UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB
SNAP4CITY

Data 4 Mobility

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Corso di: Big Data Architectures

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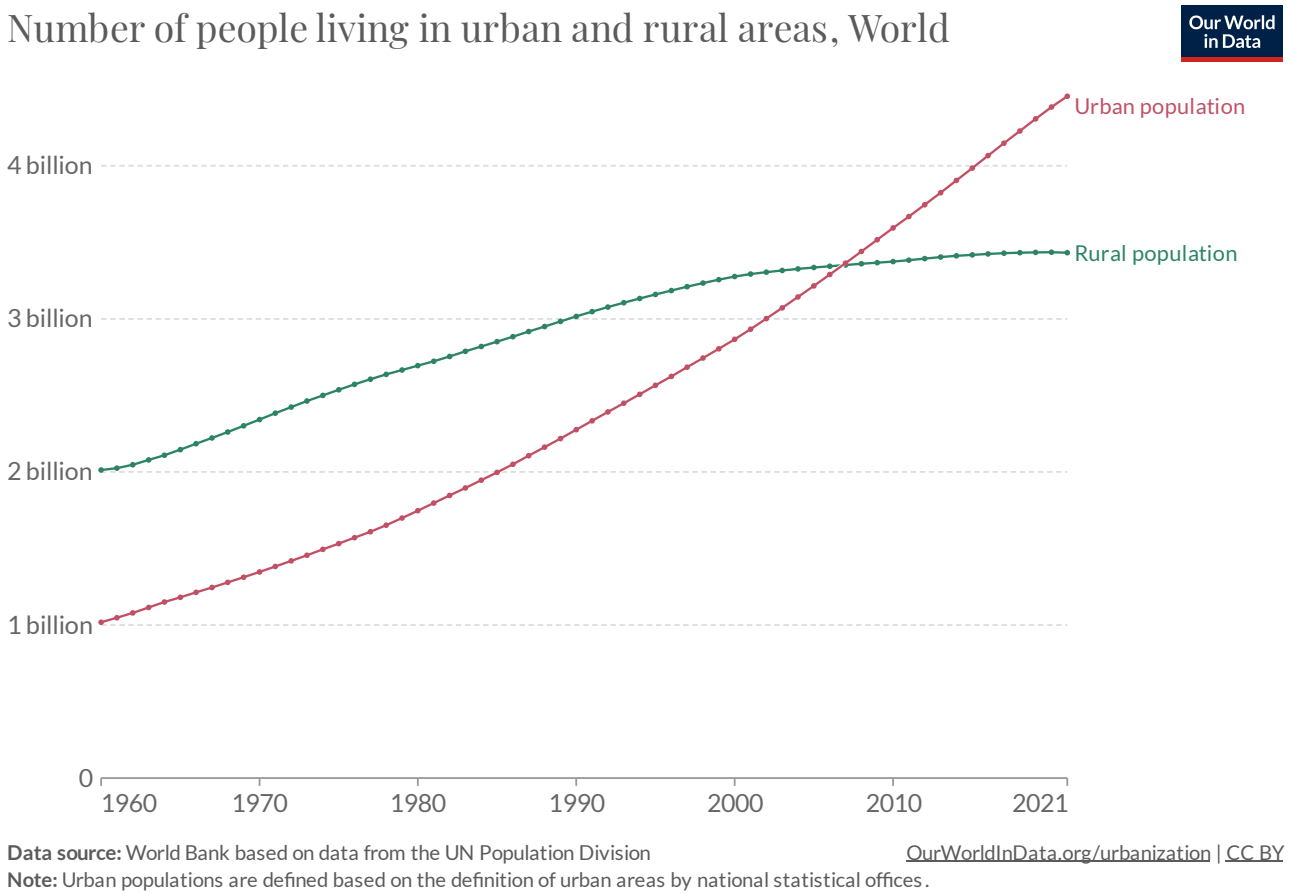
Urbanization

- Urban population is continuously growing
- Projections indicate that more than two-thirds of the world population will live in highly-dense cities by 2050



Source: https://ourworldindata.org/urbanization

Urbanization challenges

- Urbanization leads to several challenges
  - Social
  - Environmental
  - Energy
  - Healthcare
  - Infrastructure
  - Mobility and transportation

Urban mobility

- Urbanization leads to several challenges
  - Social
  - Environmental
  - Energy
  - Healthcare
  - Infrastructure
  - **Mobility and transportation**

Urban mobility – Traffic Congestion

- **Traffic congestion** is a significant challenge in urban areas and leads to
  - delays
  - increased travel times
  - reduced productivity

Urban mobility – Infrastructure

- Many cities struggle with **limited or outdated infrastructure** to support the growing demand for urban transport:
  - insufficient road capacity
  - inadequate public transport systems
  - lack of cycling and pedestrian infrastructure

Urban mobility – Environmental Impact

- Urban transport is a significant contributor to **air pollution and greenhouse gas emissions**.
- Private vehicles, particularly those running on fossil fuels, emit pollutants that **harm air quality** and contribute to climate change.

Urban mobility – Transport Mode Integration

- Fragmented and **poorly integrated transport systems** pose challenges for seamless travel experiences.
- Lack of coordination between **different modes of transport**, such as buses, trains, and bicycles, can result in inconvenient transfers, time-consuming journeys, and reduced efficiency.

Urban mobility – Affordability, Accessibility

- **Accessibility to affordable transport options** is essential for ensuring equitable mobility within urban areas.
- Limited access to public transport, high fares, and insufficient coverage in certain neighborhoods can lead to **transport poverty and social exclusion**.

Urban mobility – Safety, Security

- Ensuring the **safety and security of commuters** is a significant challenge in urban transport.
- Issues such as traffic accidents, crime, and harassment can discourage people from using public transport or walking and cycling.

Urban mobility – Behavioral Change

- Encouraging **behavioral change and shifting travel patterns** from private vehicles to sustainable modes of transport can be challenging.
- Many individuals are accustomed to using **private cars** due to convenience, habit, or lack of viable alternatives.

Urban mobility – Financial Sustainability

- Developing and maintaining urban transport infrastructure requires significant financial resources.
- Funding constraints can limit the ability of cities to invest in new projects, upgrade existing systems, and ensure ongoing maintenance.
- Exploring innovative financing mechanisms, public-private partnerships, and securing sustainable funding sources are crucial for the long-term financial sustainability of urban transport.

Urban mobility – Solutions

- Solving the urban mobility challenges requires **multidisciplinary effort**
  - Civil engineering
  - Urban planning
  - Geography
  - Human and social studies
  - Information technologies

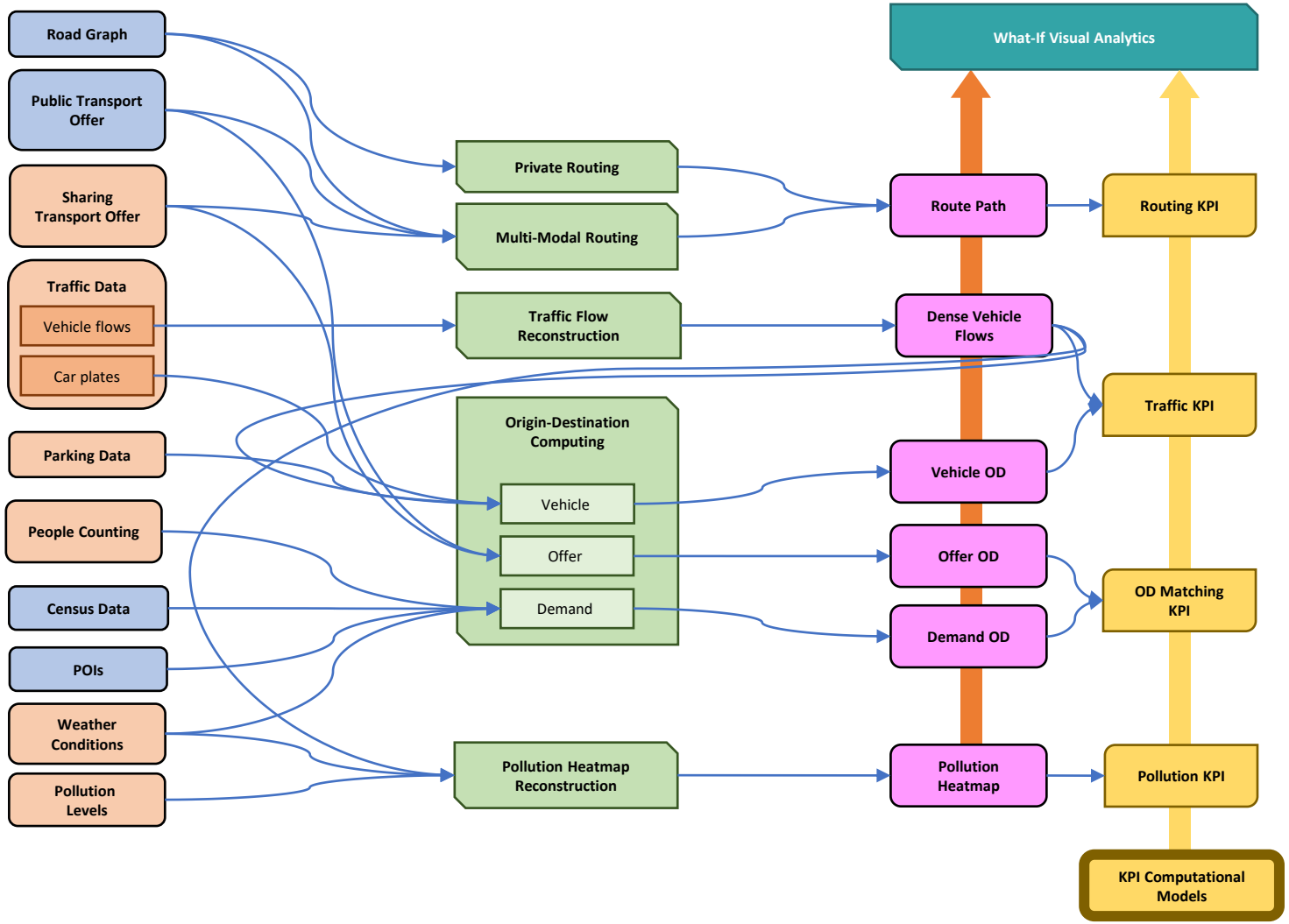
Information technologies for Urban mobility

- IT plays a pivotal role in addressing the urban mobility problem
- A platform is required to enable other experts to work on the mobility problem
- The development of a platform requires three macro-activities
  - **Data** acquisition and modelling
  - Development of **analytical software** to perform reconstruction, prediction, evaluations
  - Development of **graphical interfaces** to show and interact with the system

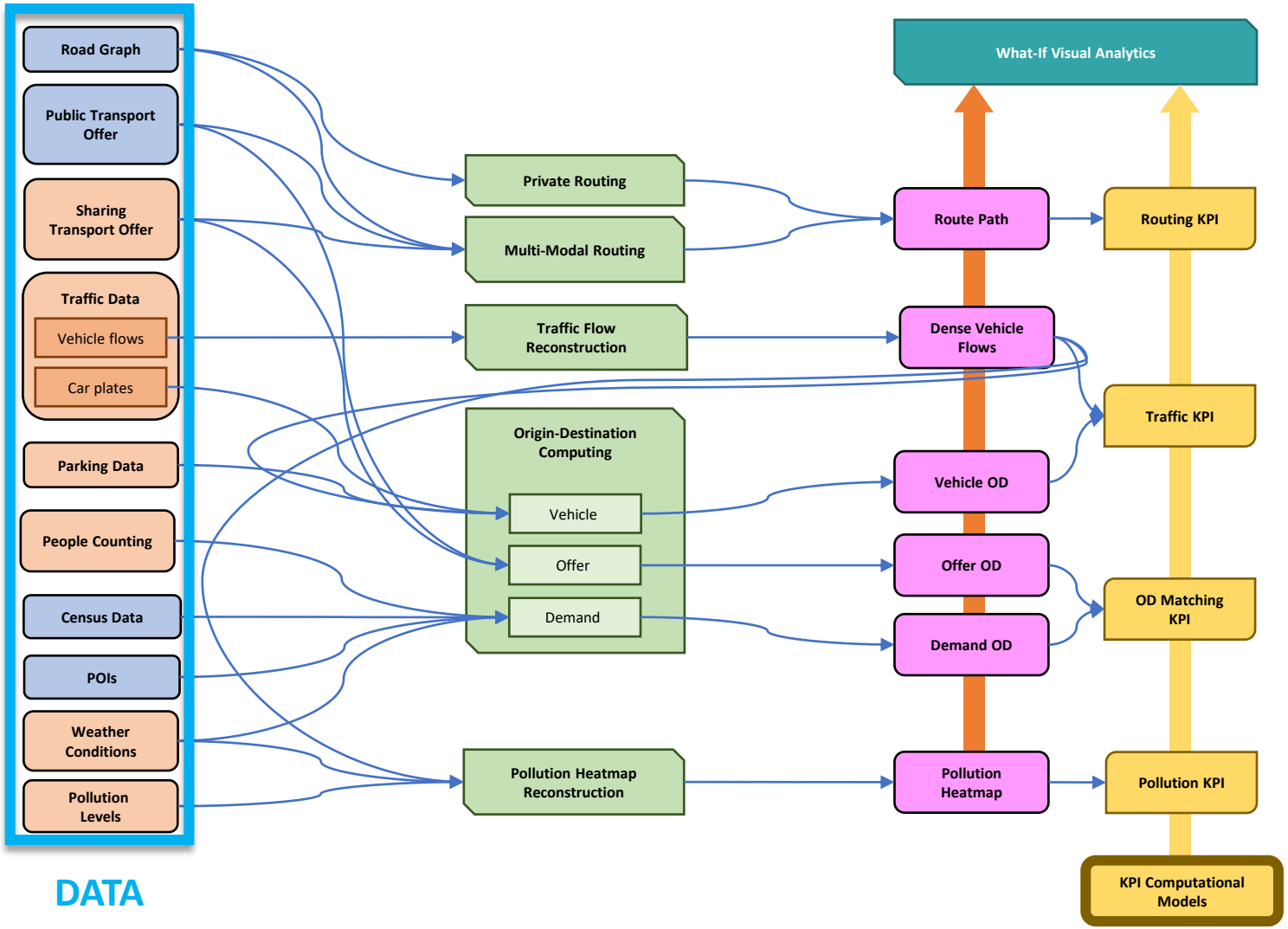
Information technologies for Urban mobility

- Main goals are
  - **Real-time assessment** of the urban mobility environment using acquired data and produced reconstructions
    - Traffic level
    - Public transport
    - …
  - **Predictive analysis** on the actual scenario or on different scenarios, i.e., What-If analysis
    - Traffic Flow Reconstruction
    - Transport demand vs offer assessment
    - …
  - Computation of **Key Performance Indicators** (KPI)
    - SUMI – Sustainable Urban Mobility Indicators
    - PUMS – Piano Urbano di Mobilità Sostenibile

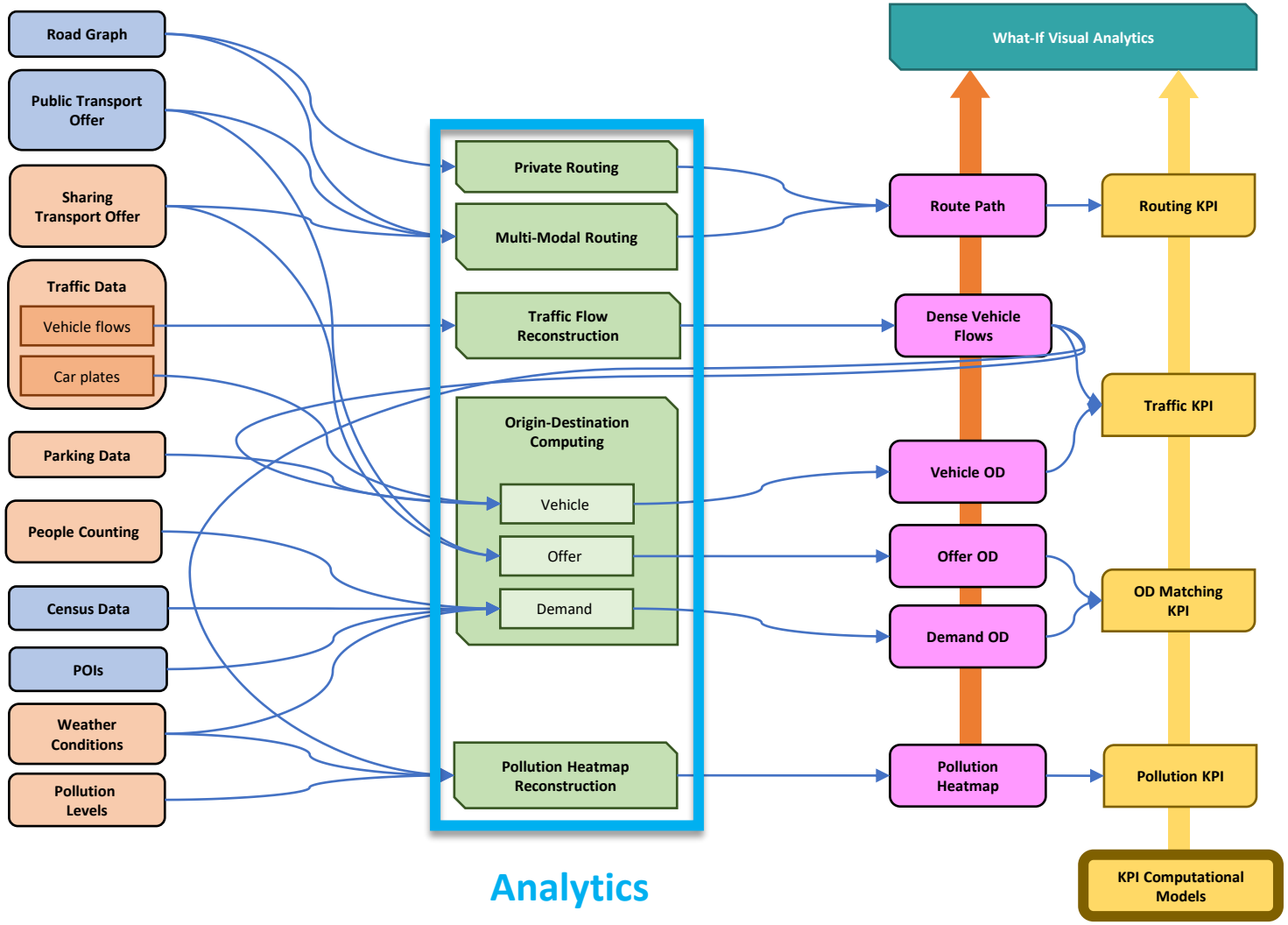
Information technologies for Urban mobility



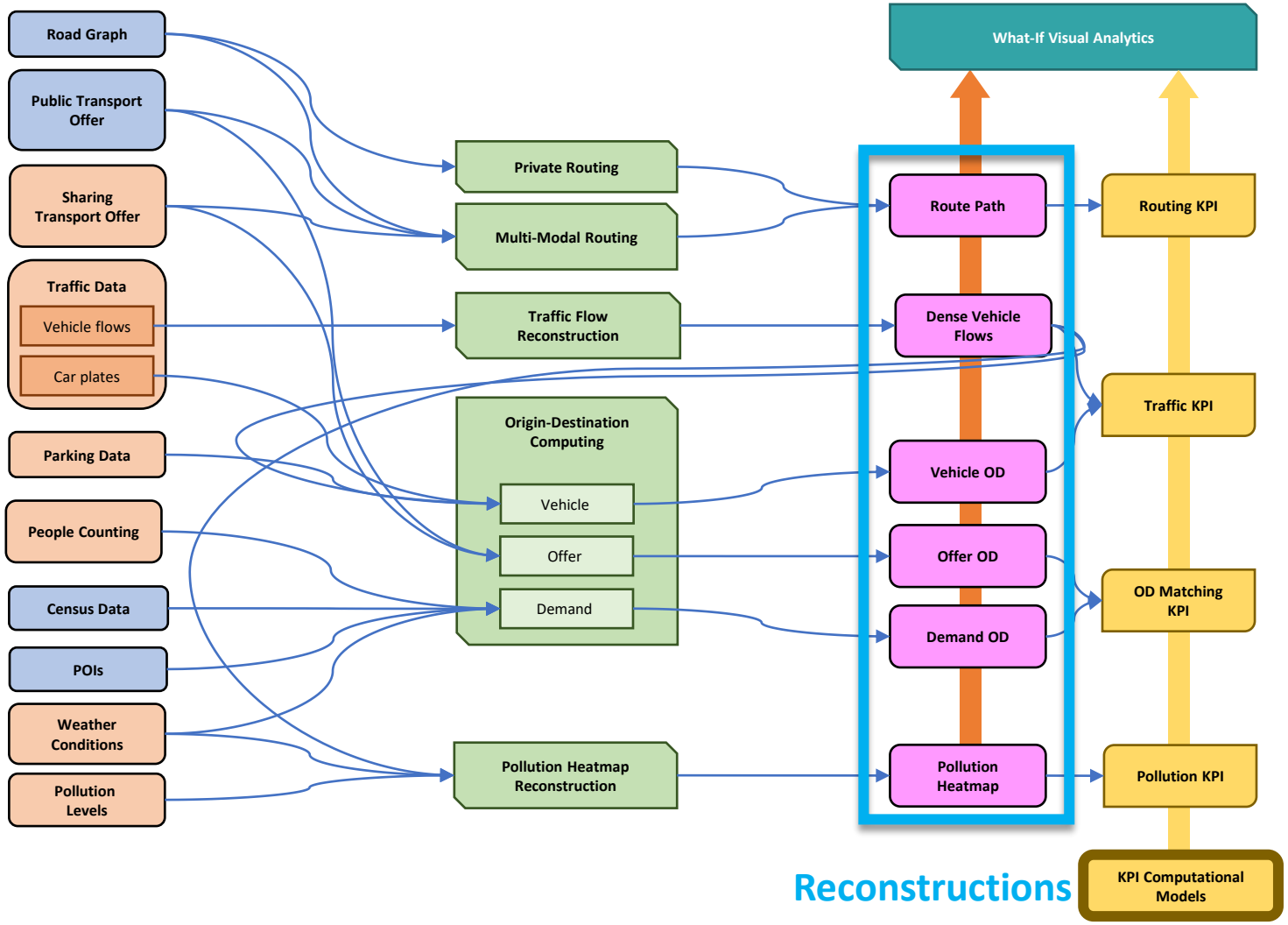
Information technologies for Urban mobility



