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C3MGBD-02: Remote Sensing Solutions

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Extending Accuracy Assessment Procedures of Global Coverage Land Cover Maps through Spatial Association Analysis

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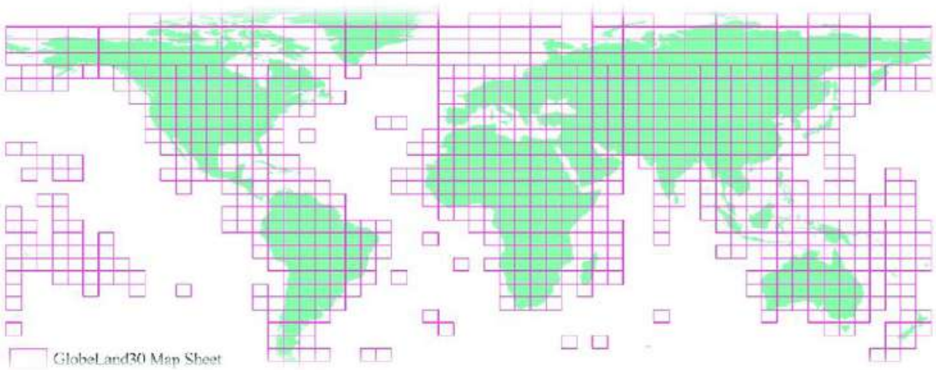
Motivations & Objectives

- Emerging availability of Global Land Cover (GLC) products driven by the modern EO platforms (frequent pass | high resolution | global coverage)

- The accuracy of GLC maps not always meets the users' requirements making the use of regional land cover maps often preferred

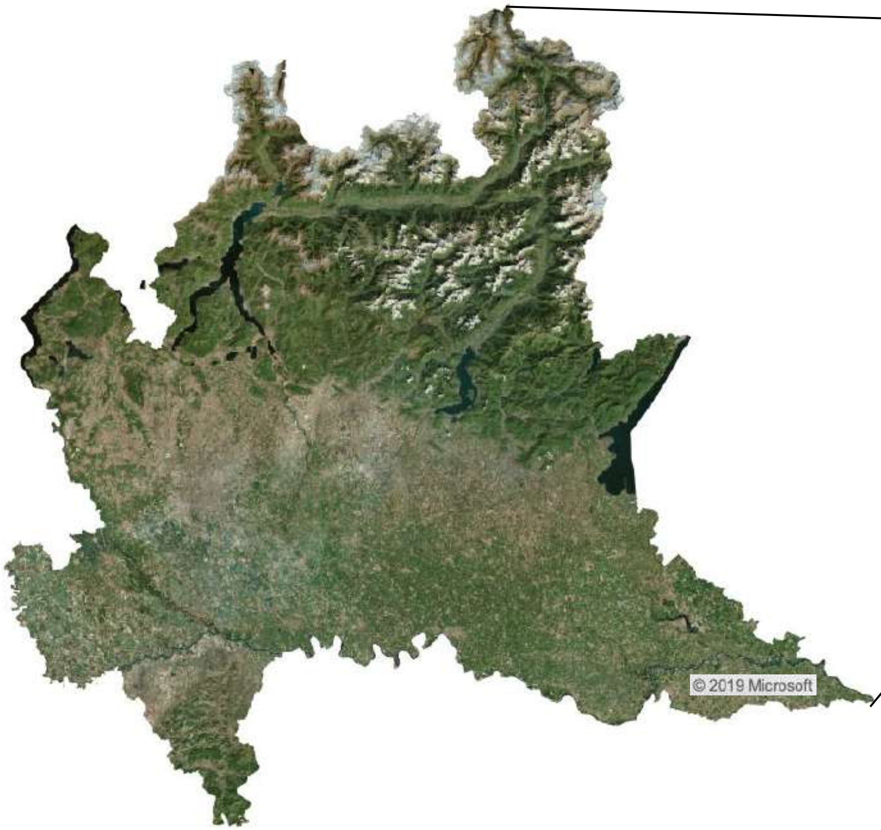
- The accuracy assessment of GLC maps still represents a pivotal task in order to promote the use of GLC map for local applications

