTE_NUMBER.csv: The route number attached to a road net element as defined by a Municipality, Provincial Ministry, or Federal Agency and is typically associated with provincial highways, secondary highways, county roads and regional roads

Data Provided by ORN_STRUCTURE.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
STRUCTURE_TYPE	The classification of a structure, that exists on a road element and is managed as a linear event.	String	cdt:structureType

ORN_STRUCTURE.csv: The classification of a structure, that exists on a road element and is managed as a linear event. The types are mutually exclusive.

Data Provided by ORN_TOLL_POINT.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
TOLL_POINT_TYPE	A point event on a road element identifying the existence of an underpass. An underpass occurs where the road element runs underneath a passage accommodating the movement of water, a building, road, rail, pedestrian or wildlife. options are: 1. Physical - A construction along or across a road element where toll can be paid to employees of the	String	cdt:tollPointType

	organization in charge of collecting the toll or to machines involving electronic methods of payment like credit cards or bank cards 2. Virtual - At a virtual point along a road element, toll will be charged via automatic registration of the passing vehicle by subscription or invoice 3. Hybrid - A tollbooth, which is both physical and virtual. Valid values: 'Hybrid', 'Physical', 'Virtual'		

ORN_TOLL_POINT.csv: A point event along a road element indicating the presence of a toll point.

Data Provided by ORN_UNDERPASS.csv			
ORN Data Tag	ORN Data Description	Type	Equivalence
UNDERPASS_TYPE	Identifies the type of underpass present at this road location.	String	cdt:underpassType

ORN_UNDERPASS.csv: A point event on a road element identifying the existence of an underpass. An underpass occurs where the road element runs underneath a passage accommodating the movement of water, a building, road, rail, pedestrian or wildlife.

How Data is Used in Python Script:

```
BASE_URI = ...
GEO = Namespace(...)
TRANSPORT = Namespace(...)
…
```

- Defines RDF namespaces used to classify data according to ISO/IEC 5087 standards and custom extensions (CDT).

```
road_network_gdf = gpd.read_file(shapefile_path)
road_network_gdf["OGF_ID"] = …
```

- Loads the ORN Road Net Element shapefile.
- Converts OGF_ID to string so it can be merged with external attribute tables.

toronto_bounds = {...}

- Defines the bounding box for filtering geometry and junctions within the Toronto area.

csv_files = {...}
...
road_network_gdf = road_network_gdf.merge(...)

- Loads ORN supplementary data: road names, jurisdiction, pavement, structure, etc.
- Renames columns to avoid conflicts.
- Merges each CSV into the main GeoDataFrame using the road network element ID.
- Each feature in the ORN_ROAD_NET_ELEMENT.shp file is uniquely identified by an OGF_ID — this serves as the **primary key** for the shapefile.
- Meanwhile, the supplementary CSV files (e.g., speed limits, road names, number of lanes, etc.) use a corresponding column named ORN_ROAD_NET_ELEMENT_ID to reference the road network elements they describe. This acts as a **foreign key** pointing back to the shapefile data.

g = Graph()
g.bind(...)

- Sets up an RDFLib Graph and binds prefixes for Turtle serialization.

for _, row in data_frames["junctions"].iterrows():
    ...

- Processes junctions as instances of TransportNode.
- Associates them with geospatial coordinates (asWKT), filtered by Toronto bounds.
- Adds junctionType as a CDT extension.

def format_date(value: str) -> str | None:

- Safely converts date strings from ORN format (YYYYMMDDHHMMSS) into standard ISO xsd:date.

road_groups = road_network_gdf.groupby("FULL_STREET_NAME_road_names")

- Groups all ORN elements sharing the same official road name to build a single Road entity made of multiple RoadLinks.

for road_name, group in road_groups:
  …

- For each road:
  - Creates a transnet:Road (TravelledWay + Road).
  - Adds hasProperPart links to each associated RoadLink.
  - Each use geno:hasName property to refer to the name of the road.
- For each ORN element (line geometry):
  - Associates them with geospatial coordinates (asWKT), filtered by Toronto bounds.
  - Creates a transnet:RoadLink instance.
  - Adds metadata (speed, lanes, pavement, etc).
  - Links to source and destination junctions.
  - Attaches location as geo:asWKT.

g.serialize(destination=output_file, format="turtle")

- Serializes the RDF graph to a Turtle file ready for semantic reasoning or ingestion into a triple store.