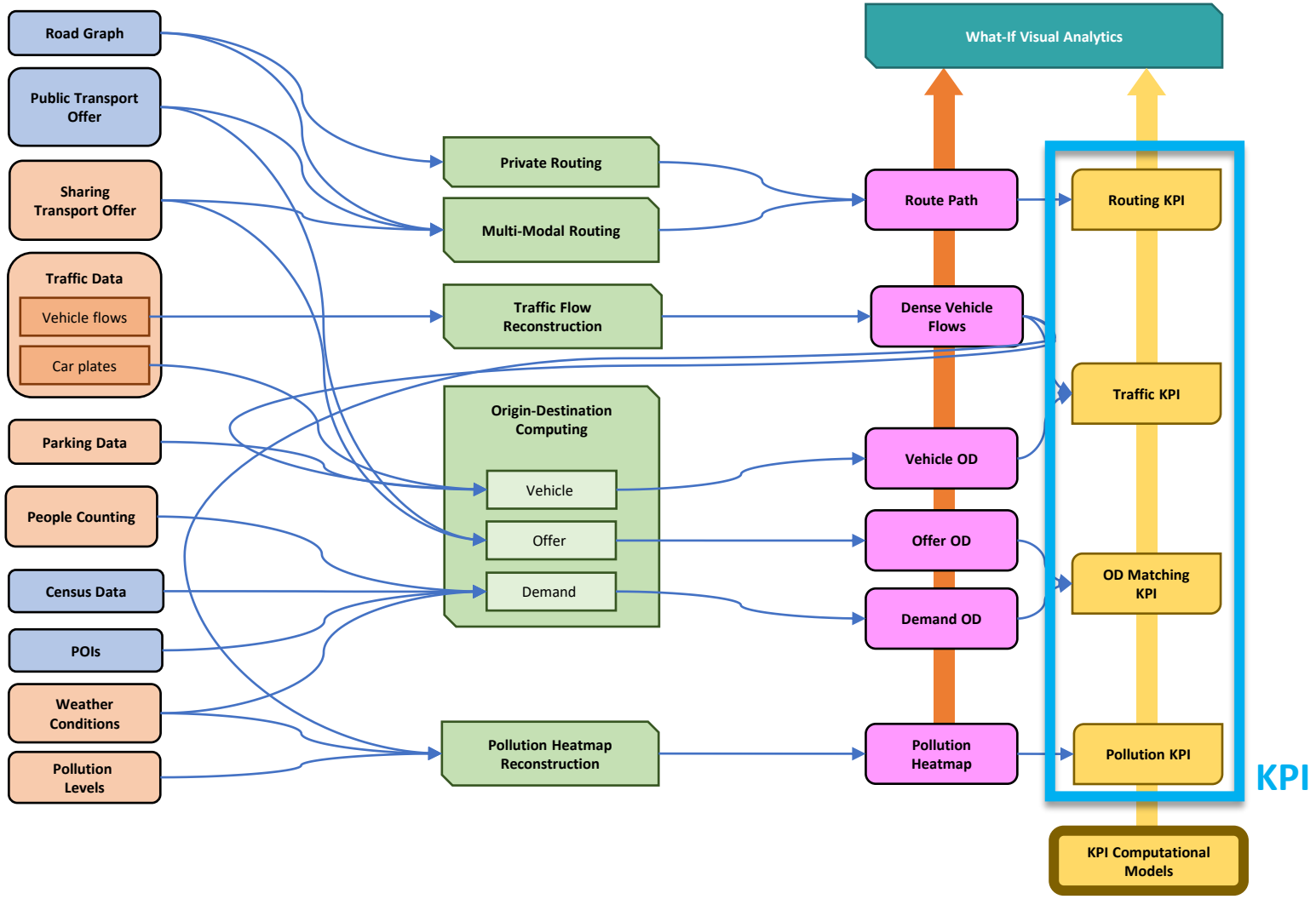
Information technologies for Urban mobility



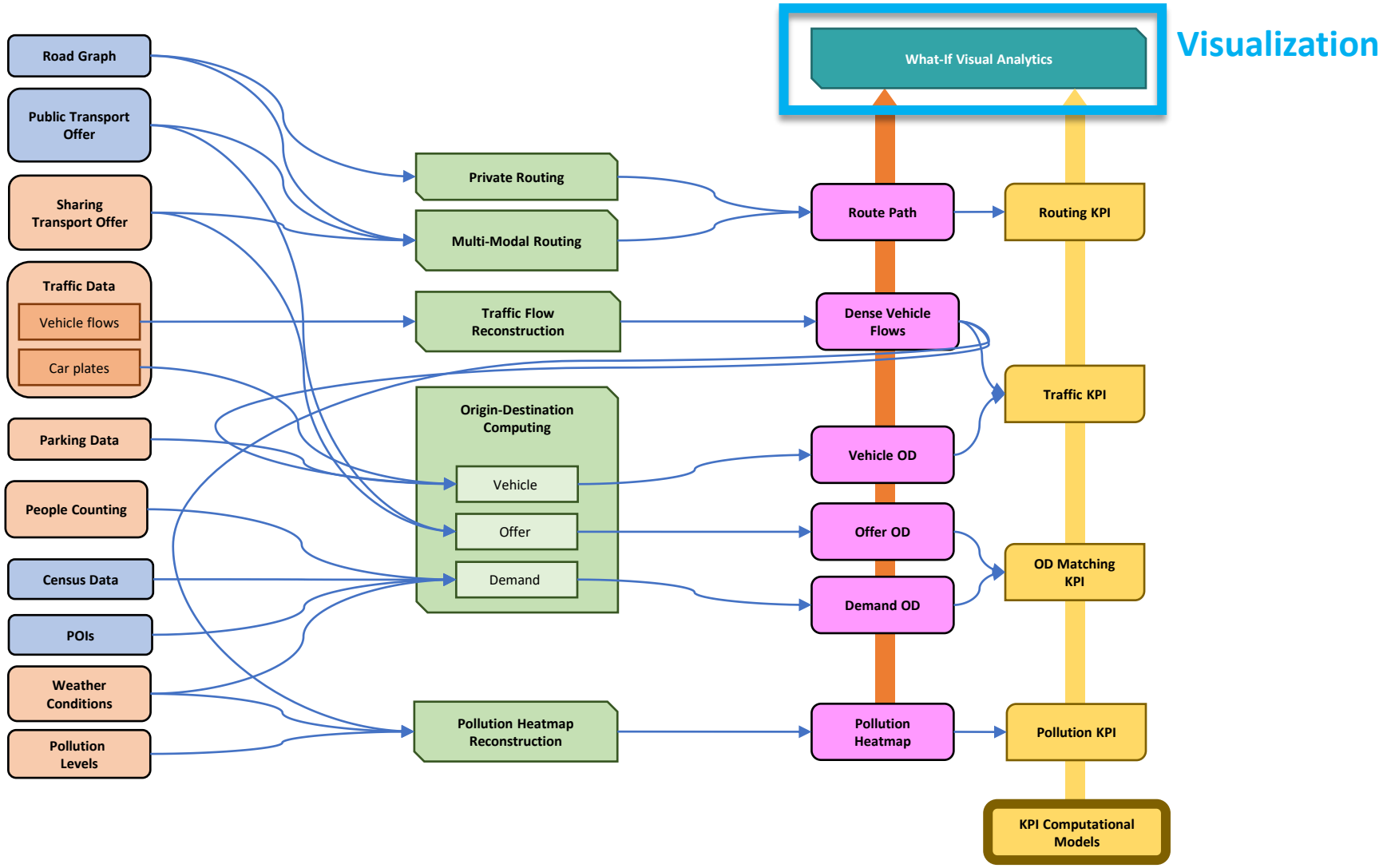
Information technologies for Urban mobility



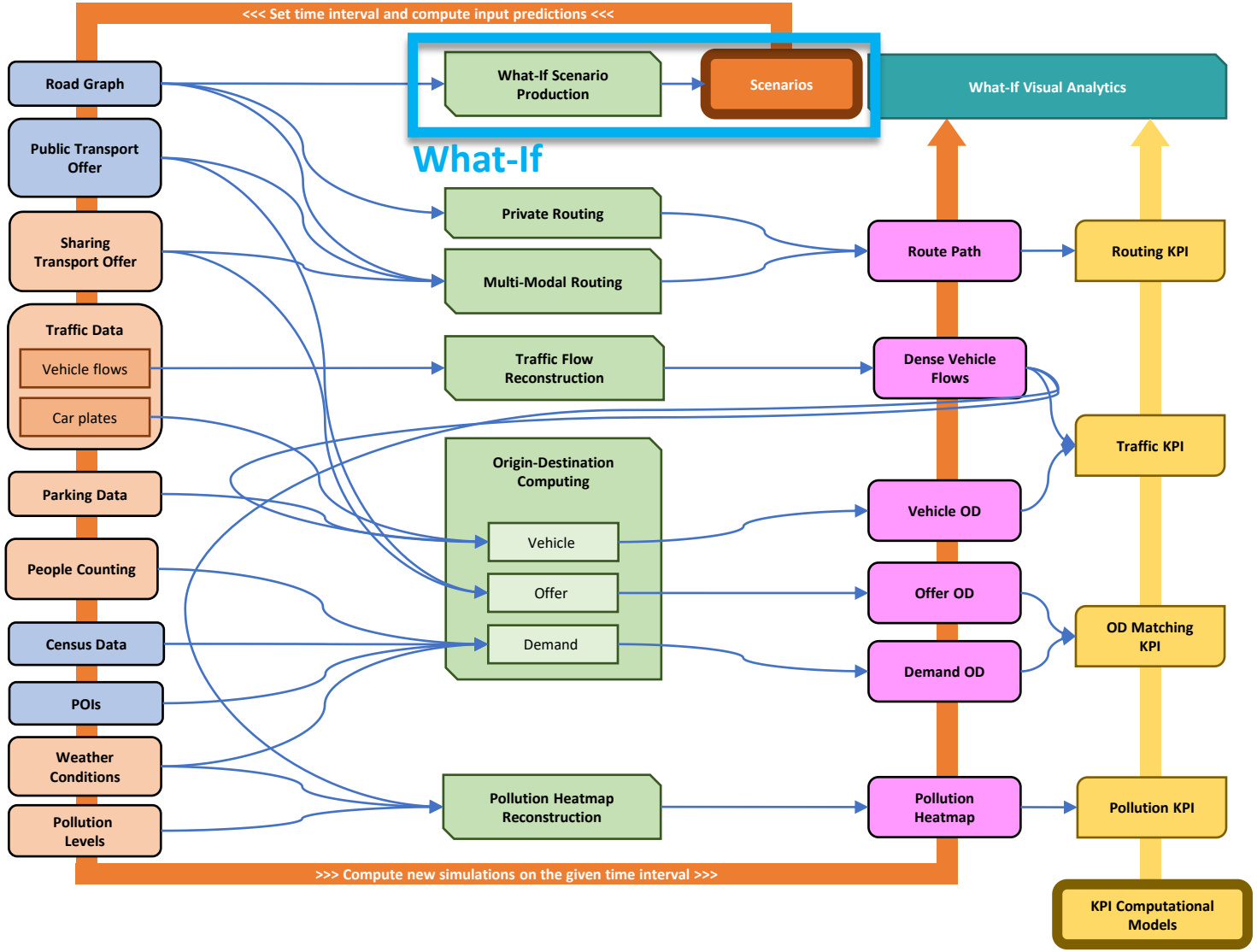
Information technologies for Urban mobility



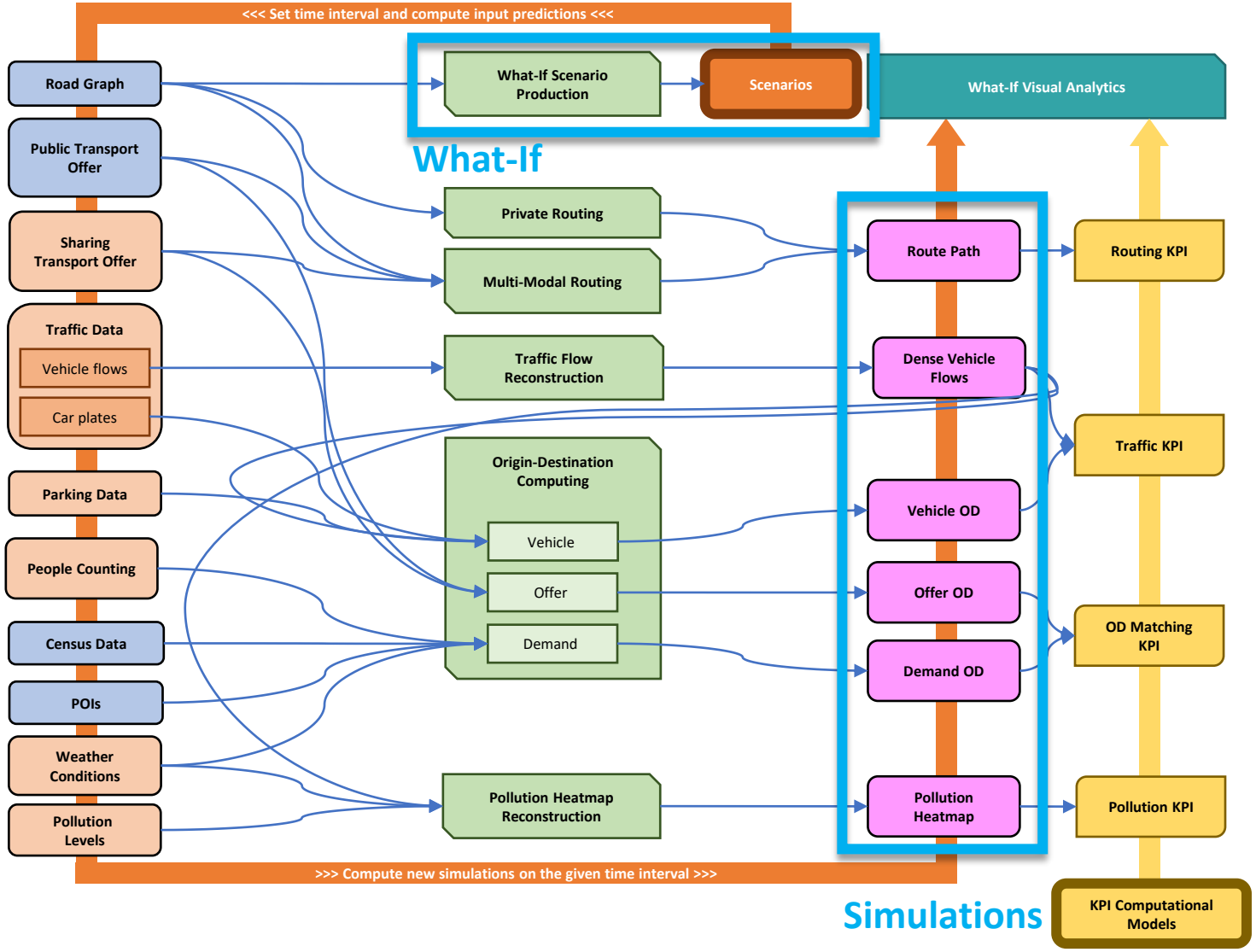
Information technologies for Urban mobility



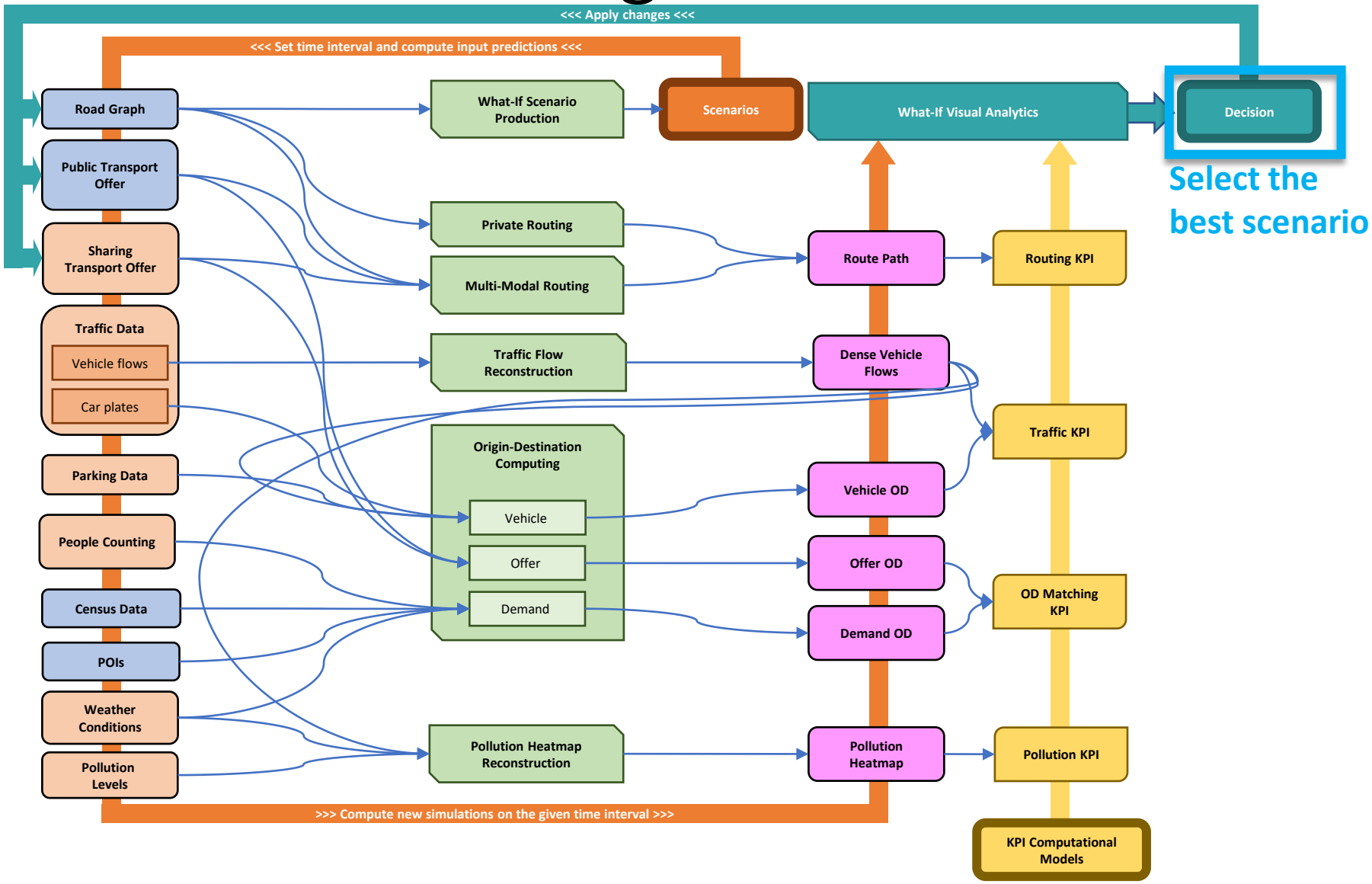
Information technologies for Urban mobility



Information technologies for Urban mobility



Information technologies for Urban mobility



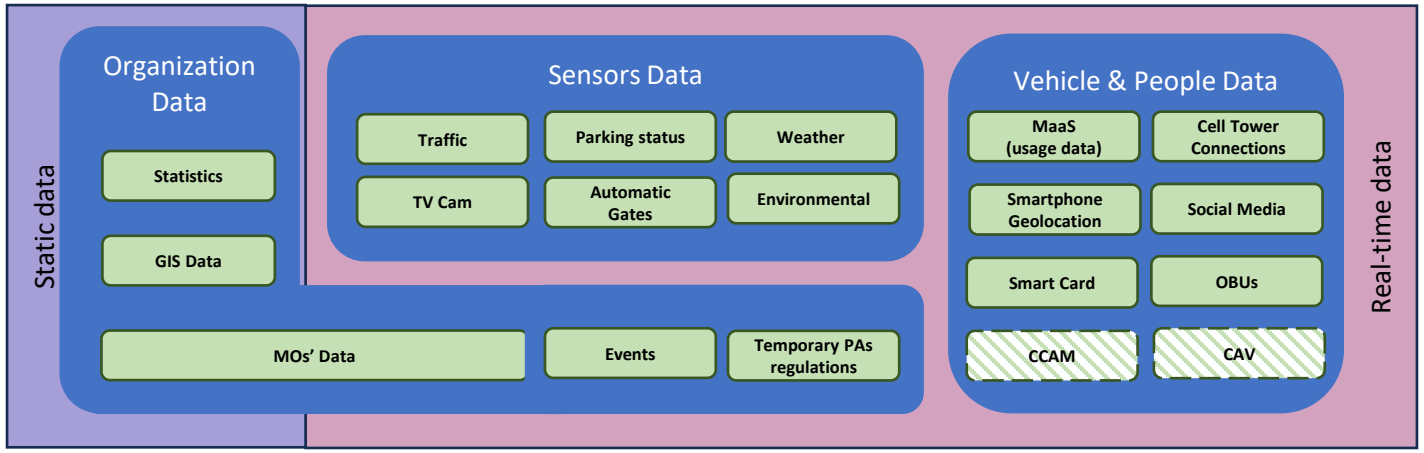
Which data? In which format?

- We will see an overview of the data required to build a platform for urban mobility management

- We will also discuss about the formats and standards used to distribute such data

Which data?