- The study focuses on the validation of the GlobeLand30 (GL30) map at a regional scale by empowering traditional accuracy assessment procedures with spatial association statistics and error patterns mapping



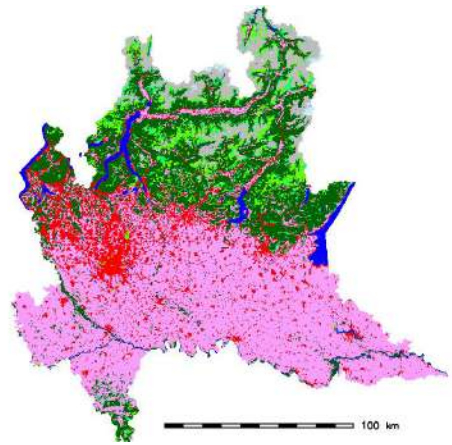
Case Study

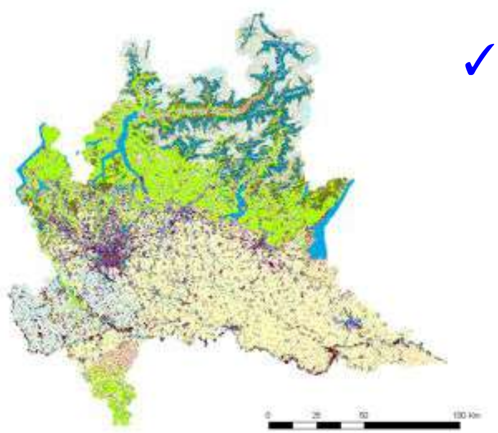
✓ The Lombardy Region, Northern Italy (~ 23870 km²)



Data Collection

✓ **GL30**: the most frequently updated (2000, 2010, and 2015 announced) high-resolution (30m) GLC multi-class (10) map currently available - (target map)





✓ **DUSAF**: the official land cover (vector) maps of Lombardy Region at a scale 1:10000, employed as reference map for the classification accuracy

Code	GL30 Class	Definition
10	Cultivated Land	Lands used for agriculture, horticulture and gardens, including paddy fields, irrigated and dry farmland, vegetation and fruit gardens, etc.
20	Forest	Lands covered with trees, with vegetation cover over 30%, including deciduous and coniferous forests, and sparse woodland with cover 10 - 30%, etc.
30	Grassland	Lands covered by natural grass with cover over 10%, etc.
40	Shrubland	Lands covered with shrubs with cover over 30%, including deciduous and evergreen shrubs, and desert steppe with cover over 10%, etc.
50	Wetland	Lands covered with wetland plants and water bodies, including inland marsh, lake marsh, river floodplain wetland, forest/shrub wetland, peat bogs, mangrove and salt marsh, etc.
60	Water bodies	Water bodies in the land area, including river, lake, reservoir, fish pond, etc.
70	Tundra	Lands covered by lichen, moss, hardy perennial herb and shrubs in the polar regions, including shrub tundra, herbaceous tundra, wet tundra and barren tundra, etc.
80	Artificial surfaces	Lands modified by human activities, including all kinds of habitation, industrial and mining area, transportation facilities, and interior urban green zones and water bodies, etc.
90	Bareland	Lands with vegetation cover lower than 10%, including desert, sandy fields, Gobi, bare rocks, saline and alkaline lands, etc.
100	Permanent snow and ice	Lands covered by permanent snow, glacier and ice cap.

Data Processing

- ✓ DUSAF rasterized at 5m and harmonized with the GL30 in terms of classification legend

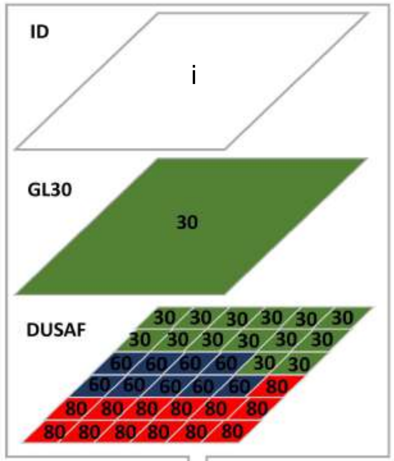
- ✓ To investigate error spatial patterns -> sub-pixel errors detection overlay procedure, designed and implemented by means of GRASS GIS for:

    - Preserving both the original resolution of the reference map and the spatial reference (ID) of the target map pixels

    - Obtaining a single table including pixel-wise disagreement counts (i.e. errors) for each class

- ✓ The table is processed by means of the DASK Python library -> multithreading computation for manipulating larger-than-memory datasets (> 10 GB in this case study)

a)



b)

ID	GL30	DUSAF									
		10	20	30	40	50	60	70	80	90	100
i	30	0	0	14	0	0	9	0	13	0	0

c)

ID	GL30	DUSAF									
		10	20	30	40	50	60	70	80	90	100
i	30	0%	0%	39%	0%	0%	25%	0%	36%	0%	0%

DASK + GRASS GIS

Preliminary Results

✓ Traditional Accuracy Assessment

The confusion matrix is extracted from the errors table

- The computed Overall Accuracy of the GL30 map is 79% for the Lombardy Region
- The agreement of class 40 (Forest) is the lowest, and that the highest confusion is between class 40 and class 20 (Shrubland)

Class		GlobeLand30								
		10	**20**	**30**	**40**	**50**	**60**	**80**	**90**	**100**
DUSAF	**10**	90	11	1	20	35	9	30	1	0
	20	5	79	13	42	16	3	2	7	0
	30	1	3	51	13	4	0	1	7	0
	40	0	3	10	14	0	0	0	5	0
	50	0	0	0	0	35	1	0	0	0
	60	0	0	0	0	8	83	0	0	0
	80	3	2	0	2	1	2	66	0	0
	90	0	1	24	8	1	1	0	79	19
	100	0	0	0	0	0	0	0	0	81

Normalized confusion matrix [%]

Class	PA	UA
10	90	82
20	79	79
30	51	40
40	14	23
50	35	39
60	83	94
80	66	82
90	79	79
100	81	88

Producer’s and User’s accuracy [%]

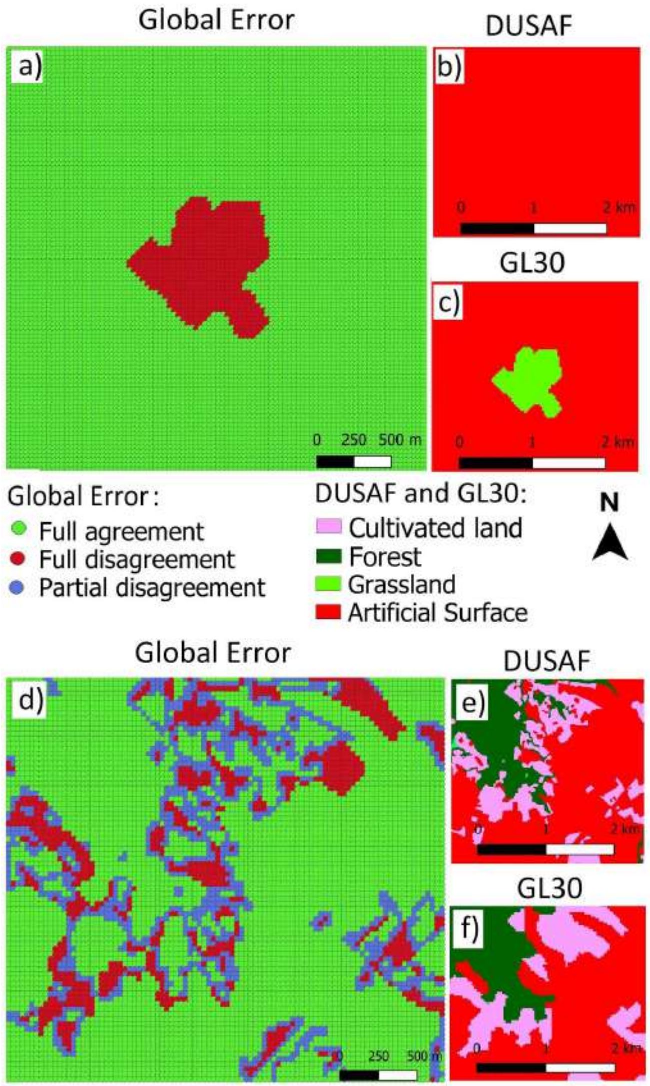
Preliminary Results

✓ Error Spatial Patterns Investigation

Maps derived from the errors table -> **visual insight** into the spatial patterns of global, interclass, or intra-class errors

- Example: urban parks (Artificial Surface according to the GL30 legend). The sharp transition full agreement / full disagreements spotted on the map (a,b,c) indicates urban parks are often totally miss-classified (as Grassland) -> relevant missing objects or underlying issues in the reference map reclassification

- Partial disagreements (d,e,f) are expected along transitions between LC classes or areas with heterogeneous LC characteristics -> patterns represent reasonable errors due to the generally lower representation quality of the target map with respect to the reference one



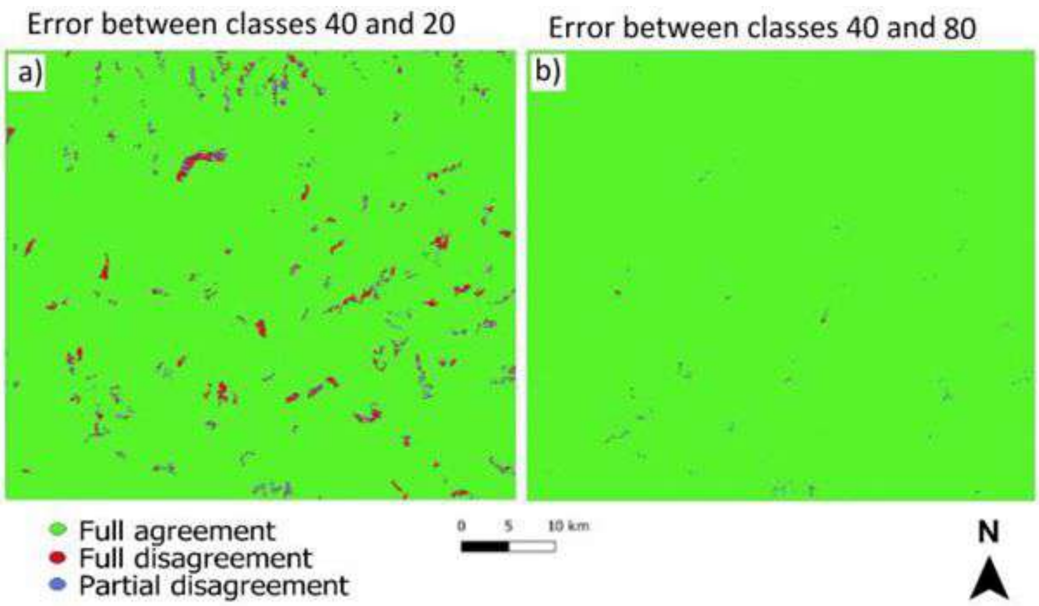
Preliminary Results

✓ Error Spatial Patterns Investigation

Measures of spatial association can be directly computed using the table

- Global Moran's I computed for the global error map is 0.80 -> marked positive spatial association)

- For highest and the lowest inter-class errors (40-20 and 40-80) the Moran's I is respectively 0.82 (a) and 0.62 (b) -> underlying connection between errors from the confusion matrix and the spatial association characterizing their patterns



Conclusions

- ✓ The **traditional accuracy assessment** (confusion matrix) provides robust indicators to describe the global accuracy of land cover maps but **no insights into the errors spatial distribution**

- ✓ The proposed errors table provides with a **comprehensive and compact input dataset** to detailed accuracy assessments facilitating both visual and statistical analysis of error spatial patterns

- ✓ Results from the spatial association measures - such as the Moran's I - may uncover **underlying error features** providing **alternative metrics** to describe as well as link the clustering of errors to the classification accuracies

- ✓ The exclusive use of **Free and Open Source Software** provides the analysis with a potential to be empowered, replicated, and improved

- ✓ **Parallel computing** is critical to the application of the proposed error table format at a national/continental scale

Future Work

- ✓ Traditional Python libraries for spatial association analysis (i.e. PySAL) are optimized neither for parallel computing nor for working with big raster files. **Development effort** is required towards these directions

- ✓ The spatial association has not been exploited analytically in this first case study. However, the **object-based classifier** (adopted by the GL30 producers) may take advantage of accuracy assessment procedures that explicitly consider the **spatial dependence of errors** to improve classification accuracy. Design and testing of robust procedures (both global and local) are critical to unpin the benefits of the spatial association analysis alongside the traditional accuracy assessment

Thank you for your attention
...Questions?