- A possible taxonomy of mobility data is to group data **according to their source**
  - Data from public or private organizations
  - Data from IoT sensors
  - Data produced directly by vehicles or people



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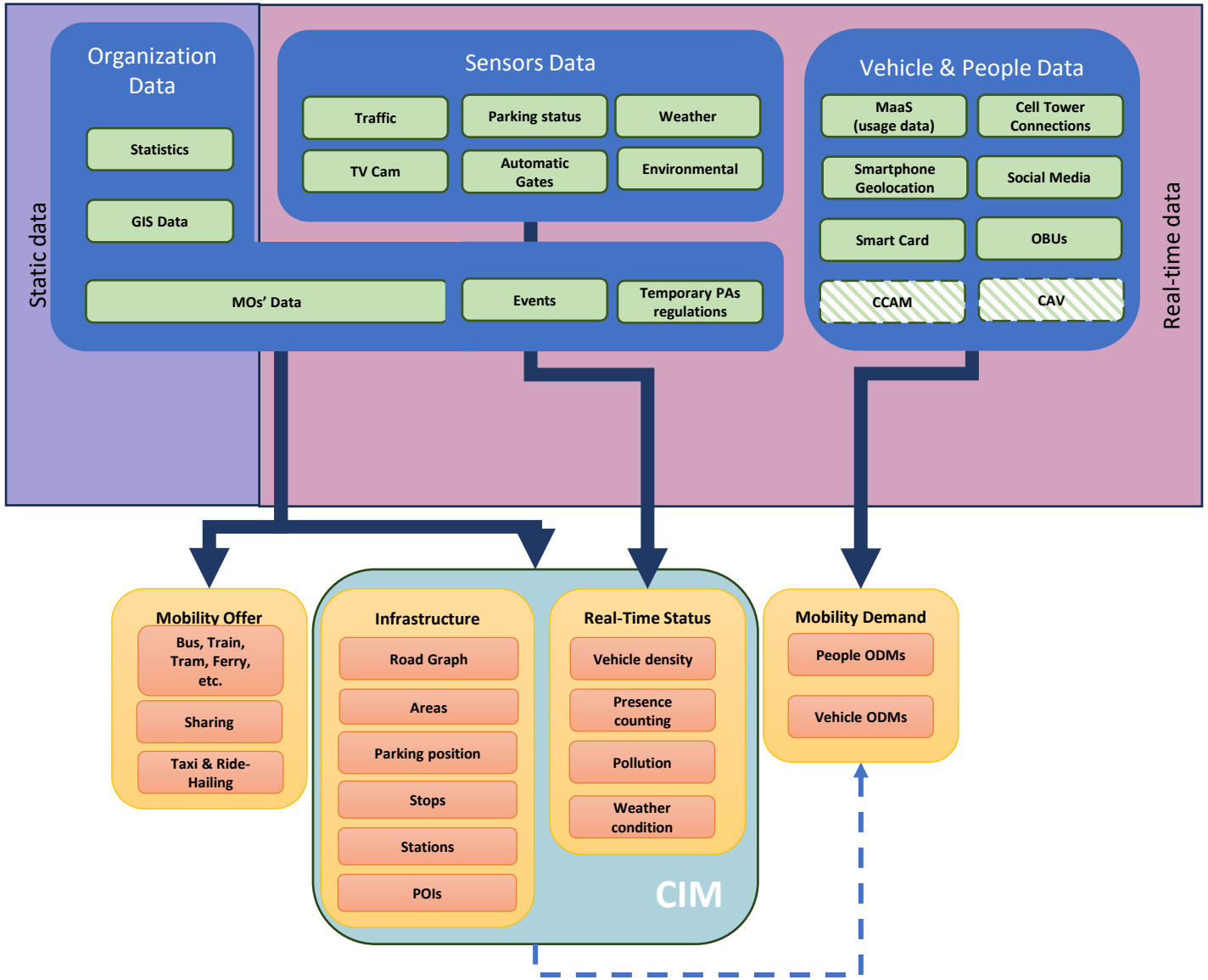
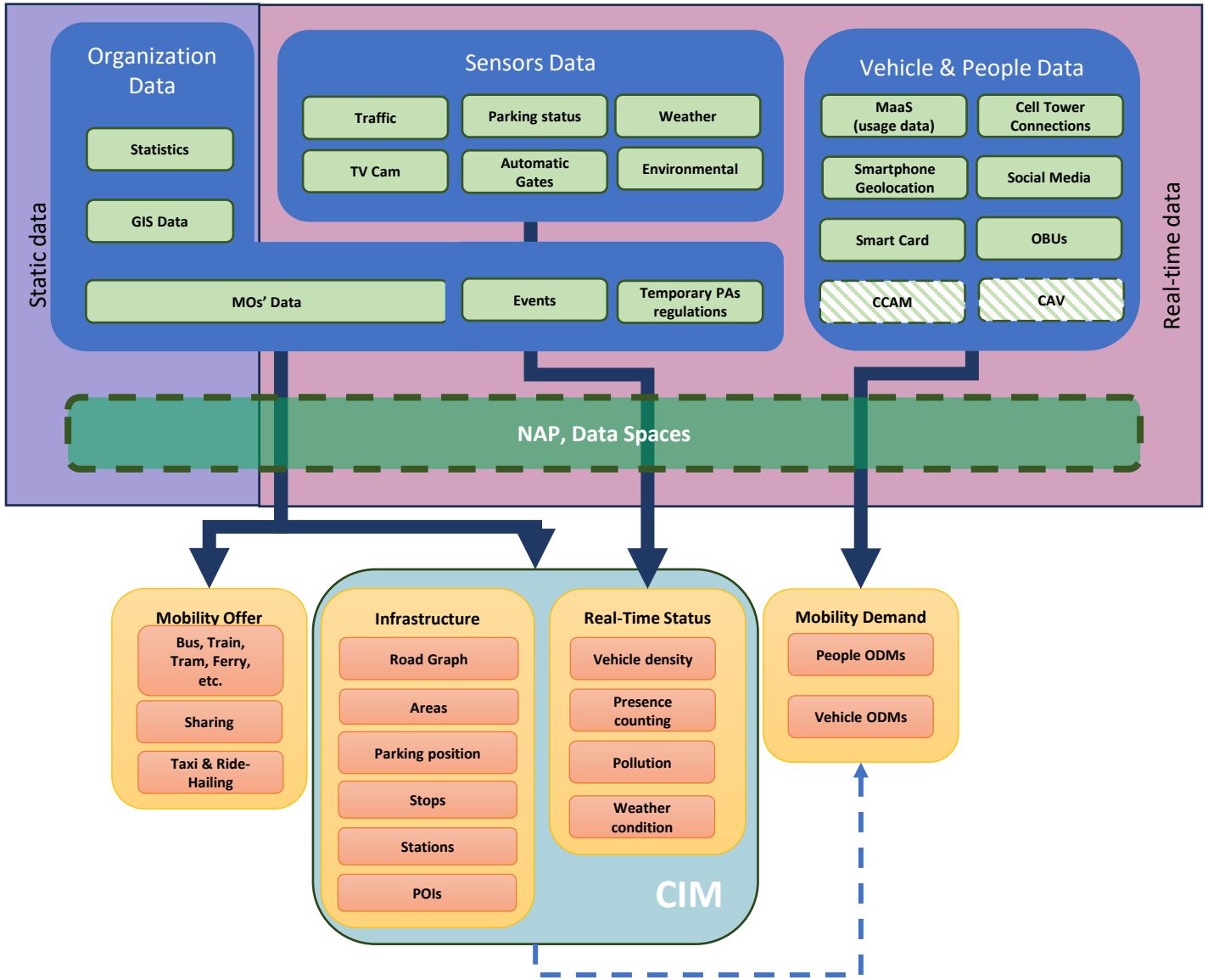

Static data
Organization Data
Statistics
GIS Data
Sensors Data
Traffic
Parking status
Weather
TV Cam
Automatic Gates
Environmental
MOs' Data
Events
Temporary PAs regulations
Vehicle & People Data
MaaS (usage data)
Cell Tower Connections
Smartphone Geolocation
Social Media
Smart Card
OBUs
CCAM
CAV
Real-time data
Mobility Offer
Bus, Train, Tram, Ferry, etc.
Sharing
Taxi & Ride-Hailing
Infrastructure
Road Graph
Areas
Parking position
Stops
Stations
POIs
Real-Time Status
Vehicle density
Presence counting
Pollution
Weather condition
CIM
Mobility Demand
People ODMs
Vehicle ODMs

Which data?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Mobility Demand
People ODMs
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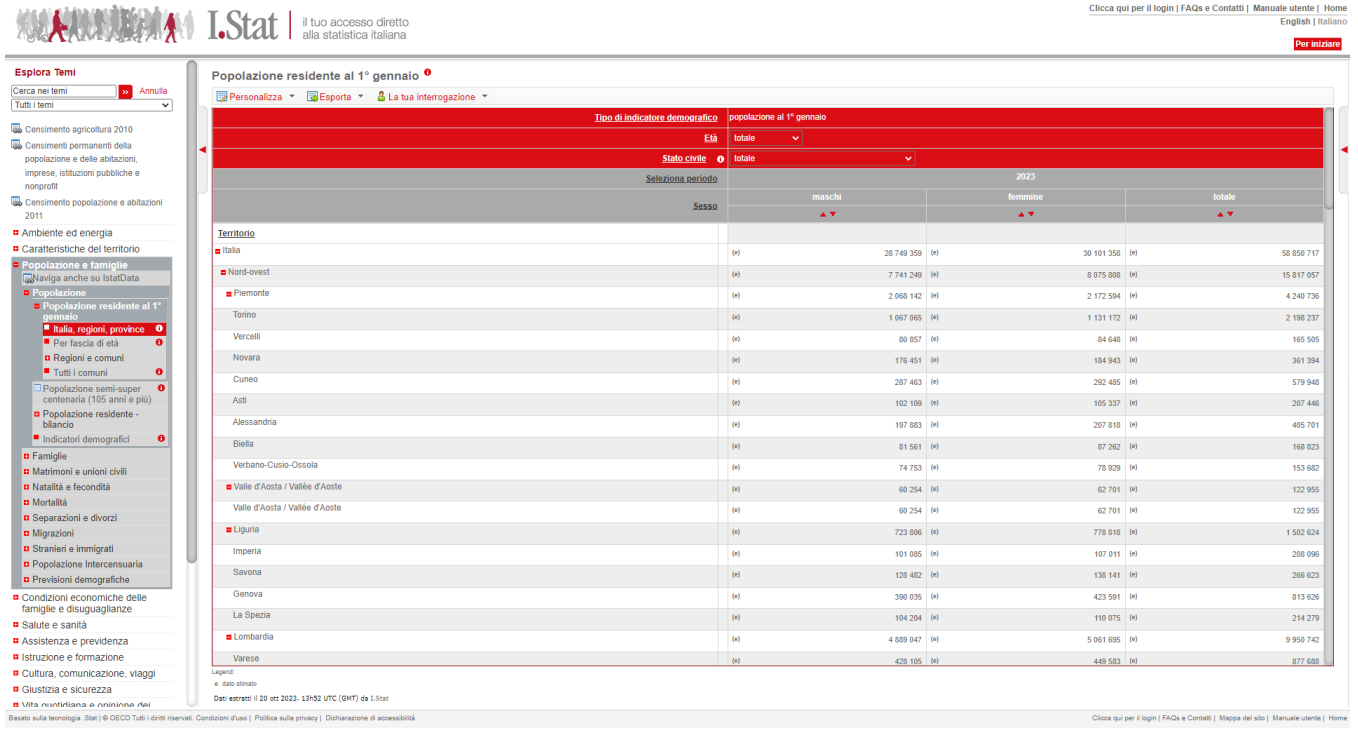
Statistics

- Statistical data include surveys, reports, census information
- Can be used to obtain a description of the
  - Population, according to gender, age, wealth
  - Vehicle models, motorizations, registration dates
  - Distribution of urban services
  - …
- Statistics are particularly useful to compute the KPIs (e.g., how many people have a bus stop at less than 100m from their home?)
- Statistical data are mainly distributed by national institute of statistics

Statistics

- In Italy we can use the ISTAT portal (https://www.istat.it/)
- The portal I.Stat (http://dati.istat.it/) let to search and download data about different categories

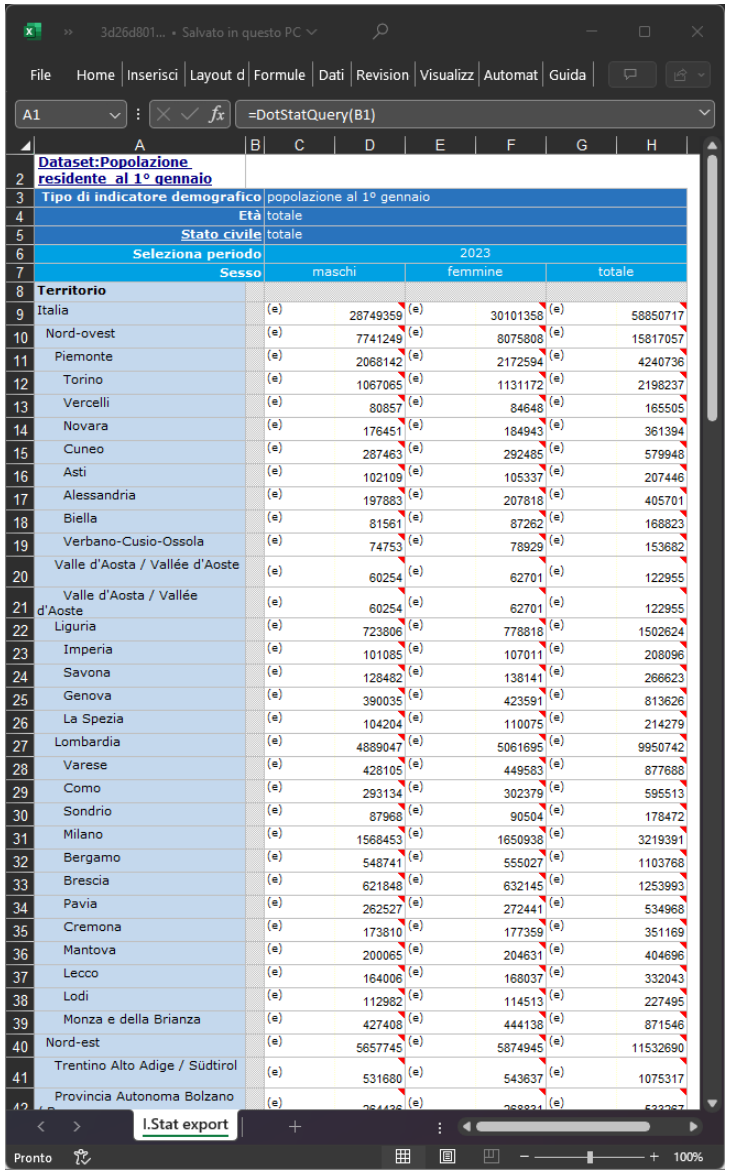


Statistics

- Data can be exported in different formats

Statistics

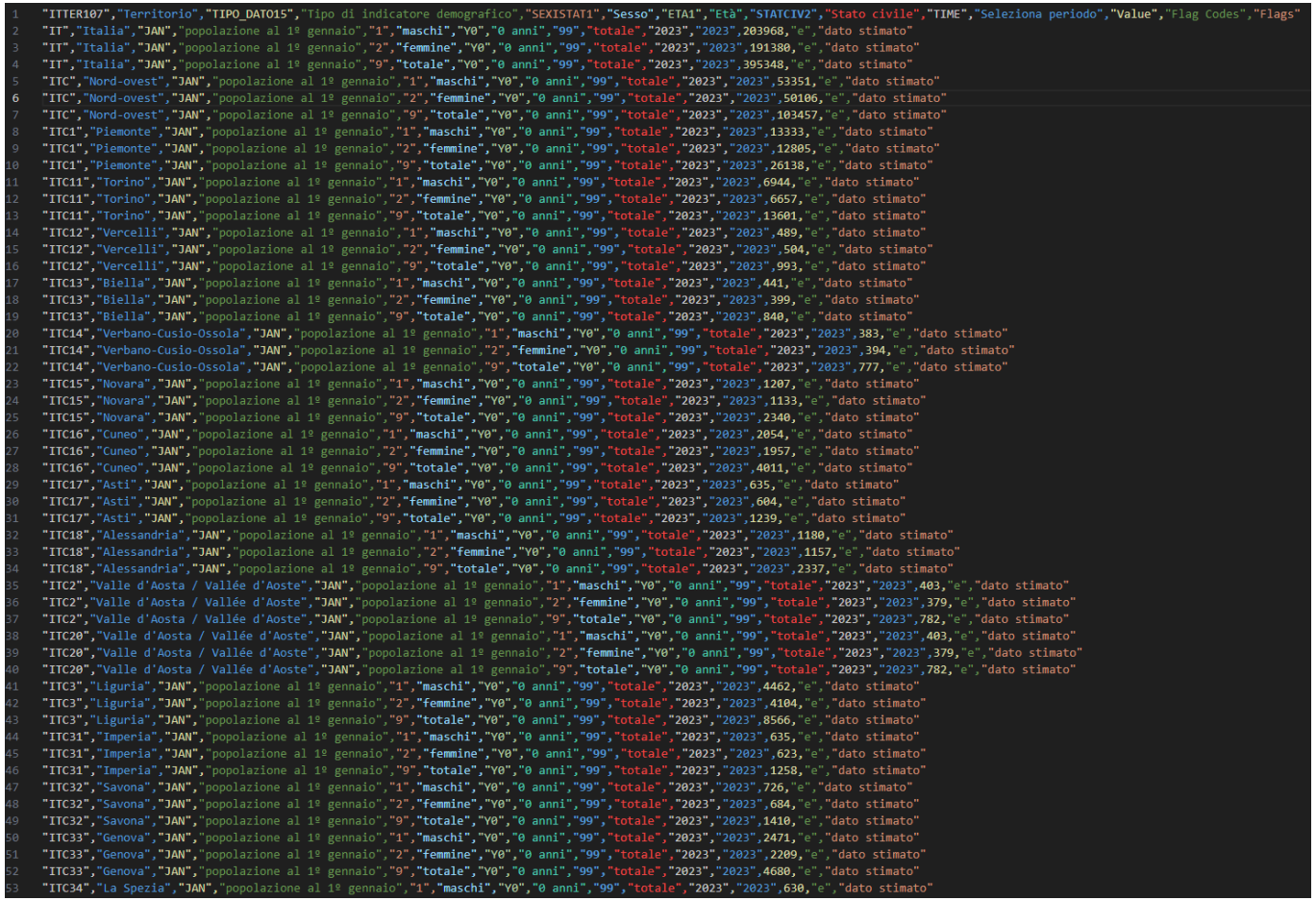
- Data can be exported in different formats
  - **Microsoft Excel**



	A	B	C	D	E	F	G	H
2	Dataset:Popolazione residente al 1° gennaio							
3	Tipo di indicatore demografico	popolazione al 1° gennaio						
4	Età	totale						
5	Stato civile	totale						
6	Seleziona periodo	2023						
7	Sesso	maschi		femmine		totale		
8	Territorio							
9	Italia	(e)	28749359	(e)	30101358	(e)	58850717	
10	Nord-ovest	(e)	7741249	(e)	8075808	(e)	15817057	
11	Piemonte	(e)	2068142	(e)	2172594	(e)	4240736	
12	Torino	(e)	1067065	(e)	1131172	(e)	2198237	
13	Vercelli	(e)	80857	(e)	84648	(e)	165505	
14	Novara	(e)	176451	(e)	184943	(e)	361394	
15	Cuneo	(e)	287463	(e)	292485	(e)	579948	
16	Asti	(e)	102109	(e)	105337	(e)	207446	
17	Alessandria	(e)	197883	(e)	207818	(e)	405701	
18	Biella	(e)	81561	(e)	87262	(e)	168823	
19	Verbano-Cusio-Ossola	(e)	74753	(e)	78929	(e)	153682	
20	Valle d'Aosta / Vallée d'Aoste	(e)	60254	(e)	62701	(e)	122955	
21	Valle d'Aosta / Vallée d'Aoste	(e)	60254	(e)	62701	(e)	122955	
22	Liguria	(e)	723806	(e)	778818	(e)	1502624	
23	Imperia	(e)	101085	(e)	107011	(e)	208096	
24	Savona	(e)	128482	(e)	138141	(e)	266623	
25	Genova	(e)	390035	(e)	423591	(e)	813626	
26	La Spezia	(e)	104204	(e)	110075	(e)	214279	
27	Lombardia	(e)	4889047	(e)	5061695	(e)	9950742	
28	Varese	(e)	428105	(e)	449583	(e)	877688	
29	Como	(e)	293134	(e)	302379	(e)	595513	
30	Sondrio	(e)	87968	(e)	90504	(e)	178472	
31	Milano	(e)	1568453	(e)	1650938	(e)	3219391	
32	Bergamo	(e)	548741	(e)	555027	(e)	1103768	
33	Brescia	(e)	621848	(e)	632145	(e)	1253993	
34	Pavia	(e)	262527	(e)	272441	(e)	534968	
35	Cremona	(e)	173810	(e)	177359	(e)	351169	
36	Mantova	(e)	200065	(e)	204631	(e)	404696	
37	Lecco	(e)	164006	(e)	168037	(e)	332043	
38	Lodi	(e)	112982	(e)	114513	(e)	227495	
39	Monza e della Brianza	(e)	427408	(e)	444138	(e)	871546	
40	Nord-est	(e)	5657745	(e)	5874945	(e)	11532690	
41	Trentino Alto Adige / Südtirol	(e)	531680	(e)	543637	(e)	1075317	
42	Provincia Autonoma Bolzano	(e)		(e)		(e)		

Statistics

- Data can be exported in different formats
  - Microsoft Excel
  - **CSV**



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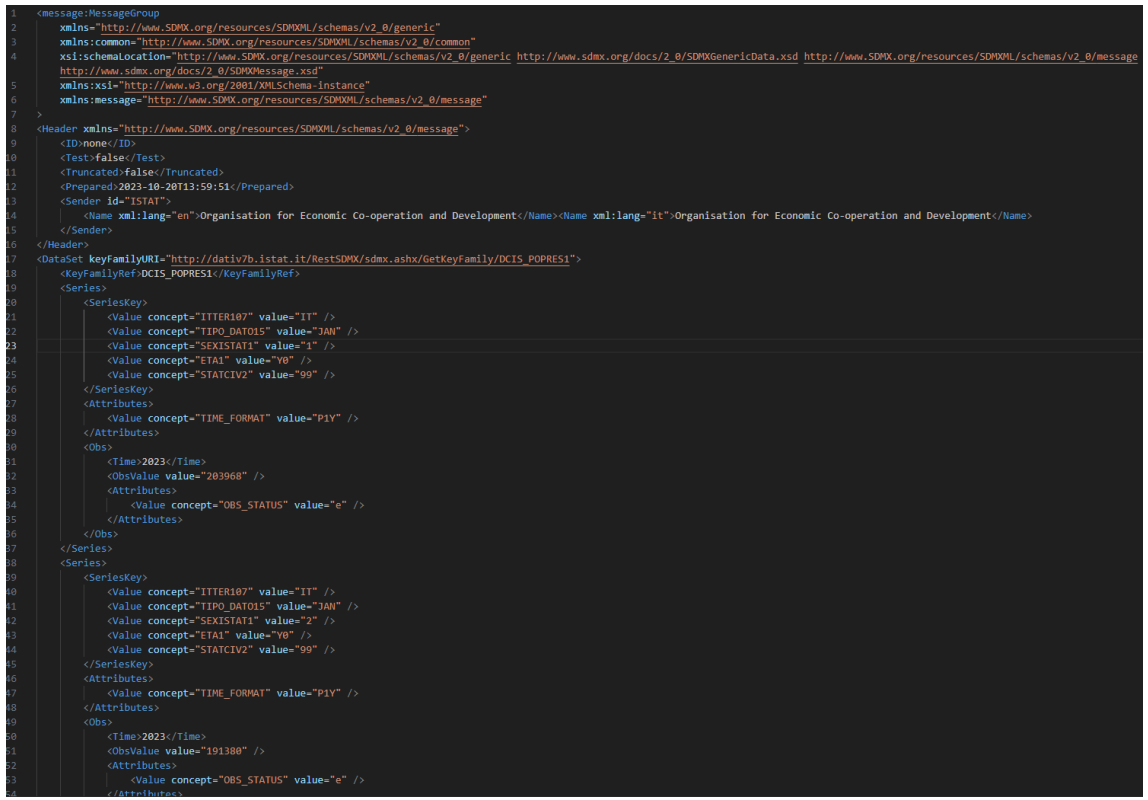
"ITC33","Genova","JAN","popolazione al 1º gennaio","1","maschi","Y0","0 anni","99","totale","2023","2023",2471,"e","dato stimato"
"ITC33","Genova","JAN","popolazione al 1º gennaio","2","femmine","Y0","0 anni","99","totale","2023","2023",2209,"e","dato stimato"
"ITC33","Genova","JAN","popolazione al 1º gennaio","9","totale","Y0","0 anni","99","totale","2023","2023",4680,"e","dato stimato"
"ITC34","La Spezia","JAN","popolazione al 1º gennaio","1","maschi","Y0","0 anni","99","totale","2023","2023",630,"e","dato stimato"
```

Statistics

- Data can be exported in different formats
  - Microsoft Excel
  - CSV
  - **SDMX** (Statistical Data and Metadata eXchange),
    - see https://sdmx.org/
    - ISTAT seems to implement the SDMX-ML based on XML



GIS Data

- Geographic Information System (GIS) data:
  - Data to represent geographic information

GIS Data

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  - **Vector data**: each described entity is geo-localized with different shapes
    - **Point**

GIS Data

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  - Data to represent geographic information
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    - **Point**
    - **Line**

GIS Data

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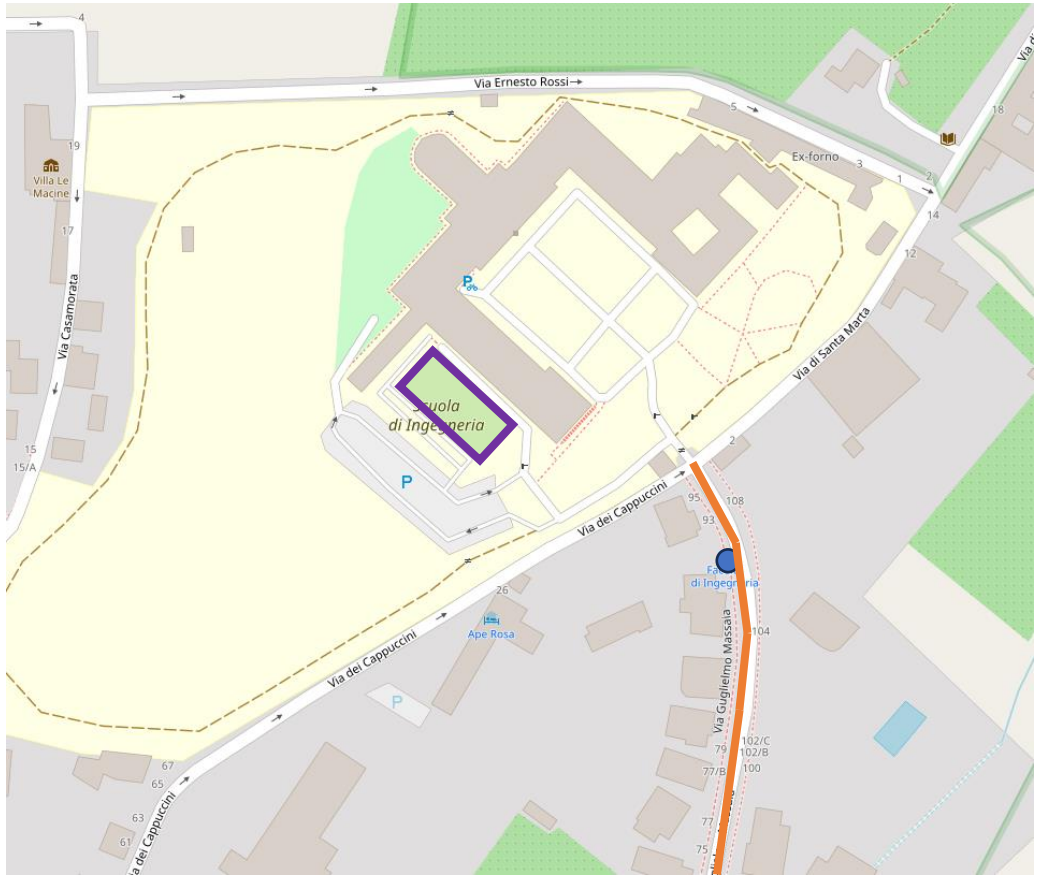
  - **Vector data**: each described entity is geo-localized with different shapes
    - **Point**
    - **Line**
    - **Polygon**



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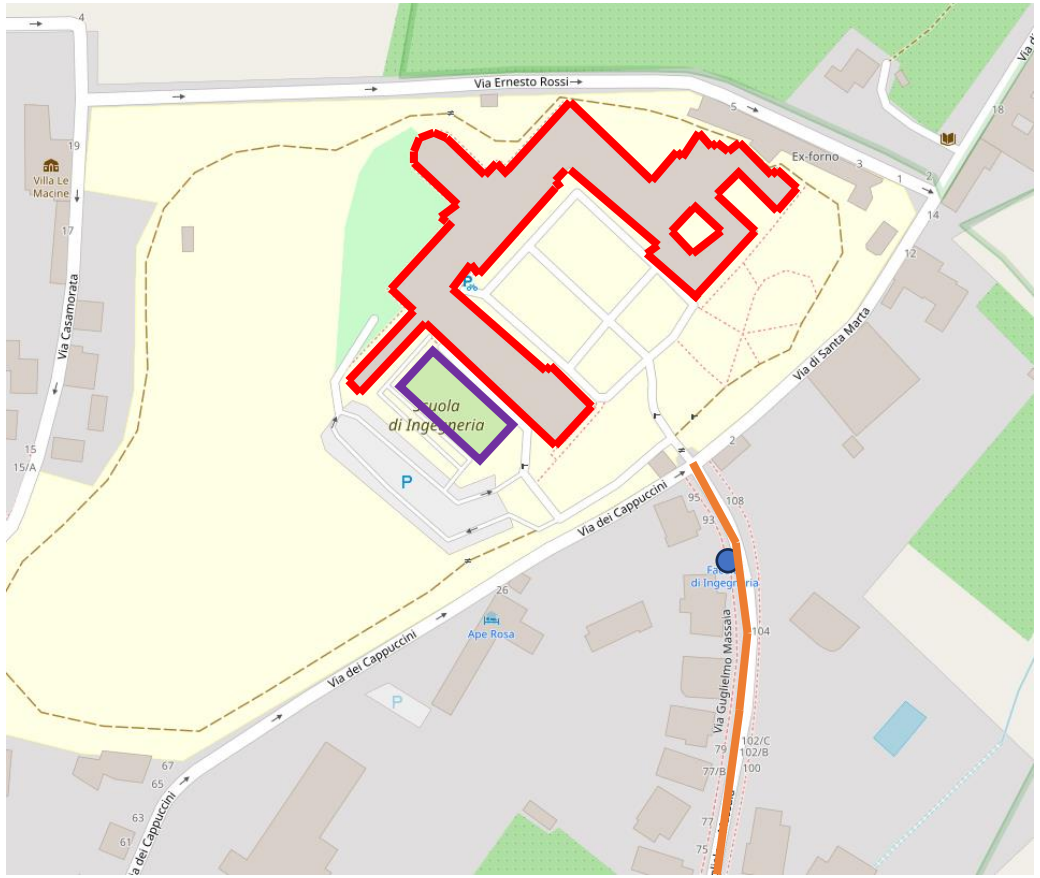
    - **Polygon**
    - **Multi-polygon**



GIS Data

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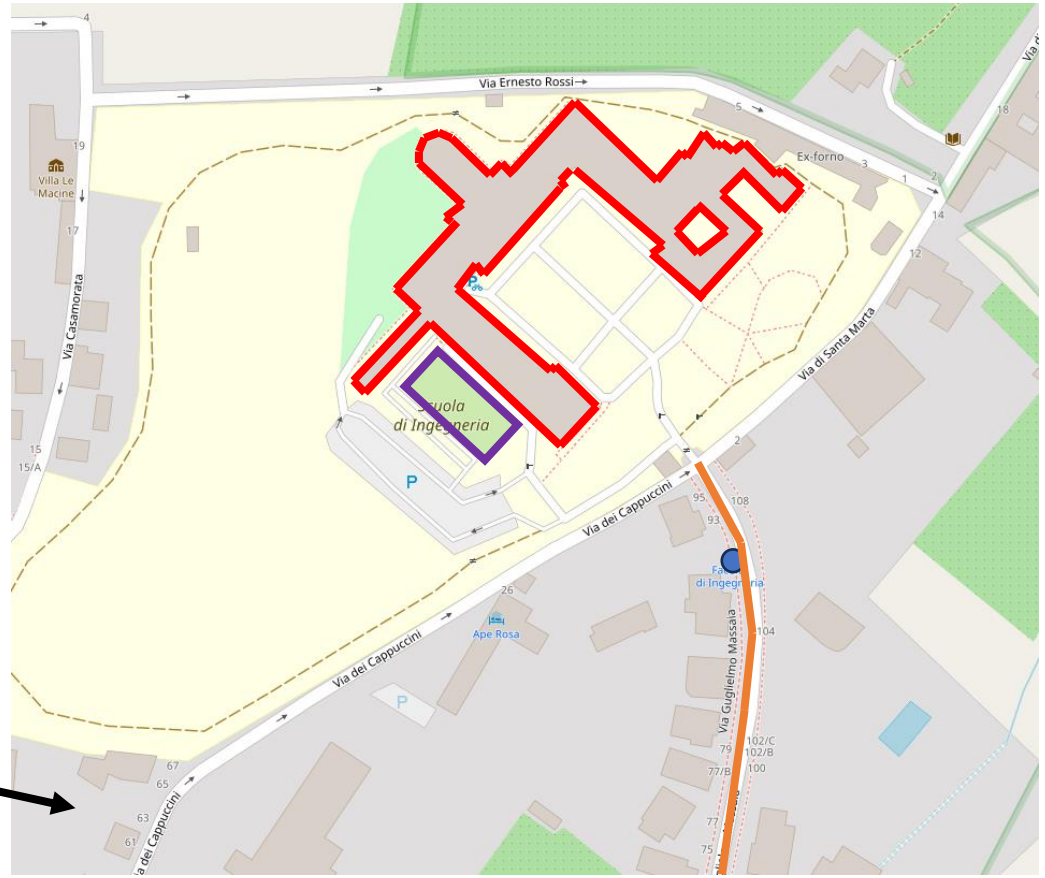
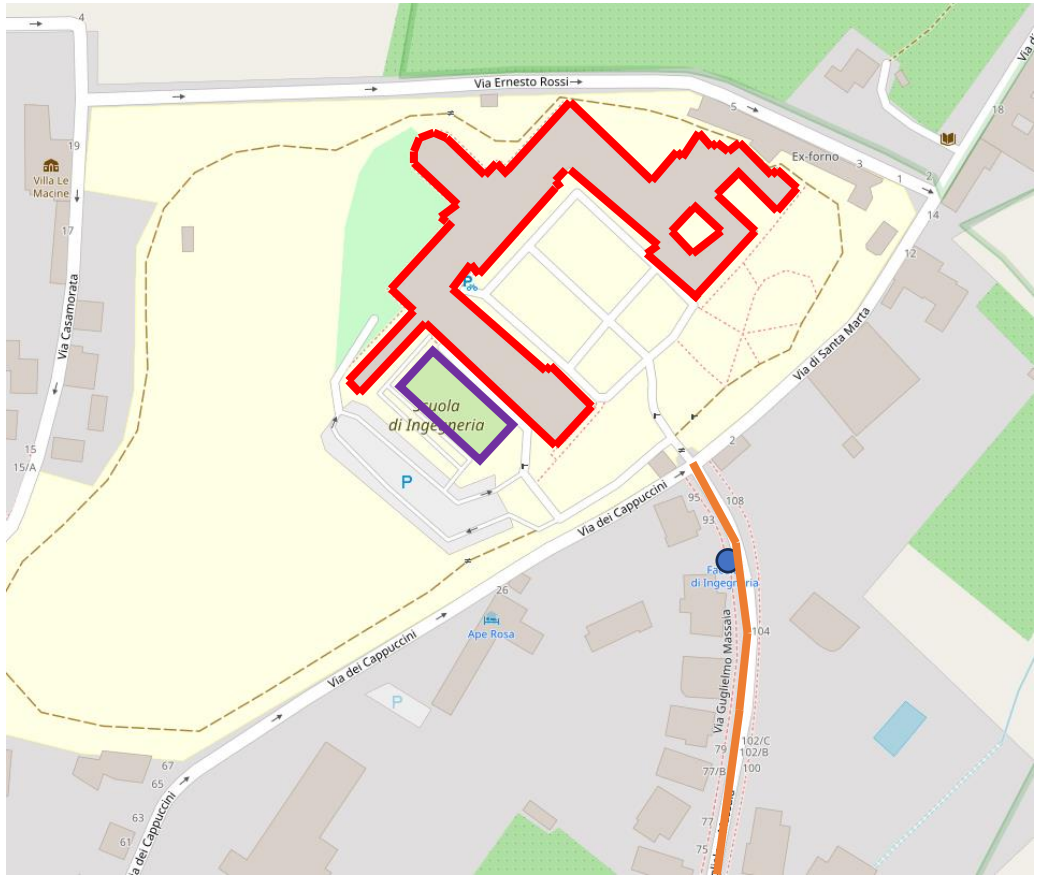
  - **Vector data**: each described entity is geo-localized with different shapes
    - **Point**
    - **Line**
    - **Polygon**
    - **Multi-polygon**
  - **Raster data**: images with localization information



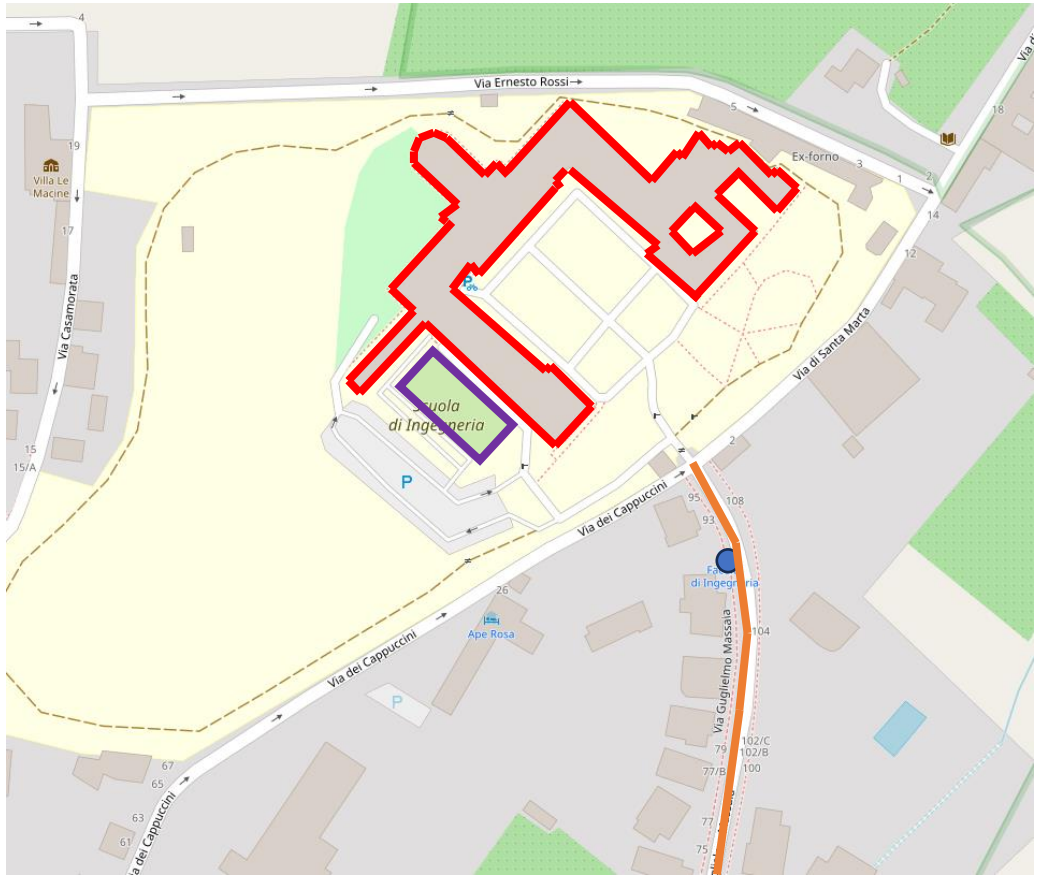
GIS Data – Vectors

- GIS data are used to represent and describe the infrastructures
  - **Roads** represented as line segments



GIS Data – Vectors

- GIS data are used to represent and describe the infrastructures
  - **Roads** represented as line segments
  - **Areas** represented as polygons



GIS Data – Vectors

- GIS data are used to represent and describe the infrastructures
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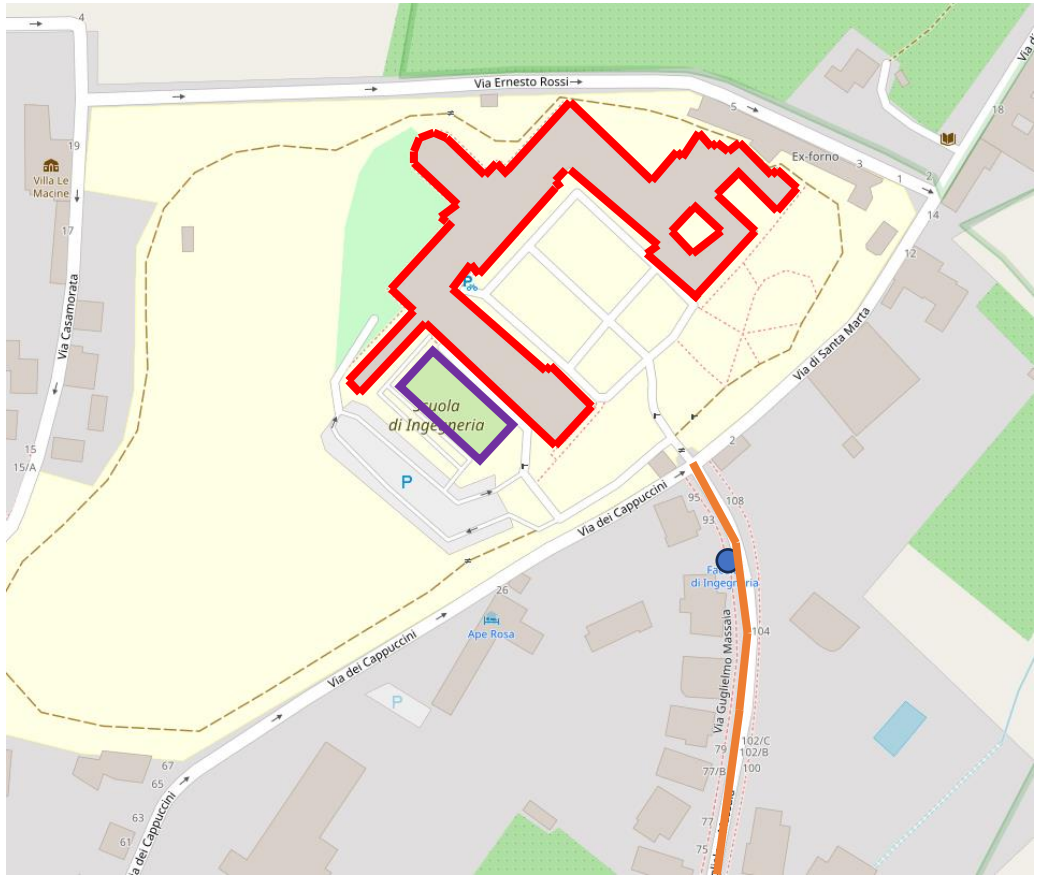
  - **Building ground shapes** represented as polygons or multi-polygons



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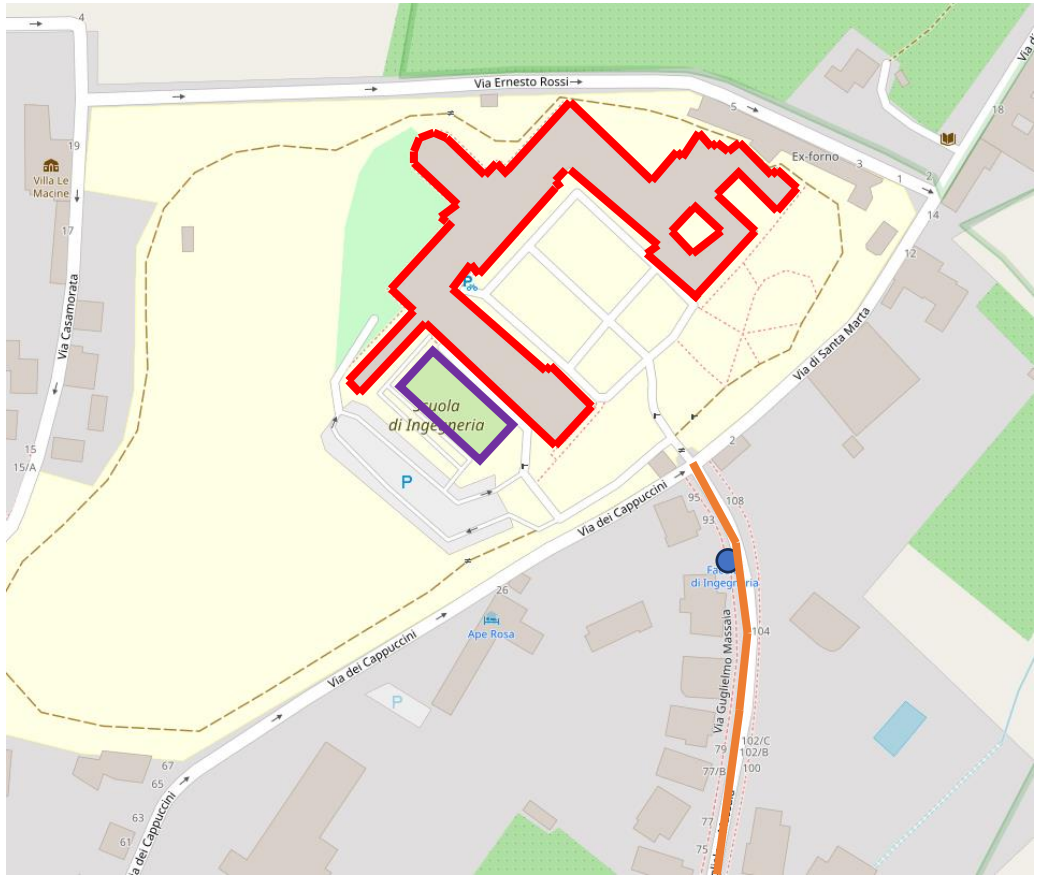

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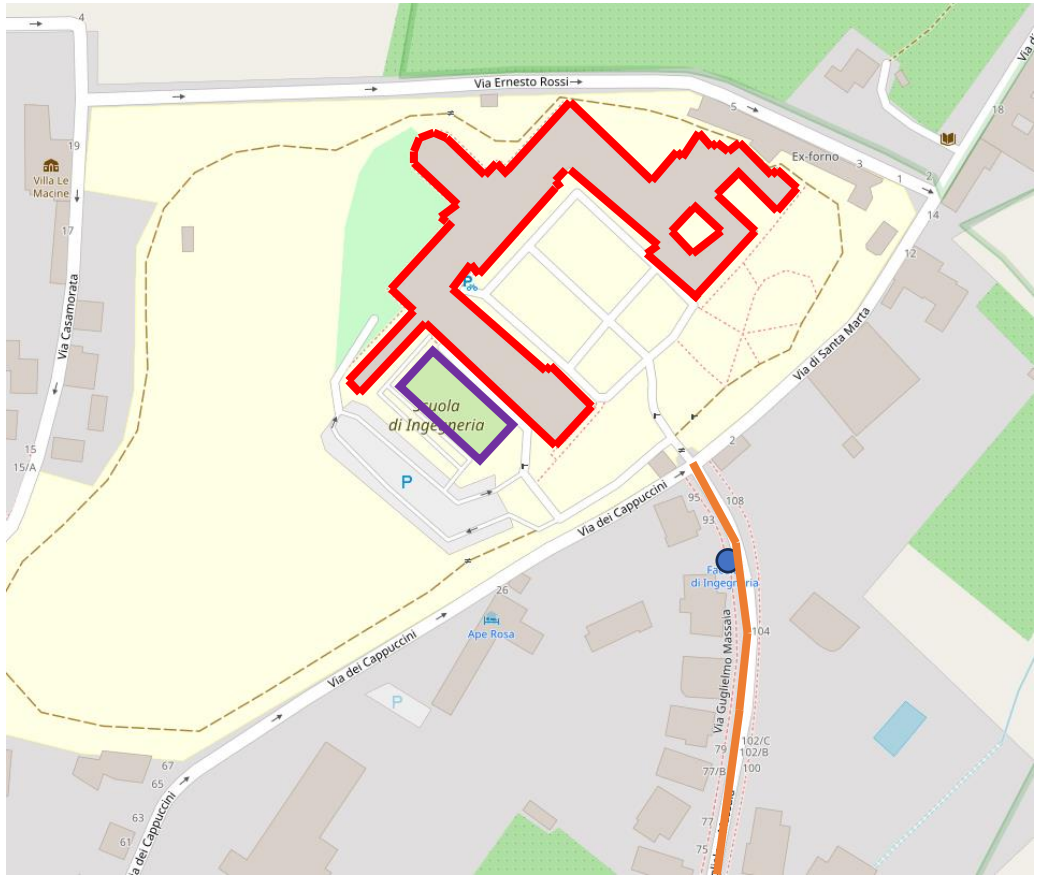
  - **Point of Interest** (POI) as point



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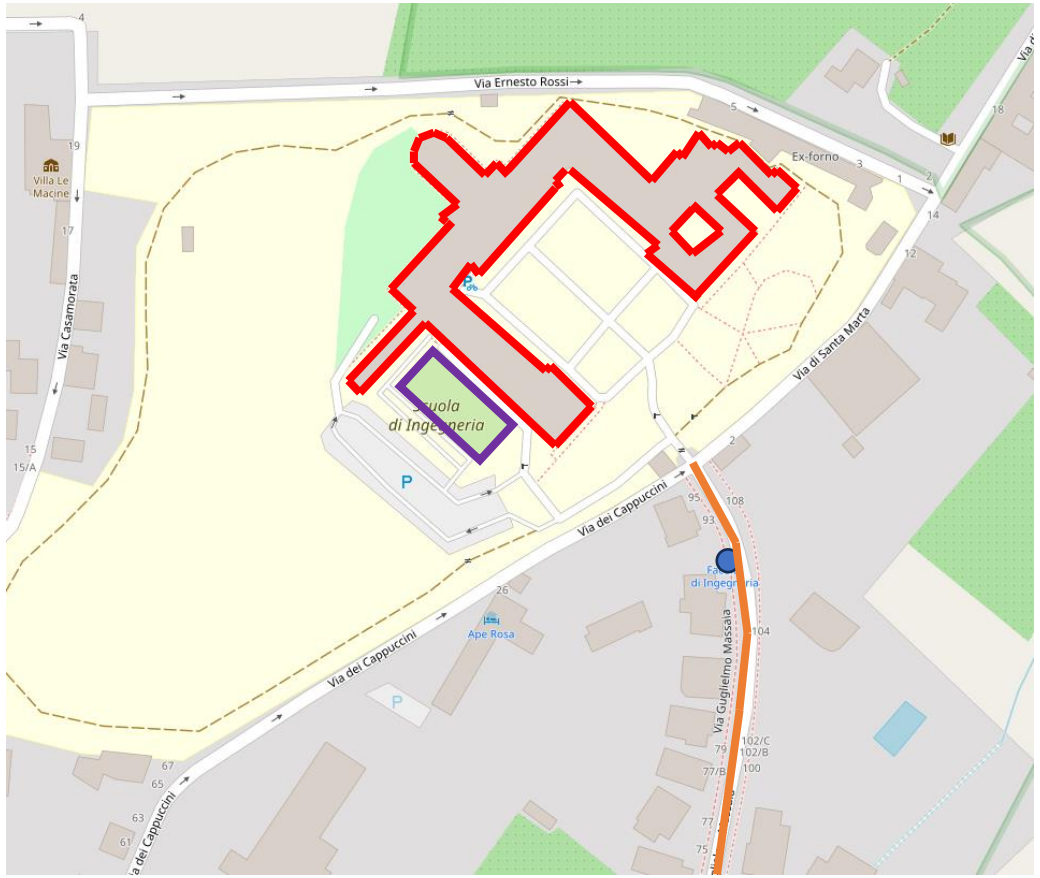
  - **Areas** represented as polygons
  - **Building ground shapes** represented as polygons or multi-polygons
  - **Traffic signs** and **traffic lights** as points
  - **Point of Interest** (POI) as point
  - **Parking** as points or polygons



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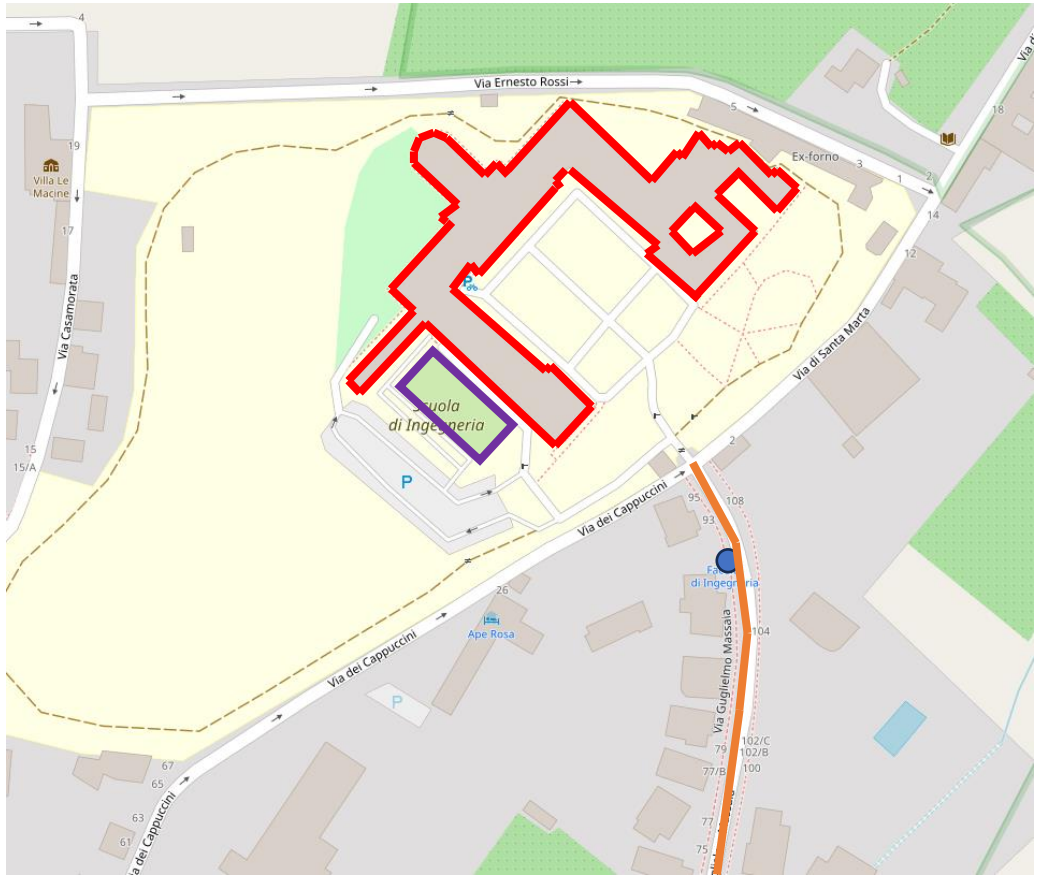
  - **Point of Interest** (POI) as point
  - **Parking** as points or polygons
  - **…**



GIS Data – Raster

- GIS data are used to represent and describe the infrastructures
  - **Ground maps**

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- GIS data are used to represent and describe the infrastructures
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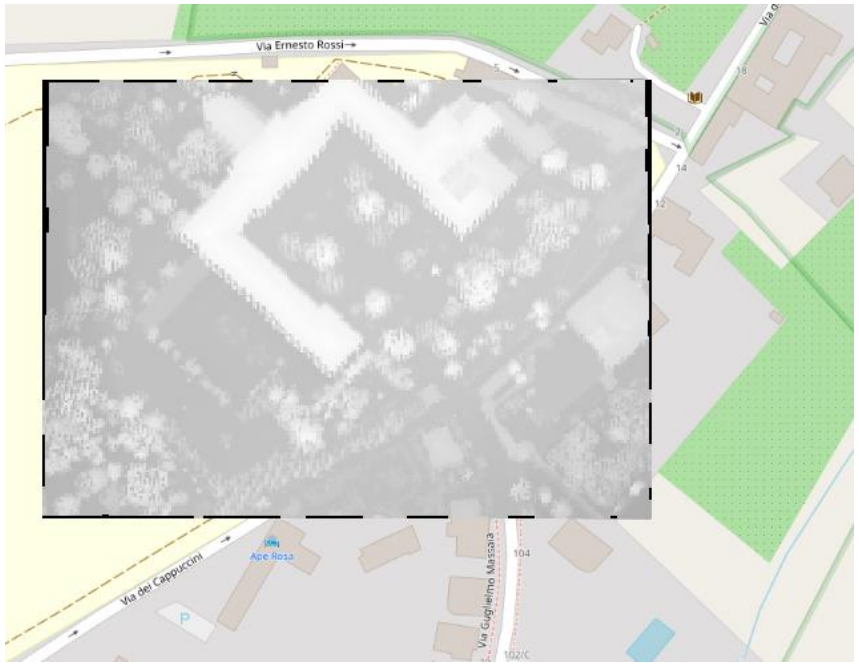
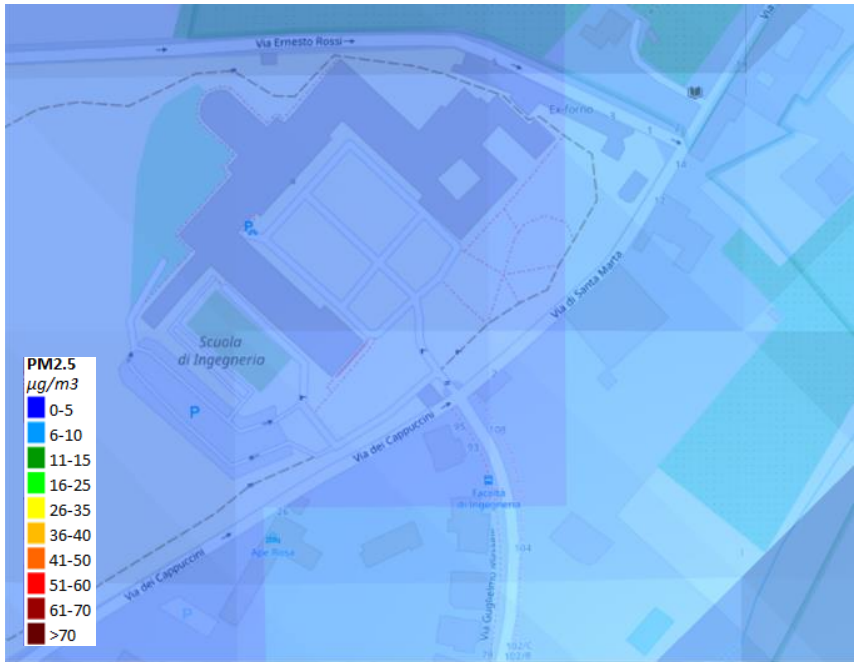
  - **Aerial/satellite photos (orthomaps)**
  - **Elevation maps**



GIS Data – Raster

- GIS data are used to represent and describe the infrastructures
  - **Ground maps**, of different kinds
  - **Aerial/satellite photos (orthomaps)**
  - **Elevation maps**
  - **Heatmaps**



GIS Data – OSM

- GIS data can be retrieved from different services
- OpenStreetMap (https://www.openstreetmap.org/) is one of the most complete and updated source

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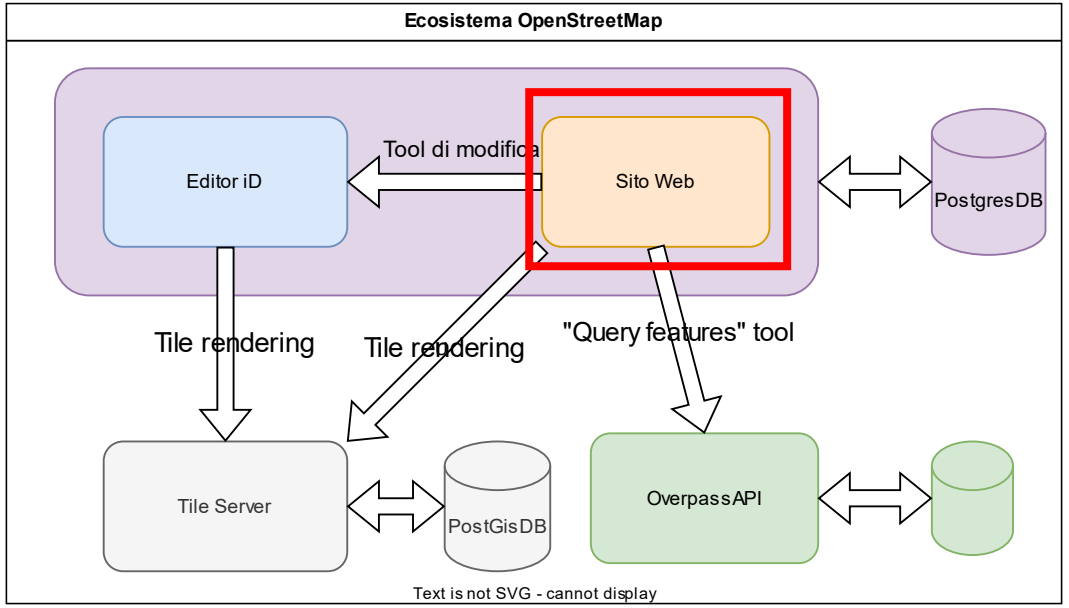

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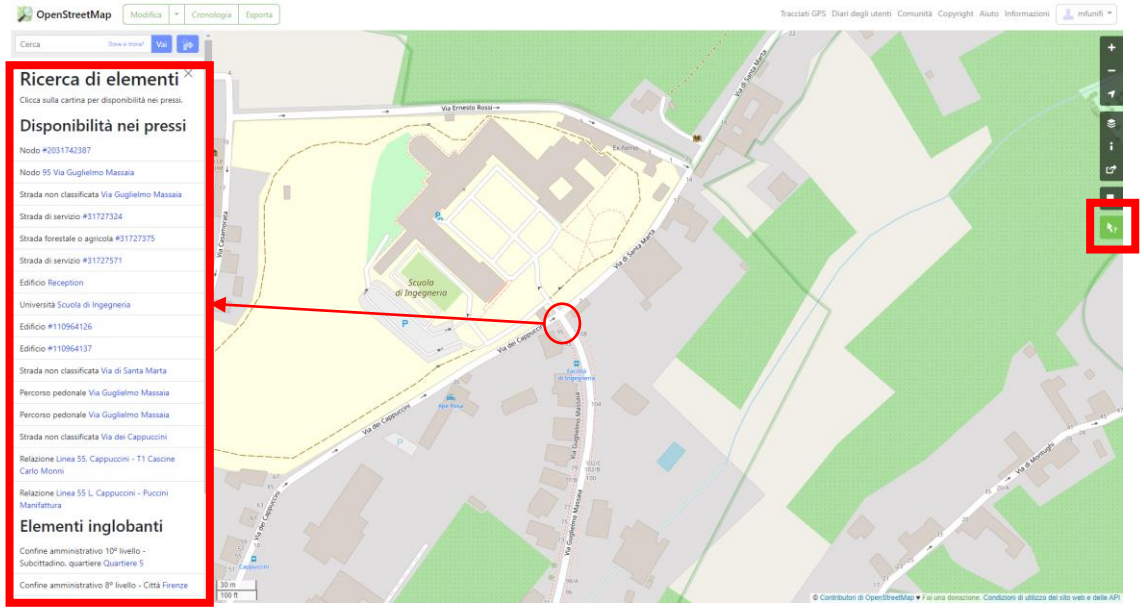

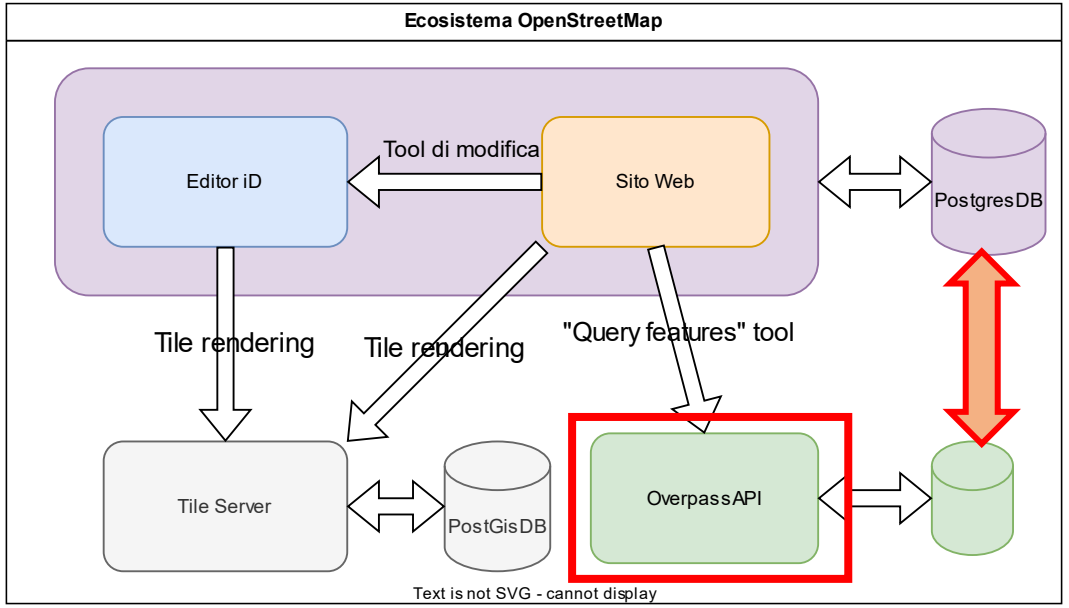

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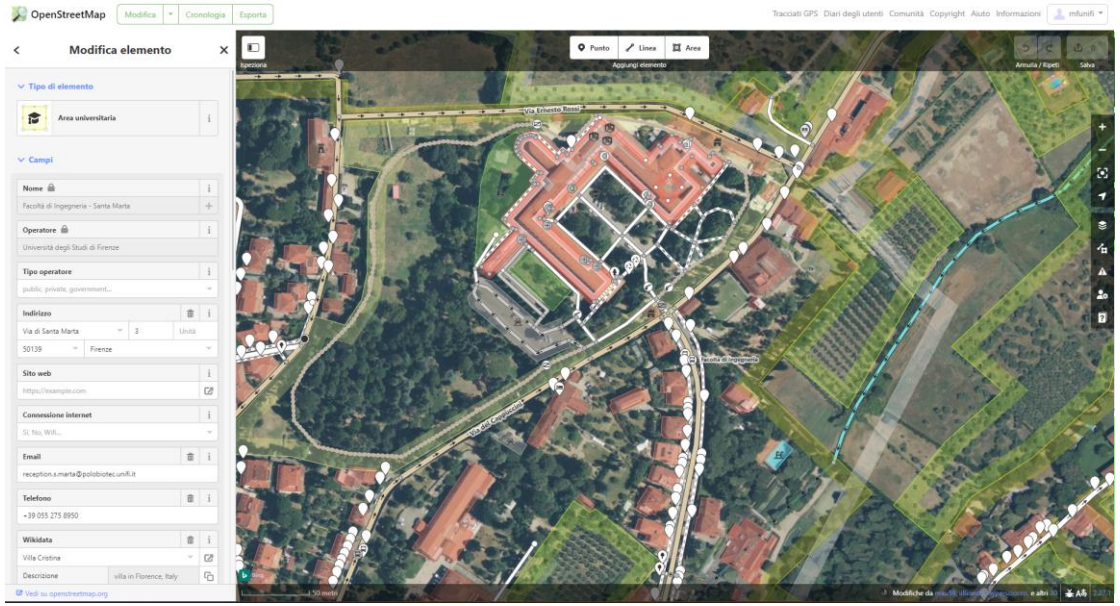

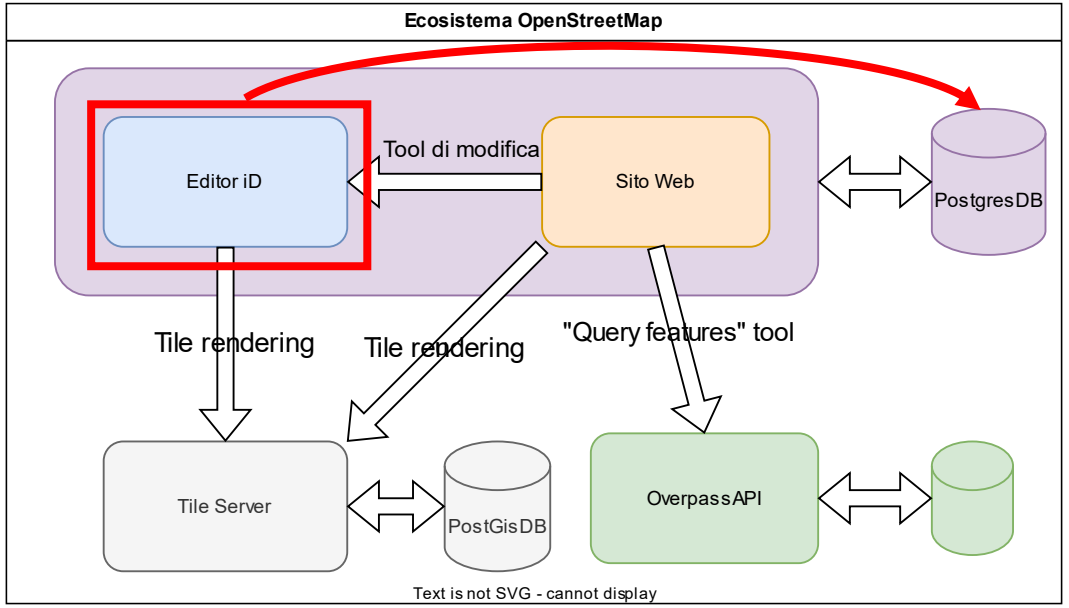

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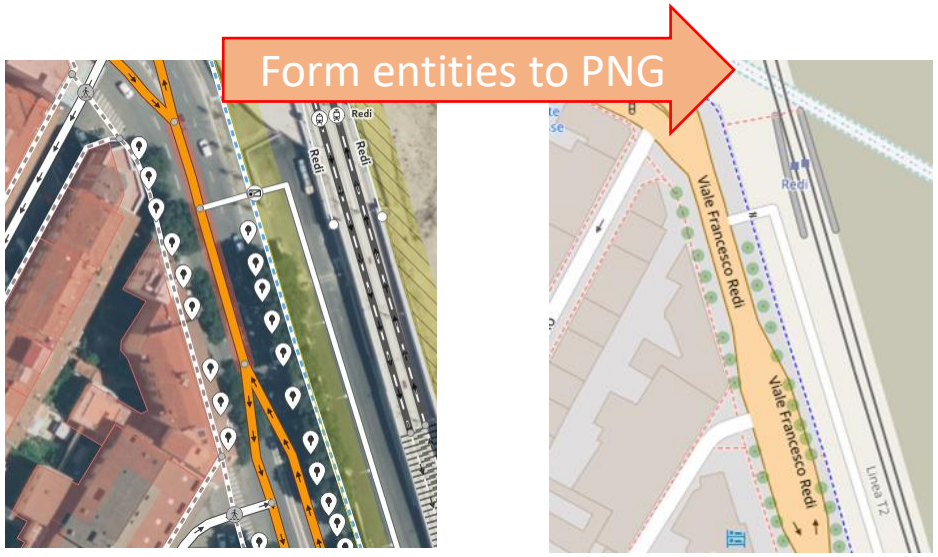

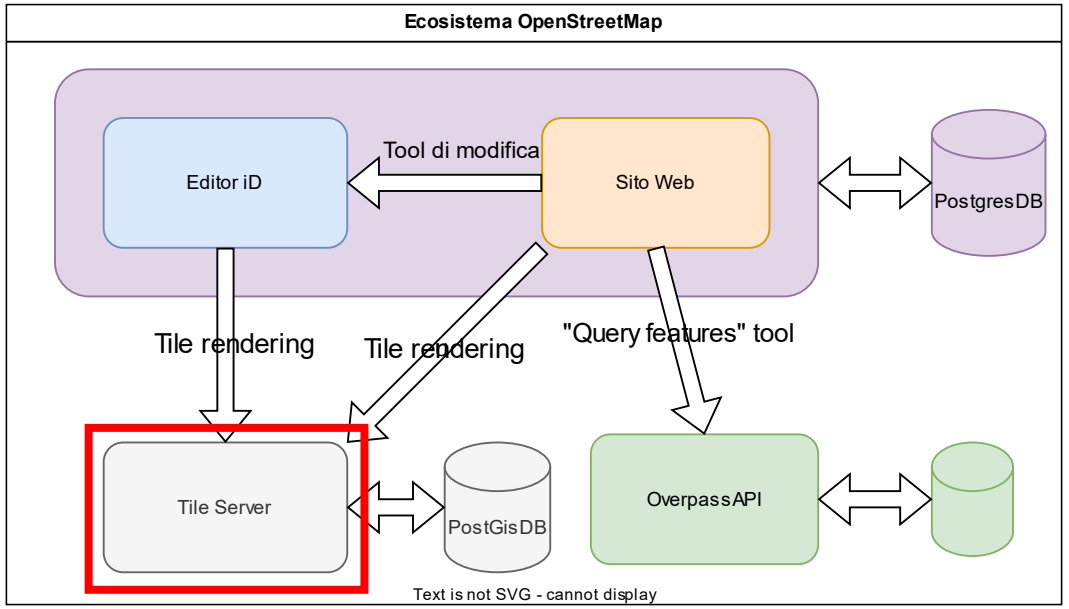

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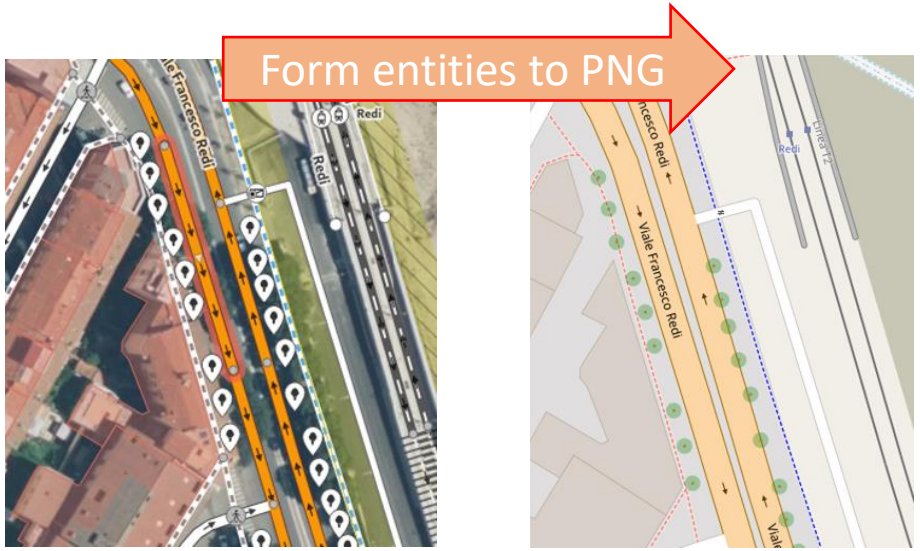
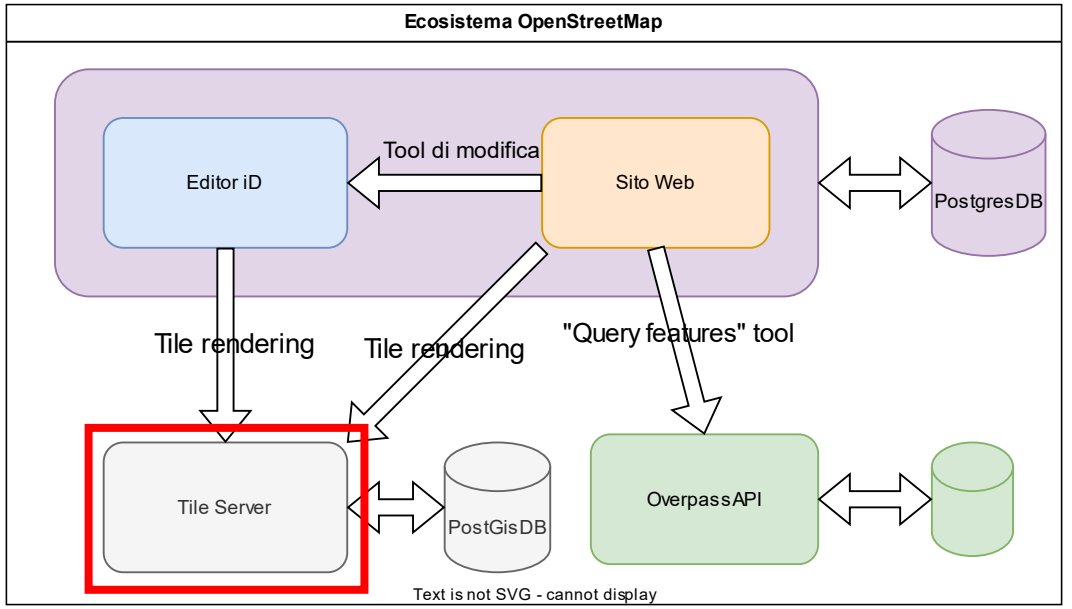
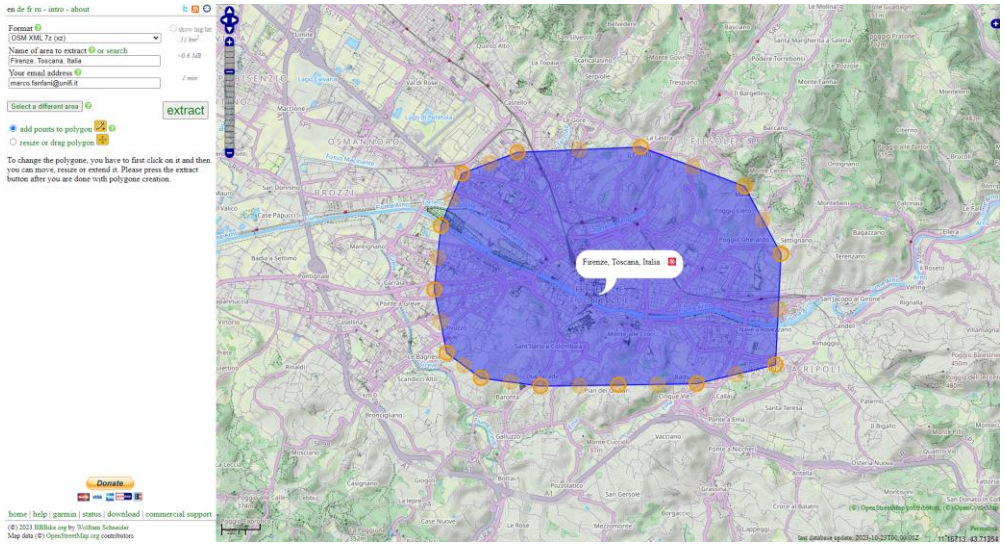




GIS Data – OSM

- GIS data can be retrieved from different services
- OpenStreetMap (https://www.openstreetmap.org/) is one of the most complete and updated source
- Data from OSM DB can be exported using web services:
  - Geofabrik (https://download.geofabrik.de/)
  - HOT Export Tool (https://export.hotosm.org/)
  - BBBike (https://download.bbbike.org/osm/)



GIS Data – Vector formats

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  - Nodes

```
<node id="1533919" lat="43.7958032" lon="11.2447127" version="1">
    <tag k="crossing" v="zebra"/>
    <tag k="crossing:island" v="no"/>
    <tag k="crossing:markings" v="yes"/>
    <tag k="highway" v="crossing"/>
    <tag k="tactile_paving" v="no"/>
</node>
```

GIS Data – Vector formats

- OSM data can be obtained in different formats
- The preferred format is the XML OSM standard. It includes descriptions of
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  - Ways

```
<node id="1533919" lat="43.7958032" lon="11.2447127" version="1">
    <tag k="crossing" v="zebra"/>
    <tag k="crossing:island" v="no"/>
    <tag k="crossing:markings" v="yes"/>
    <tag k="highway" v="crossing"/>
    <tag k="tactile_paving" v="no"/>
</node>
```

```
<way id="111566019" version="1">
    <nd ref="266934805"/>
    <nd ref="8256676004"/>
    <nd ref="2473224"/>
    <tag k="cycleway" v="track"/>
    <tag k="highway" v="primary"/>
    <tag k="lanes" v="3"/>
    <tag k="name" v="Viale Giacomo Matteotti"/>
    <tag k="oneway" v="yes"/>
    <tag k="surface" v="asphalt"/>
</way>
```

GIS Data – Vector formats

- OSM data can be obtained in different formats
- The preferred format is the XML OSM standard. It includes descriptions of
  - Nodes
  - Ways
  - Relations

```
<node id="1533919" lat="43.7958032" lon="11.24
    <tag k="crossing" v="zebra"/>
    <tag k="crossing:island" v="no"/>
    <tag k="crossing:markings" v="yes"/>
    <tag k="highway" v="crossing"/>
    <tag k="tactile_paving" v="no"/>
</node>
```

```
<way id="111566019" version="1">
    <nd ref="266934805"/>
    <nd ref="8256676004"/>
    <nd ref="2473224"/>
    <tag k="cycleway" v="track"/>
    <tag k="highway" v="primary"/>
    <tag k="lanes" v="3"/>
    <tag k="name" v="Viale Giacomo Matteotti"/>
    <tag k="oneway" v="yes"/>
    <tag k="surface" v="asphalt"/>
</way>
```

```
<relation id="9128948" version="1">
    <member type="way" ref="28618378" role="outer"/>
    <member type="way" ref="656322769" role="inner"/>
    <tag k="addr:city" v="Firenze"/>
    <tag k="addr:housename" v="Santa Marta"/>
    <tag k="addr:housenumber" v="3"/>
    <tag k="addr:postcode" v="50139"/>
    <tag k="addr:street" v="Via di Santa Marta"/>
    <tag k="amenity" v="university"/>
    <tag k="building" v="university"/>
    <tag k="building:levels" v="3"/>
    <tag k="building:levels:underground" v="1"/>
    <tag k="email" v="reception.s.marta@polobiotec.unifi.it"/>
    <tag k="name" v="Facoltà di Ingegneria - Santa Marta"/>
    <tag k="old_name" v="Villa Cristina"/>
    <tag k="operator" v="Università degli Studi di Firenze"/>
    <tag k="phone" v="+39 055 275 8950"/>
    <tag k="phone_1" v="+39 055 275 8951"/>
    <tag k="roof:levels" v="0"/>
    <tag k="type" v="multipolygon"/>
    <tag k="wikidata" v="Q4011923"/>
    <tag k="wikipedia" v="it:Villa Cristina"/>
</relation>
```

GIS Data – Vector formats

- Alternatively, OSM data can be downloaded as GeoJSON files


```
{
    "type": "Feature",
    "properties": {
        "osm_id": "9128948",
        "osm_type": "relation",
        "building": "university",
        "name": "Facoltà di Ingegneria - Santa Marta",
        "type": "multipolygon",
    },
    "geometry": {
        "type": "MultiPolygon",
        "coordinates": [
            [
                [
                    [
                        11.252543706842182,
                        43.798166701044707
                    ],
                    [
                        11.252441106842232,
                        43.798236701044694
                    ],
                    [
                        11.252745706842136,
                        43.798472201044646
                    ],
                    [
                        11.252709606842153,
                        43.79849500104465
                    ],
                    [
                        11.252774806842131,
                        43.798546501044655
                    ],
                    [
                        11.25257860684223,
                        43.798678101044651
                    ],
                    [
                        11.252561106842244,
                        43.79869930104465
                    ],
```

GIS Data – Vector formats

- Alternatively, OSM data can be downloaded as GeoJSON files
- GeoJSON augment the standard JSON format with **geographical features**


```
{
    "type": "Feature",
    "properties": {
        "osm_id": "9128948",
        "osm_type": "relation",
        "building": "university",
        "name": "Facoltà di Ingegneria - Santa Marta",
        "type": "multipolygon",
    },
    "geometry": {
        "type": "MultiPolygon",
        "coordinates": [
            [
                [
                    [
                        11.252543706842182,
                        43.798166701044707
                    ],
                    [
                        11.252441106842232,
                        43.798236701044694
                    ],
                    [
                        11.252745706842136,
                        43.798472201044646
                    ],
                    [
                        11.252709606842153,
                        43.79849500104465
                    ],
                    [
                        11.252774806842131,
                        43.798546501044655
                    ],
                    [
                        11.25257860684223,
                        43.798678101044651
                    ],
                    [
                        11.252561106842244,
                        43.79869930104465
                    ],
```

GIS Data – Sources

- GeoJSON can define several geometric structure

```
"geometry": {
  "type": "Point",
  "coordinates": [102.0, 0.5]
}
```

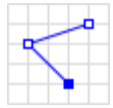
```
"geometry": {
  "type": "LineString",
  "coordinates": [
    [102.0, 0.0],
    [103.0, 1.0],
    [104.0, 0.0],
    [105.0, 1.0]
  ]
}
```

```
"geometry": {
  "type": "Polygon",
  "coordinates": [
    [
      [100.0, 0.0],
      [101.0, 0.0],
      [101.0, 1.0],
      [100.0, 1.0],
      [100.0, 0.0]
    ]
  ]
}
```

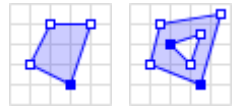
GIS Data – Vector formats

- GeoJSON can define several geometric structure


```
"geometry": {
  "type": "Point",
  "coordinates": [102.0, 0.5]
}
```

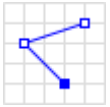
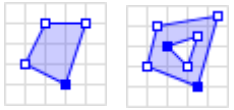
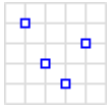
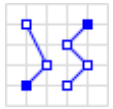
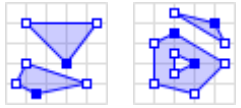
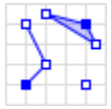


```
"geometry": {
  "type": "LineString",
  "coordinates": [
    [102.0, 0.0],
    [103.0, 1.0],
    [104.0, 0.0],
    [105.0, 1.0]
  ]
}
```



```
"geometry": {
  "type": "Polygon",
  "coordinates": [
    [
      [100.0, 0.0],
      [101.0, 0.0],
      [101.0, 1.0],
      [100.0, 1.0],
      [100.0, 0.0]
    ]
  ]
}
```

GIS Data – Vector formats

- GeoJSON can define several geometric structure
  - **Point**
  - **Linestring** 
  - **Polygon** 
  - **Multipoint** 
  - **MultiLinestring** 
  - **Multipolygon** 
  - **GeometryCollection** 

GIS Data – Vector formats

- GeoJSON use the **EPGS:4326 – WGS84** coordinate reference system (CRS), defining the coordinate of point in **latitude** and **longitude**

- When using different CRS, this information must be specified

```
"crs": {
  "type": "name",
  "properties": {
    "name": "urn:ogc:def:crs:EPSG::3003"
  }
},
```

GIS Data – Vector formats

- OSM data can be retrieved also as **Esri Shapefile format**
  - Developed and regulated by Esri as a *mostly open* specification for data interoperability
  - It can represent the entities already seen (points, lines, polygons, …)
  - It is composed by several mandatory and optional files
    - *.shp* — shape format;
    - *.shx* — shape index format;
    - *.dbf* — attribute format, columnar attributes for each shape;
    - *.prj* — projection description

GIS Data – Sources

- OSM data can be retrieved directly from the PostgreSQL DB
- This relational DB is composed by tables representing
  - Nodes (i.e., points)
  - Ways (i.e., lines and polygons)
  - Relations (i.e., multilines and multipolygons)
- OSM can be deployed on-premise, see https://github.com/openstreetmap/openstreetmap-website

Is good to know…

- Another format to represent geometric spatial objects is the Well-Known Text (WKT) format.
- Similarly to GeoJSON, WKT can encode spatial entities like

Point	POINT(1 2)
LineString	LINESTRING(1.5 2.45, 3.21 4)
Polygon	POLYGON((1 2,1 4,3 4,3 2,1 2)) POLYGON((0.5 0.5,5 0,5 5,0 5,0.5 0.5), (1.5 1,4 3,4 1,1.5 1))
MultiPoint	MULTIPOINT(0 0,1 1)
MultilineString	MULTILINESTRING((0 0,–1 –2,–3 –4),(2 3,3 4,6 7))
MultiPolygon	MULTIPOLYGON(((0 1,3 0,4 3,0 4,0 1)), ((3 4,6 3,5 5,3 4)), ((0 0,–1 –2,–3 –2,–2 –1,0 0)))
GeometryCollection	GEOMETRYCOLLECTION(POINT(5 8), LINESTRING(–1 3,1 4))

GIS Data – Raster formats

- Raster data, i.e., images, requires different formats
- Most common formats include
  - PNG
  - GeoTIFF
  - Esri grid ASCII (ASC)

GIS Data – Raster formats

- Portable Network Graphics (PNG) is a raster-graphics file format that supports lossless data compression
- PNG is often the best raster format for maps, since the lossless compression keeps text and line work legible by preventing the compression artifacts (unlike JPEG)
- PNG can handle transparency (useful to indicate no-data values)
- PNG is widely used in many applications, in particular for web applications
- However, **PNG does not embed geographic information!**

GIS Data – Raster formats

- Maps represented as PNG are usually provided by GeoServers
- A GeoServer implements the OpenGIS Web Map Service (WMS) interface standard over HTTP/HTTPS

GIS Data – Raster formats

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- A GeoServer implements the OpenGIS Web Map Service (WMS) interface standard over HTTP/HTTPS

Example REST call:

https://wmsserver.snap4city.org/geoserver/Snap4City/wms?service=WMS&request=GetMap&layers=dtm_orografico_SuperRes_epgs4326_RGB&format=image%2Fpng&transparent=true&width=256&height=256&bbox=11.24725341796875,43.76911045236617,11.25,43.77109381775649

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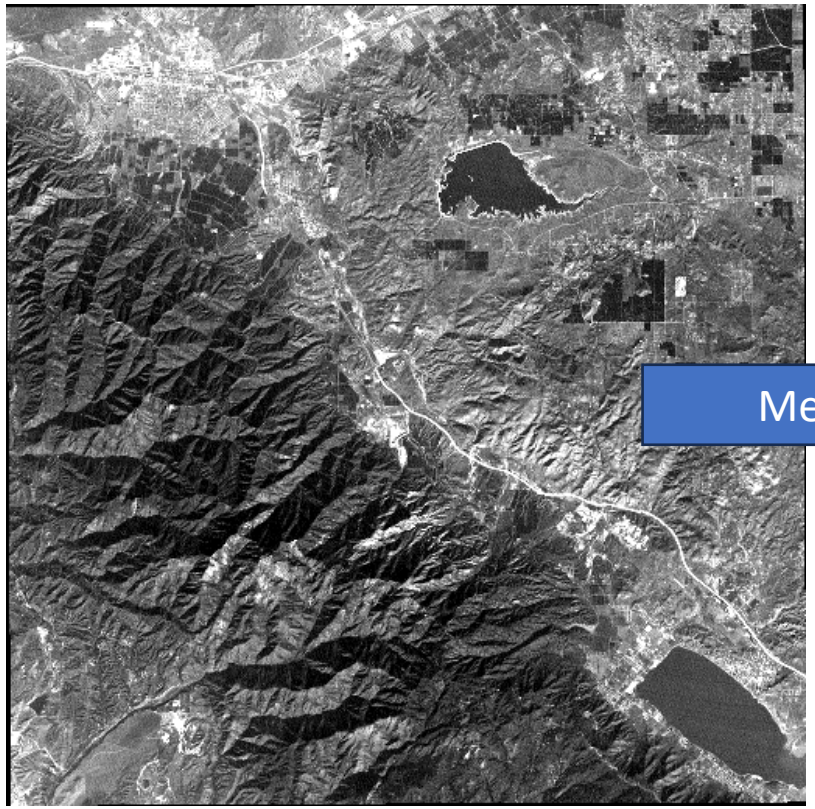
- In practice, is the client that requests the PNG for a specific geographic bounding box

GIS Data – Raster formats

- GeoTIFF is a public domain metadata standard which allows **georeferencing information** to be embedded into a TIFF file.



Metadata

```
Driver: GTiff/GeoTIFF
Files: cea.tif
Size is 514, 515
Coordinate System is:
PROJCRS[
  ...
]
Data axis to CRS axis mapping: 1,2
Origin = (-28493.166784412522247,4255884.543802191503346)
Pixel Size = (60.022136983193739,-60.022136983193739)
Metadata:
  AREA_OR_POINT=Area
Image Structure Metadata:
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (  -28493.167, 4255884.544) (117d38'27.05"W, 33d56'37.74"N)
Lower Left  (  -28493.167, 4224973.143) (117d38'27.05"W, 33d39'53.81"N)
Upper Right (    2358.212, 4255884.544) (117d18'28.38"W, 33d56'37.74"N)
Lower Right (    2358.212, 4224973.143) (117d18'28.38"W, 33d39'53.81"N)
Center      (  -13067.478, 4240428.844) (117d28'27.71"W, 33d48'15.38"N)
Band 1 Block=514x15 Type=Byte, ColorInterp=Gray
```

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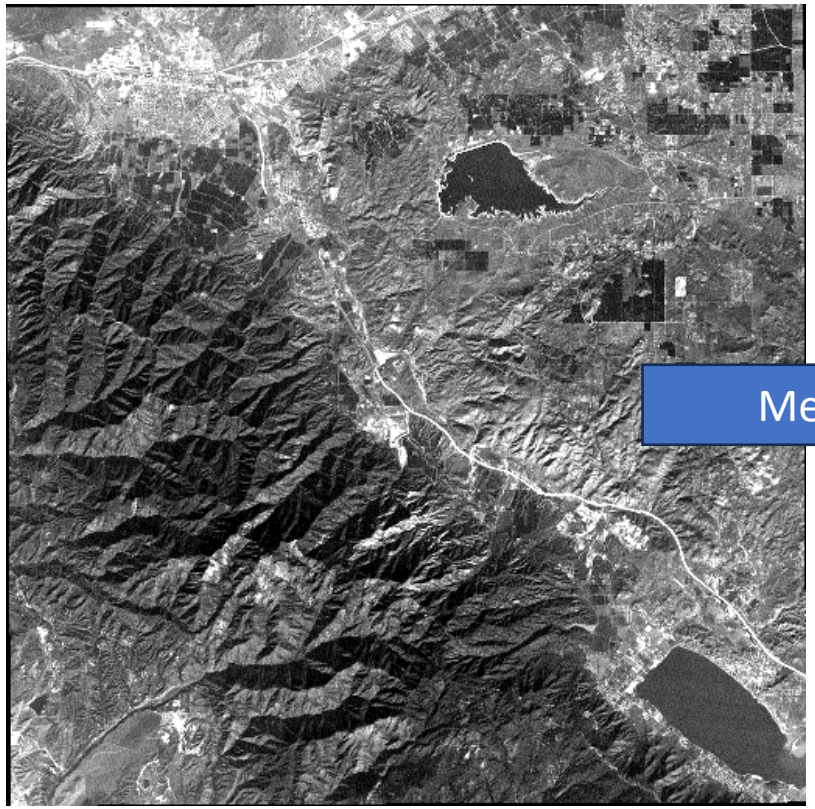

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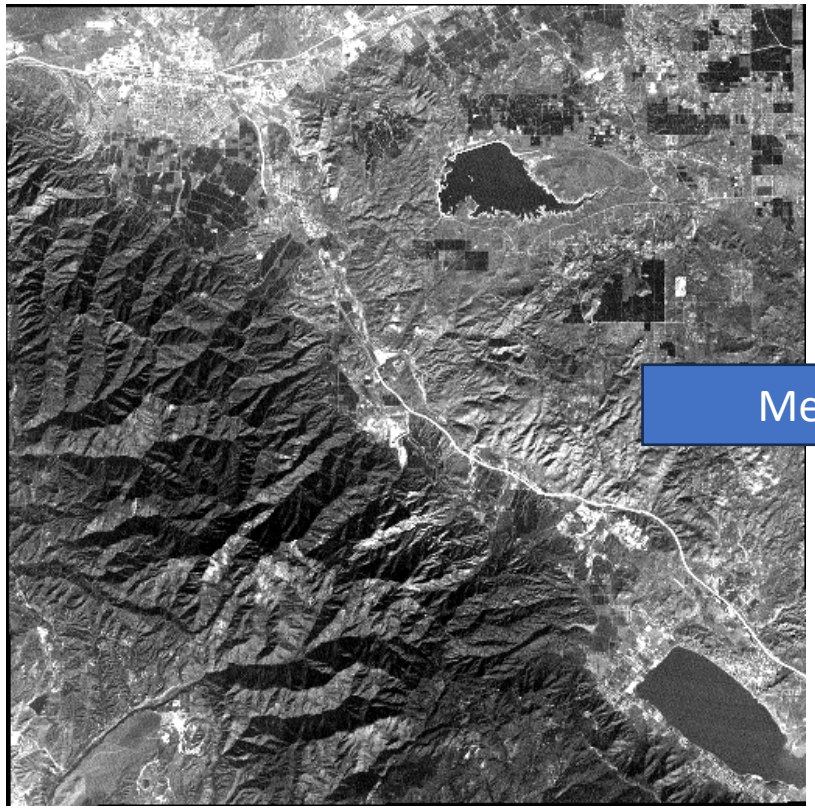

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```

GIS Data – Raster formats

- Esri grid ASCII (ASC) is a text format to represent matrix data with geographic information

GIS Data – Raster formats

- Esri grid ASCII (ASC) is a text format to represent matrix data with geographic information
- ASC is composed by two main part
  - Header with metadata

```
NCOLS 1640
NROWS 1240
XLLCENTER 1675980.500
YLLCENTER 4846780.500
CELLSIZE 1
NODATA_VALUE -9999.000
```

GIS Data – Raster formats

- Esri grid ASCII (ASC) is a text format to represent matrix data with geographic information
- ASC is composed by two main part
  - Header with metadata
  - Cell values

```
NCOLS 1640
NROWS 1240
XLLCENTER 1675980.500
YLLCENTER 4846780.500
CELLSIZE 1
NODATA_VALUE -9999.000
 41.236 41.226 41.226 41.226 41.256 41.216 41.206 41.156 …
 41.226 41.176 41.176 41.176 41.196 41.206 41.226 41.227 …
 41.287 41.307 41.287 41.257 41.287 41.307 41.317 41.317 …
 41.307 41.397 41.367 41.397 41.407 41.427 41.487 41.467 …
 41.447 48.407 51.757 52.207 47.947 49.867 46.577 46.197 …
 …
```

GIS Data – Raster formats

- Esri grid ASCII (ASC) is a text format to represent matrix data with geographic information
- ASC is composed by two main part
  - Header with metadata
  - Cell values
- Note that, there are not CRS information!

```
NCOLS 1640
NROWS 1240
XLLCENTER 1675980.500
YLLCENTER 4846780.500
CELLSIZE 1
NODATA_VALUE -9999.000
 41.236 41.226 41.226 41.226 41.256 41.216 41.206 41.156 …
 41.226 41.176 41.176 41.176 41.196 41.206 41.226 41.227 …
 41.287 41.307 41.287 41.257 41.287 41.307 41.317 41.317 …
 41.307 41.397 41.367 41.397 41.407 41.427 41.487 41.467 …
 41.447 48.407 51.757 52.207 47.947 49.867 46.577 46.197 …
 …
```

Mobility offer

- The mobility offer includes all the available public mobility services offered by public or private companies
  - Bus
  - Tram
  - Train
  - Ferry
  - Bike sharing
  - Car sharing
  - Scooter sharing
  - Taxi
  - Car hailing (e.g., Uber, Lyft)

Mobility offer – Public transport

- For the public transports (bus, tram, etc.) a mobility offer must include
  - **Routes**, that are the trajectories covered with indication of the stops
  - **Trips**, that are the specific instances of a route at given time with give schedule

Mobility offer – Public transport

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- This and other information are distributed from the transport operator using standards like **GTFS/GTFS-RT** and **NeTEx/SIRI**

Mobility offer – GTFS Schedule (static)

- The **General Transit Feed Specification (GTFS)** is an Open Standard used to distribute information about transit systems
- It is composed by a list of CVS text files archived in a zip file
- The text file list includes:
  - *agency.txt*: info on the transit operator
  - *stops.txt*: stop list
  - *ruotes.txt*: route list
  - *trips.txt*: trip list for each route
  - *stop_times.txt*: arrival and departure times for each stop and each trip
  - *calendar.txt / calendar_dates.txt*: working days and exceptions
  - *shapes.txt*: lat/long coordinate to draw the routes on a map
  - *fare_attributes.txt*: prices of the service
  - …

Mobility offer – GTFS Schedule (static)

routes.txt

route_id,agency_id,route_short_name,route_long_name,route_type,route_color,route_text_color
"2182839646","303","T1.3","Servizio Tramvia Firenze - Linea T1.3","0","D86018","000000“
"3209345033","303","T2","Servizio Tramvia Firenze - Linea T2","0","D86018","000000"

trips.txt

route_id,service_id,trip_id,trip_headsign,trip_short_name,direction_id,shape_id
"2182839646","4527_593642","4527_549189","Careggi - Ospedale","","0","2182839646"
"2182839646","4527_593642","4527_549190","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549191","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549192","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549193","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549194","Villa Costanza","","1","978952710"

stops.txt

stop_id,stop_name,stop_lat,stop_lon,stop_code
"FM9004_103","De Andre","43.7547865043581","11.1790362683518","FM9004“
"FM9005_103","Resistenza","43.7579847316209","11.1822112945389","FM9005“
"FM9006_103","Resistenza","43.7580441494077","11.1822068713052","FM9006“
…
"FM9035_103","Vittorio Emanuele Ii","43.7958712112307","11.2415139153139","FM9035“
"FM9036_103","Morgagni-Universita","43.7995953955465","11.2439861801234","FM9036“
"FM9037_103","Careggi - Ospedale","43.8033027414408","11.2465976104274","FM9037"

stop_times.txt

trip_id,arrival_time,departure_time,stop_id,stop_sequence,shape_dist_traveled
"4527_549189","05:29:00","05:29:00","FM9004_103","1","0"
"4527_549189","05:30:00","05:30:00","FM9006_103","2",".44279"
"4527_549189","05:32:00","05:32:00","FM9008_103","3","1.04775"
"4527_549189","05:34:00","05:34:00","FM9010_103","4","1.93364"
"4527_549189","05:36:00","05:36:00","FM9012_103","5","2.96611"
"4527_549189","05:37:00","05:37:00","FM9014_103","6","3.46874"
"4527_549189","05:38:00","05:38:00","FM9016_103","7","4.00089"
"4527_549189","05:40:00","05:40:00","FM9018_103","8","4.34465"
"4527_549189","05:41:00","05:41:00","FM9020_103","9","4.66609“
"4527_549189","05:42:00","05:42:00","FM9022_103","10","4.98182“
"4527_549189","05:43:00","05:43:00","FM9024_103","11","5.41694“
"4527_549189","05:45:00","05:45:00","FM9026_103","12","6.08557“
"4527_549189","05:49:00","05:49:00","FM9027_103","13","6.92863“
"4527_549189","05:51:00","05:51:00","FM9028_103","14","7.3331“
"4527_549189","05:54:00","05:54:00","FM9029_103","15","7.84536“
"4527_549189","05:56:00","05:56:00","FM9030_103","16","8.339“
"4527_549189","05:57:00","05:57:00","FM9031_103","17","8.61417“
"4527_549189","05:59:00","05:59:00","FM9032_103","18","8.9197“
"4527_549189","06:00:00","06:00:00","FM9033_103","19","9.29738“
"4527_549189","06:02:00","06:02:00","FM9034_103","20","9.66363“
"4527_549189","06:04:00","06:04:00","FM9035_103","21","10.00552“
"4527_549189","06:06:00","06:06:00","FM9036_103","22","10.53703“
"4527_549189","06:08:00","06:08:00","FM9037_103","23","11.03527"

Mobility offer – GTFS Schedule (static)

routes.txt

```
route_id,agency_id,route_short_name,route_long_name,route_type,route_color,route_text_color
"2182839646","303","T1.3","Servizio Tramvia Firenze - Linea T1.3","0","D86018","000000“
"3209345033","303","T2","Servizio Tramvia Firenze - Linea T2","0","D86018","000000"
```

trips.txt

```
route_id,service_id,trip_id,trip_headsign,trip_short_name,direction_id,shape_id
"2182839646","4527_593642","4527_549189","Careggi - Ospedale","","0","218283964
"2182839646","4527_593642","4527_549190","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549191","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549192","Villa Costanza","","1","978952710"
"2182839646","4527_593642","4527_549193","Careggi - Ospedale","","0","3583783680"
"2182839646","4527_593642","4527_549194","Villa Costanza","","1","978952710"
```

stops.txt

```
stop_id,stop_name,stop_lat,stop_lon,stop_code
"FM9004_103","De Andre","43.7547865043581","11.1790362683518","FM9004“
"FM9005_103","Resistenza","43.7579847316209","11.1822112945389","FM9005“
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"FM9036_103","Morgagni-Universita","43.7995953955465","11.2439861801234","FM9036“
"FM9037_103","Careggi - Ospedale","43.8033027414408","11.2465976104274","FM9037"
```

stop_times.txt

```
trip_id,arrival_time,departure_time,stop_id,stop_sequence,shape_dist_traveled
"4527_549189","05:29:00","05:29:00","FM9004_103","1","0"
"4527_549189","05:30:00","05:30:00","FM9006_103","2",".44279"
"4527_549189","05:32:00","05:32:00","FM9008_103","3","1.04775"
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"4527_549189","05:42:00","05:42:00","FM9022_103","10","4.98182“
"4527_549189","05:43:00","05:43:00","FM9024_103","11","5.41694“
"4527_549189","05:45:00","05:45:00","FM9026_103","12","6.08557“
"4527_549189","05:49:00","05:49:00","FM9027_103","13","6.92863“
"4527_549189","05:51:00","05:51:00","FM9028_103","14","7.3331“
"4527_549189","05:54:00","05:54:00","FM9029_103","15","7.84536“
"4527_549189","05:56:00","05:56:00","FM9030_103","16","8.339“
"4527_549189","05:57:00","05:57:00","FM9031_103","17","8.61417“
"4527_549189","05:59:00","05:59:00","FM9032_103","18","8.9197“
"4527_549189","06:00:00","06:00:00","FM9033_103","19","9.29738“
"4527_549189","06:02:00","06:02:00","FM9034_103","20","9.66363“
"4527_549189","06:04:00","06:04:00","FM9035_103","21","10.00552“
"4527_549189","06:06:00","06:06:00","FM9036_103","22","10.53703“
"4527_549189","06:08:00","06:08:00","FM9037_103","23","11.03527"
```

Mobility offer – GTFS-RT (RealTime)

- The **GTFS-RT** is a feed specification that allows public transportation agencies to provide real-time updates about their fleet
- Provide three types of real-time updates to users:
  - Trip updates - delays, cancellations, changed routes
  - Service alerts - stop moved, unforeseen events affecting a station, route or the entire network
  - Vehicle positions - information about the vehicles including location and congestion level
- Feeds are served via HTTP as binary files based on Protocol Buffers

Protocol Buffers

- Protocol buffers are Google's language-neutral, platform-neutral, extensible mechanism for serializing structured data
- You define how you want your data to be structured once, then you can use special generated source code to easily write and read your structured data to and from a variety of data streams
- It is based on the definition of a *.proto* file where each structured data to serialize is described in a *message*

```
message Person {
  optional string name = 1;
  optional int32 id = 2;
  optional string email = 3;
}
```

- Then, you need to generate classes to read and write the defined messages
- There are compilers for different languages to generate the classes

https://protobuf.dev/overview/

Mobility offer – GTFS-RT (RealTime)

- Vehicle position feed example (ASCII representation)

```
header {
  gtfs_realtime_version: "2.0"
  incrementality: FULL_DATASET
  timestamp: 1656230726
}
entity {
  id:    "1"
  vehicle {
    trip {
      trip_id: "trip1"
      start_time: "14:05:00"
      start_date: "20220628"
      schedule_relationship: SCHEDULED
      route_id: "ROUTE1"
      direction_id: 0
    }
    position {
      latitude: 123.45
      longitude: 12.345
    }
    timestamp: 1656390815
    vehicle {
      id: "vehicle1"
    }
    occupancy_status: MANY_SEATS_AVAILABLE
  }
}
entity {
...
```

Mobility offer – NeTEx

- The **Network Timetable Exchange** standard is intended to be a general-purpose XML format designed for the exchange of transport data
- NeTEx is the first standard that also covers **multimodal fares**
- NeTEx includes
  - Schedules
  - Stops
  - Routes
  - Service days
  - Fares

Mobility offer – NeTEx

- NeTEx is described in four parts
  - Part 1: Public transport **network topology** exchange format
  - Part 2: Public transport **scheduled timetables** exchange format
  - Part 3: Public transport **fares** exchange format
  - Part 4: Passenger Information European Profile

- Part 5 is under development and will focus on car sharing, cycle sharing, carpooling, car/cycle rental

- More info:
  - https://netex-cen.eu/
  - https://github.com/entur/profile-examples

Mobility offer – SIRI

- The Service Interface for Real time Information (SIRI) allows pairs of server computers to exchange structured real-time information about transport services
- SIRI complements NeTEx for real-time data exchange
- Messages consist of XML documents, whose tags and content are exactly specified by the SIRI XML Schemas
- SIRI allow both synchronous request/response and asynchronous subscribe/publish protocols

Mobility offer – NeTEx & SIRI

- Both NeTEx and SIRI shared a common conceptual model provided by **Transmodel** (http://www.transmodel-cen.eu/), that is an abstract model of common public transport concepts and data structures

- More info:
  - https://netex-cen.eu/
  - https://www.siri-cen.eu/
  - https://github.com/entur/profile-examples

Mobility offer – Sharing

- In case of sharing mobility offers, static data are less relevant since there are not fixed routes or scheduled trips
- Real-time data on vehicle position and their availability are more important
- The most advanced standards covering sharing mobility are the **General Bikeshare Feed Specification** (GBFS) and the **Mobility Data Specification** (MDS)

Mobility offer – GBFS

- The **General Bikeshare Feed Specification** (GBFS) is based on a series of JSON
  - *gbfs.json* – an index with links to the other files
  - *vehicle_types.json* – list types of available vehicles
  - *station_information.json* – list of all stations, their capacities and locations
  - *station_status.json* – available vehicles and docks at each station
  - *vehicle_status.json* – describes all vehicles that are not currently in active rental
  - …

Mobility offer – GBFS

gbfs.json


```
{
  "last_updated": 1698165756,
  "ttl": 0,
  "version": "2.2",
  "data": {
    "en": {
      "feeds": [
        {
          "name": "gbfs_versions",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/gbfs_versions.json"
        },
        {
          "name": "system_information",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/system_information.json"
        },
        {
          "name": "vehicle_types",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/vehicle_types.json"
        },
        {
          "name": "station_information",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/station_information.json"
        },
        {
          "name": "free_bike_status",
          "url": "https://gbfs.helbiz.com/v2.2/firenze/free_bike_status.json"
        },
...
```


vehicle_status.json


```
{
  "last_updated": 1698166031,
  "ttl": 0,
  "version": "2.2",
  "data": {
    "bikes": [
      {
        "bike_id": "X8CS5R",
        "lat": 43.788457,
        "lon": 11.271341,
        "is_reserved": false,
        "is_disabled": true,
        "vehicle_type_id": "moped",
        "rental_uris": {
          "android": "https://...
          "ios": "https://...
        },
        "last_reported": 1660338193,
        "current_range_meters": 13.5,
        "pricing_plan_id": "price_moped"
      },
...
```

Mobility offer – MDS

- The **Mobility Data Specification** (MDS) is focused on managing shared mobility services
- MDS standardizes communication and data-sharing between cities and private mobility providers
- MDS is based on three primary APIs that allow cities and providers to communicate
  - *Provider* allows private mobility companies to report historical data to cities
  - *Policy* allows cities to set rules for how and where different vehicles can operate, how many can operate, and other high-level policy initiatives
  - *Agency* allows real-time updates and collaboration between city officials and providers

Mobility offer – GBFS & MDS

- GBFS is intended to provide real-time data to the final user
- MDS is designed to exchange data between the mobility operator and the public administration, including real-time and historical data
- Their adoption is still limited, in particular in Italy
- When widely deployed they can offer
  - A clear status of the shared mobility offer
  - Data to estimate the mobility patterns of the users

Sensor data

- IoT/IoE sensors are exploited to acquire **real-time measurements and information** of the mobility environment

- Such sensors can provide different kind of data:
  - traffic vehicle density
  - number of passages though specific areas
  - number of vehicles in a parking
  - environmental information on whether, pressure, pollutant
  - …

Sensor data

- Messages from IoT Sensors depend on the specific sensor setup
- Typically, text format as JSON or XML are used

Sensor data

- **Data transmission** follows a client/server architecture, with push or pull modalities
- Most common **pull protocols** are
  - REST call over HTTP/HTTPS
  - FTP
- **Push protocols** (data-driven with subscriptions) are
  - WebSocket (WS)
  - Constrained Application Protocol (CoAP)
  - Message Queue Telemetry Transport (MQTT)
  - Advanced Message Queuing Protocol (AMQP)
  - FIWARE NGSI and NGSI-V2

Sensor data

- **Camera sensors** are a more particular case: video transmission usually requires a continuous data flow
- Different **codec** and **video container** can be used (for example the H.264 codec with mp4 container)
- Several protocols are available, such as
  - HTTP Live Streaming (HLS)
  - Real-Time Messaging Protocol (RTMP)
  - Web Real-Time Communications (WebRTC)
  - Real-Time Streaming Protocol (RTSP)
  - Dynamic Adaptive Streaming over HTTP (MPEG-DASH)

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- More recently **cameras with processing units (CPU and GPU)** are available to elaborate the video feed on-the-edge and extracted information can be transmitted with text messages

Sensor data

- Among the information provided from sensors, **traffic data** are very important for smart mobility application
- Not all the cities deployed enough sensors to capture traffic information, or you may not have access to the sensors' data
- Alternative solution are available
  - **Paid solutions**: companies like Waze or Here offer API to retrieve data feed, that can include information also on events such as road accidents
  - **Open data**: for some areas* traffic data are released freely. These data are sent with different formats. One of the possible format (in particular from European providers) is the **DATEX-II** standard.

* https://github.com/graphhopper/open-traffic-collection

DATEX-II

- DATEX-II is a data exchange standard for exchanging traffic information
- DATEX-II contains
  - **Road and traffic related events** (called "Traffic elements"): abnormal traffic, accidents, public event, driving conditions, obstructions, …
  - **Operator actions**: network management, traffic control, roadworks, …
  - **Impacts**: information on lane availability and on delays
  - **Measured or elaborated data**: travel times, traffic speed, traffic status, weather measurements, …
  - **Messages displayed on Variable Message Signs** (VMS)
  - **Service information:** closed rest area, information about other transport means (e.g., delays on trains), ...
- Data is presented in **XML**

IoT Actuators

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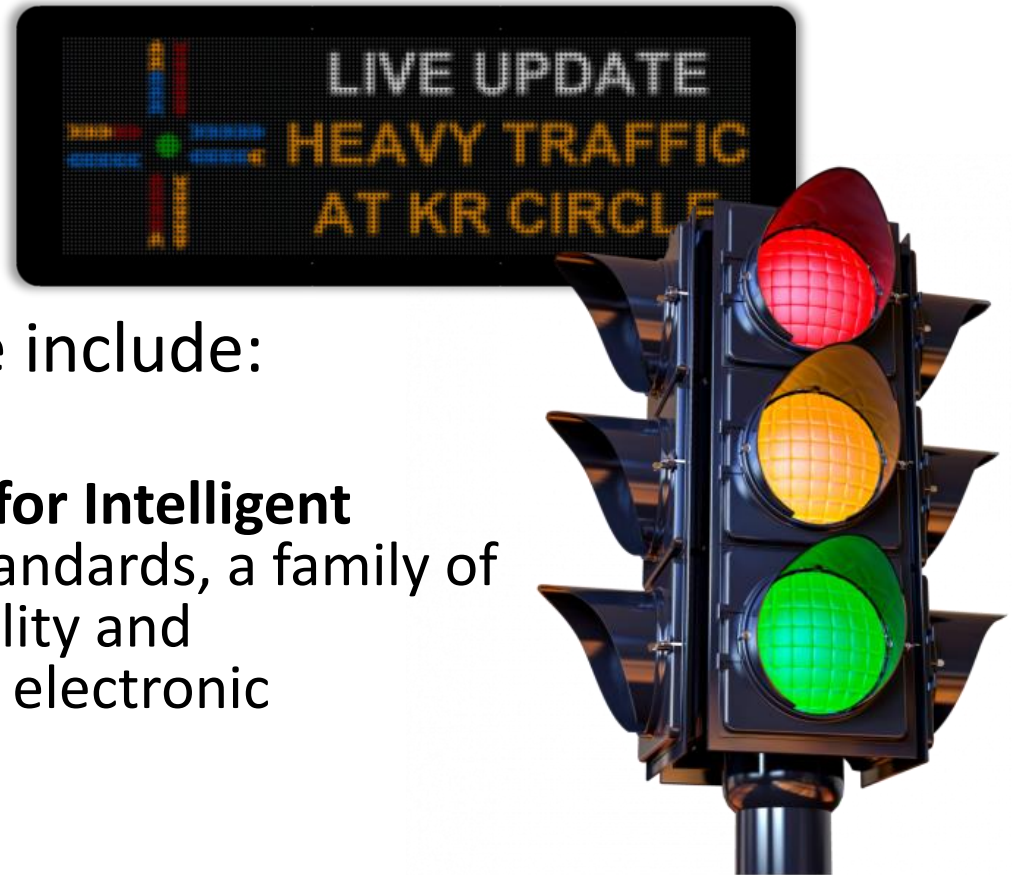
- Such devices include for example
  - **Variable Message Signs (VMSs)**
  - **Smart traffic lights**
- Standard and protocols used in this case include:
  - **DATEX-II**
  - **National Transportation Communications for Intelligent Transportation System Protocol (NTCIP)** standards, a family of standards designed for enable interoperability and interchangeability between computers and electronic traffic control equipment



Vehicle and People data

- In this group we consider data produced directly from vehicles or persons
- These data are a relevant source to estimate the **demand of mobility**
- These are typically the most difficult data to acquire, mainly due to privacy issues

Mobile devices

- Smartphones, tables, etc., can be used to observe the mobility pattern of the users

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Mobile devices

- Smartphones, tables, etc., can be used to observe the mobility pattern of the users
- A coarse information, useful for extra-urban travels, can be obtained from the **connection to cell towers** of telecommunication operators
- A finer representation can be obtained from geo-localization (i.e., GPS position) of **mobile apps** as for example routing and travel planning apps like Google Maps, Waze, Moovit, etc.

Mobile devices

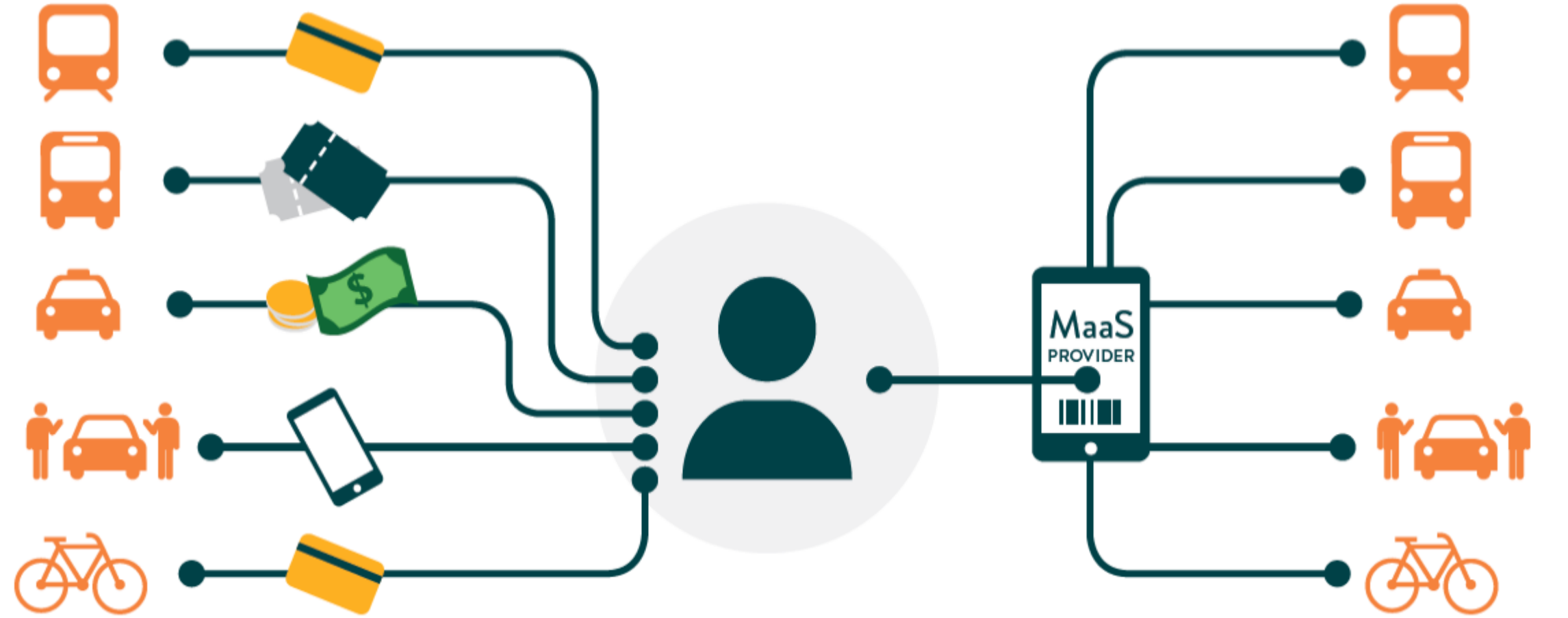
- Both data from telecommunication operators and app vendors are not released freely but **require to be purchased**
- Data are provided in an anonymized and aggregated modality
- Even if acquired in real-time, are released as **historical data**
- Data retrieval is done using vendors' APIs, without specific standard

MaaS

- **Mobility-as-a-Service** technologies could provide in the near future a valuable source of information

- MaaS integrates the whole mobility offer, and constitute the main interface (via dedicated apps) for the user to access to the transport services
  - Integrates public and private mobility services
  - Provide multimodal urban and extra-urban travel solutions
  - Offers service to plan, book, pay, and use mobility solutions

MaaS



MaaS

Level 0: No integration

Each mobility operator provide to the user his specific offer, using his app/website. The user must provide for himself to plan, book, and pay his travels

MaaS

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

A first level of integration. A single app/website can provide the user with a multimodal travel solution and give to the user information on pricing (maybe link to the mobility operator payment service). The user still must book/pay his travels independently.

MaaS

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

At this level the system provides an integrated travel solution that the user can book or pay directly from the MaaS app/website. The MaaS acts as a fare collector and then redistributes the payments to the involved mobility operator. The MaaS handle ticketing and vehicle access.

MaaS

Level 3: Full integration of services, including subscriptions, passes, best-fares, bundled offers

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

With the full MaaS integration, the system is able to provide the user with bundled offers, including subscriptions and best-fares

MaaS

Level 4: Integration of social goals though public-private cooperation, rewards, and incentives

Level 3: Full integration of services, including subscriptions, passes, best-fares, bundled offers

Level 2: Booking and payment integration (includes function to search, book, and pay single travels)

Level 1: Multimodal travel planning, Fare information

Level 0: No integration

Finally, using rewards and incentives the Public Administrations can drive the change towards more sustainable and green mobility solutions with the aim to avoid the use of private cars

MaaS (usage data)

- A MaaS system can then be able to collect the mobility patterns of the users, and, if managed by public organization such data could be released and used in smart mobility platforms

- MaaS are new technologies under development. Possible standards and formats are yet to be defined or under development.

- The **Transport Operator to Mobility Provider (TOMP) API** is a standardized interface for data exchange between transport operators and MaaS providers. It encompasses the entire user trip, from planning to booking, execution, and payment.

Vehicle data

- **On-Board Units** (OBUs) are an electronic devices installed in vehicles able to record traffic and driving data and connect to roadside and satellite systems to transmit and collect data for various applications

- These are the fundamental device to enable **vehicle-to-everything** (V2X, including V2V, V2I, V2P, V2N) communications and to develop CAV (Connected autonomous vehicle) and CCAM (Cooperative, connected and automated mobility)

- OBUs communication happen with dedicated protocol stacks, and data are exchanged in XML or JSON formats, or using specific standards

Vehicle data

- **Abstract Syntax Notation 1 (ASN.1)** is a standard interface description language (IDL) for defining data structures that can be serialized and deserialized in a cross-platform way, more recently adopted for V2X communications
- **SENSORIS** is a global standardized interface to exchange information between in-vehicle sensors and a dedicated cloud, as well as between clouds. It enables real-time, cloud-based information services that support mobility and automated driving
- **Extended Vehicle (ExVe)** is a concept that allows external service providers to access vehicle data and functions via a standardized interface
- **Open Diagnostic Data Exchange (ODX)** is a standard that defines a common data format for exchanging diagnostic data between vehicle manufacturers, suppliers, and service providers

Smartcard data

- **Smartcards** are a physical electronic authentication device used in mobility to access and pay public transport services

- Smartcards can be used as
  - Entry-only
  - Entry-exit

- Smartcard data acquired by mobility operators can be released using text formats like CSV, JSON, XML, or Keyhole Markup Language (KML) an XML notation used to represent geographic annotations

Social media data

- **Social media** can also be used to acquire data on mobility
- Most of the posts contains check-in data including location information
- Web-scraping tools are available to extract data from social media and deliver them in JSON, CVS, HTML, Excel

NAP & Data Spaces

- Mobility data, in particular real-time data, are not easy to acquire, due to **different data provides**, that can use **different distribution modalities**

- Data provides are sometimes also **difficult to find** requiring time-consuming research activities

- There is a strong need to **increase interoperability** among different provides and to realize centralized access point where to find and retrieve the data

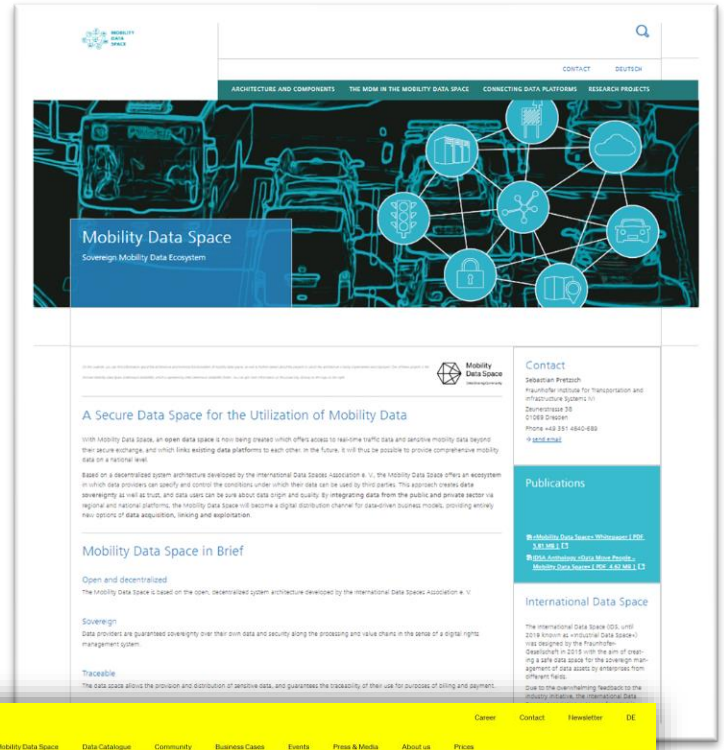
NAP & Data Spaces

- **National Access Points** (NAPs) – and Regional Access Points (RAPs) – are the solution proposed by the European Union to facilitate **access**, **easy exchange** and **reuse** of transport related data as
  - EU-wide real-time traffic information services
  - EU-wide Multimodal Travel Information Services
  - Road safety-related traffic information
  - Safe and secure parking places for trucks and commercial vehicles
- **Data Spaces** for mobility have also been proposed to brings together companies, organizations and institutions who want to monetize their data or need data for innovative mobility solutions
- NAPs and Data Spaces are still in development

Mobility Data Spaces

- A first attempt to build a data space for mobility was started in 2019 from a German consortium realizing the Mobility Data Space
  - https://mobility-data.space
  - https://mobility-dataspace.eu

- They proposed
  - decentralized and distributed system with a central directory to publish available data sources and services (i.e., a data marketplace)
  - a vocabulary provider that gives information on standards and APIs (e.g., DATEX-II, NeTEx, SIRI)



NAPCORE & PrepDSpace4Mobility

To extend such a solution to the whole European area, the European Commission started in 2022 two main actions

- The National Access Point Coordination Organisation for Europe (NAPCORE) project
- The PrepDSpace4Mobility project

NAPCORE

- NAPCORE project was kicked off to **promote and coordinate the creation of NAPs** in all the EU Member States to fulfil the European Intelligent Transport System directive (2010/40/EU)

- See https://napcore.eu/

PrepDSpace4Mobility

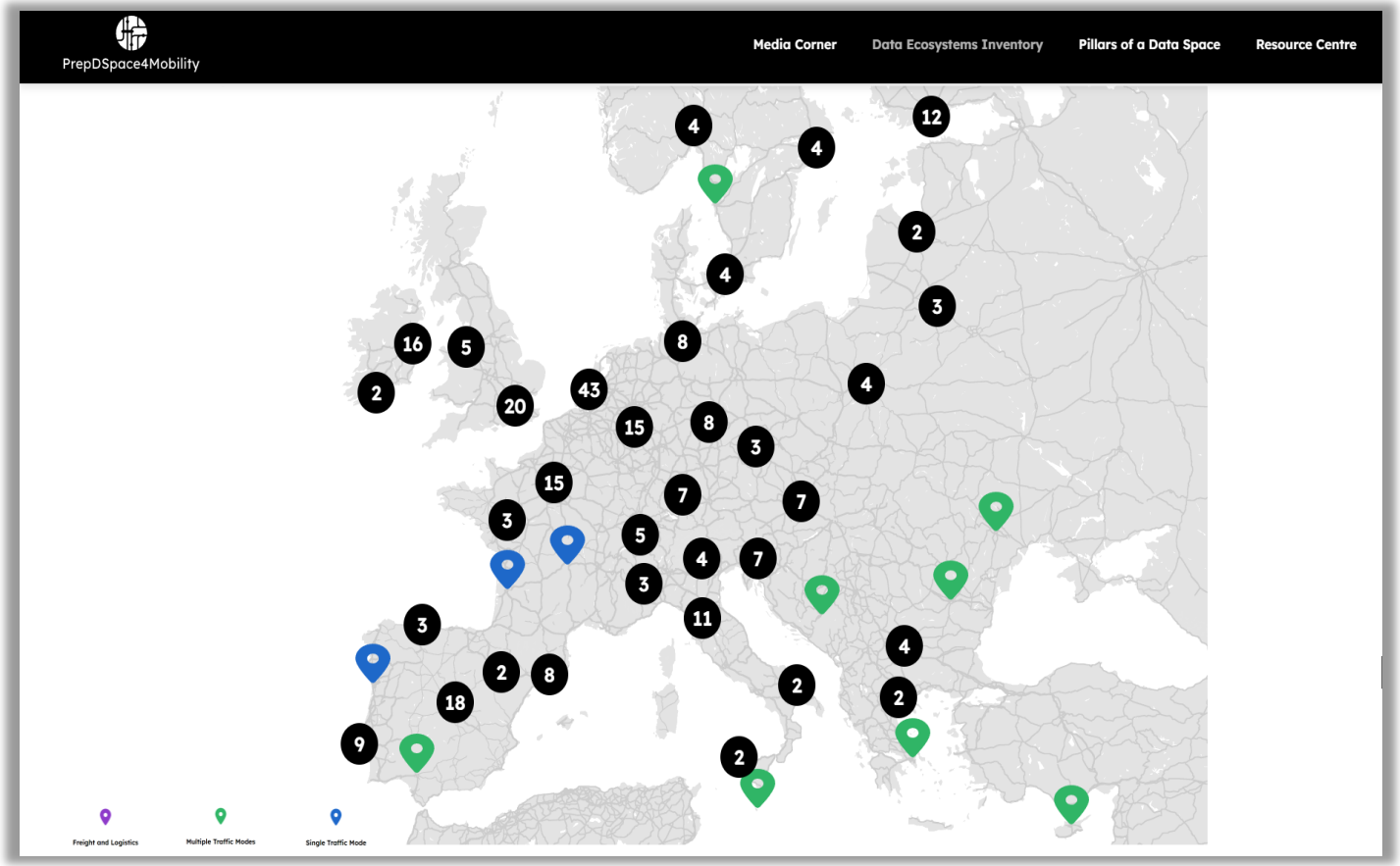
- PrepDSpace4Mobility lays the foundation for a secured and controlled way of **pooling and sharing mobility data** across Europe

- The project contributes to the development of the **common European mobility data space** by
  - mapping existing data ecosystems
  - identifying gaps and overlaps within
  - proposing common building blocks and governance frameworks

- See https://mobilitydataspace-csa.eu/

PrepDSpace4Mobility EU Project

- 272 data ecosystems included in the inventory



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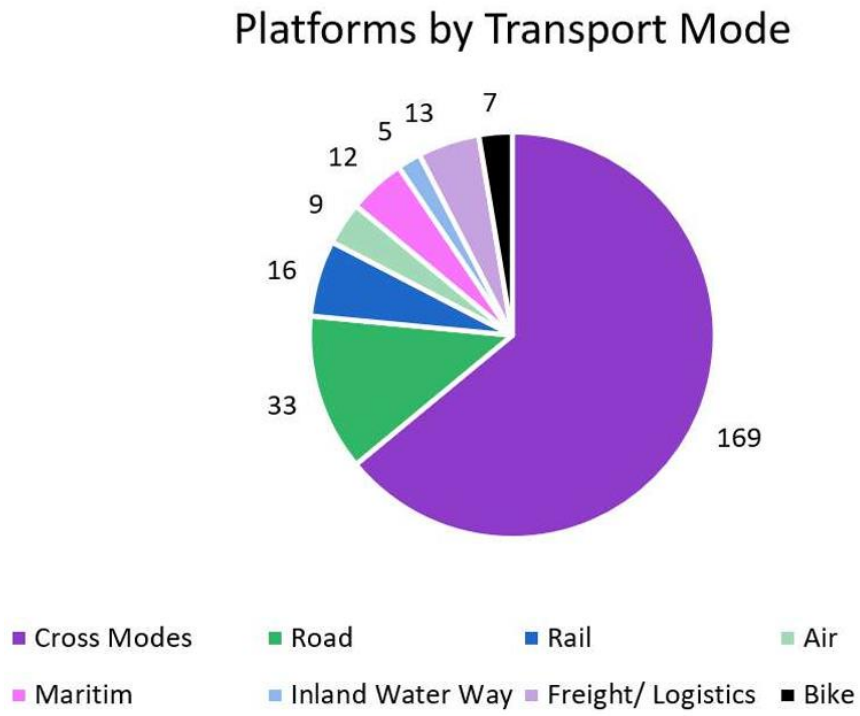

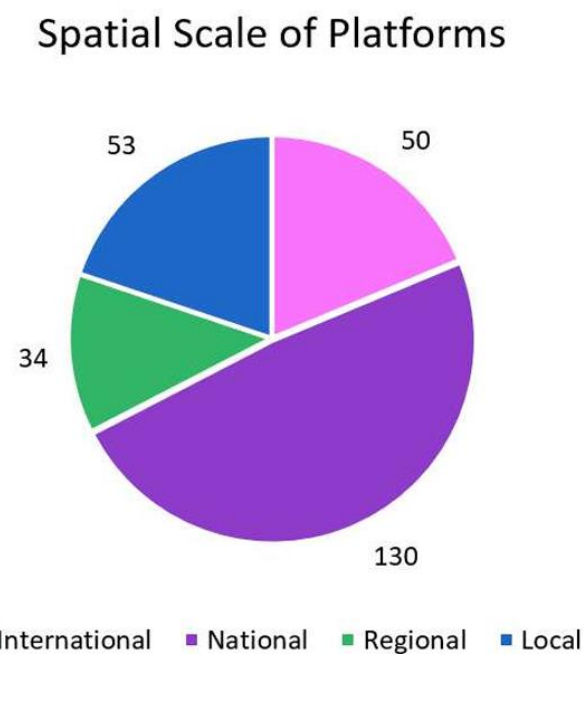

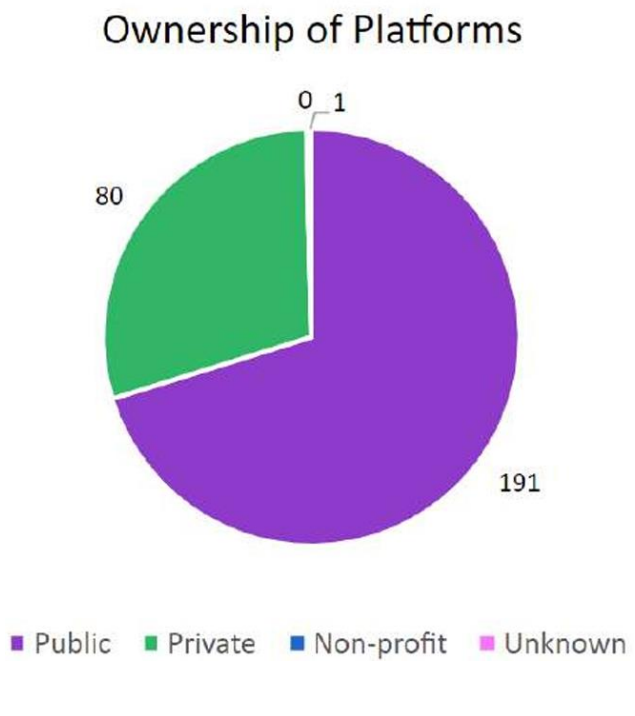

Slide credit: PrepDSpace4Mobility, https://mobilitydataspace-csa.eu/

PrepDSpace4Mobility EU Project

- Observed over **18 sectoral mobility domains**, each with their own standards, data models and protocols
- Observed over **60 different standards**
- Even in each mobility domain, **several (overlapping) standards** are in use

Slide credit: PrepDSpace4Mobility, https://mobilitydataspace-csa.eu/