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FLOATING CAR DATA (FCD) FOR MOBILITY APPLICATIONS

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Outline

1. FCD on-board units as traffic sensors
2. Representativeness of the FCD sample
3. Traffic analysis
4. Conclusions

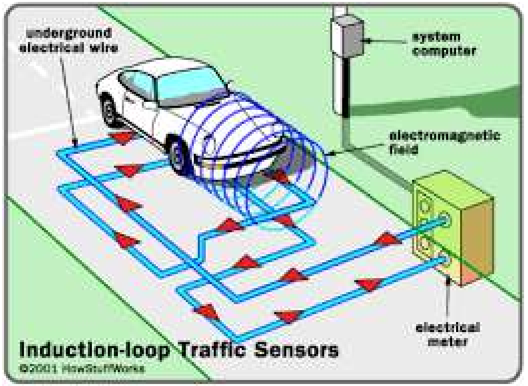
Floating Car Data (FCD)

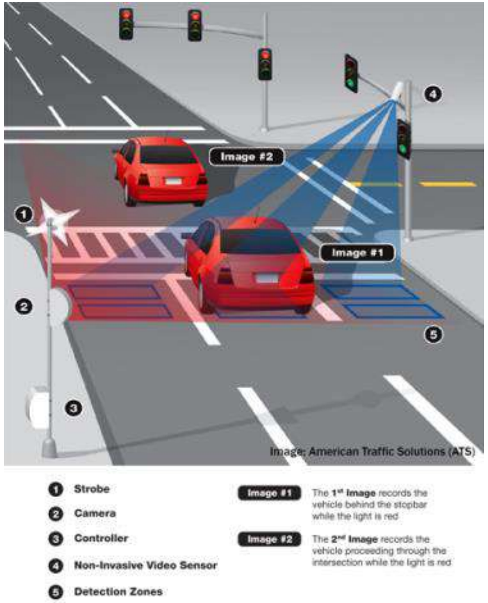
- FCD are **georeferenced data** (e.g speed, direction of travel, time) collected by on board unit (OBU) mounted on vehicles
- OBU are coupled with **different sensors** (e.g. GNSS receiver, inertial platforms, accelerometers and odometers)

Floating Car Data (FCD)

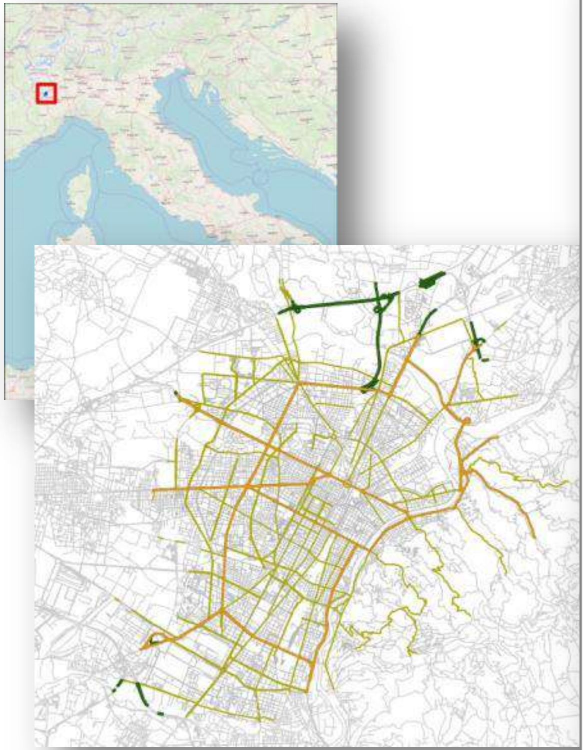
FCD is becoming more and more relevant for mobility domain applications, addressing **physical sensors limitations**:

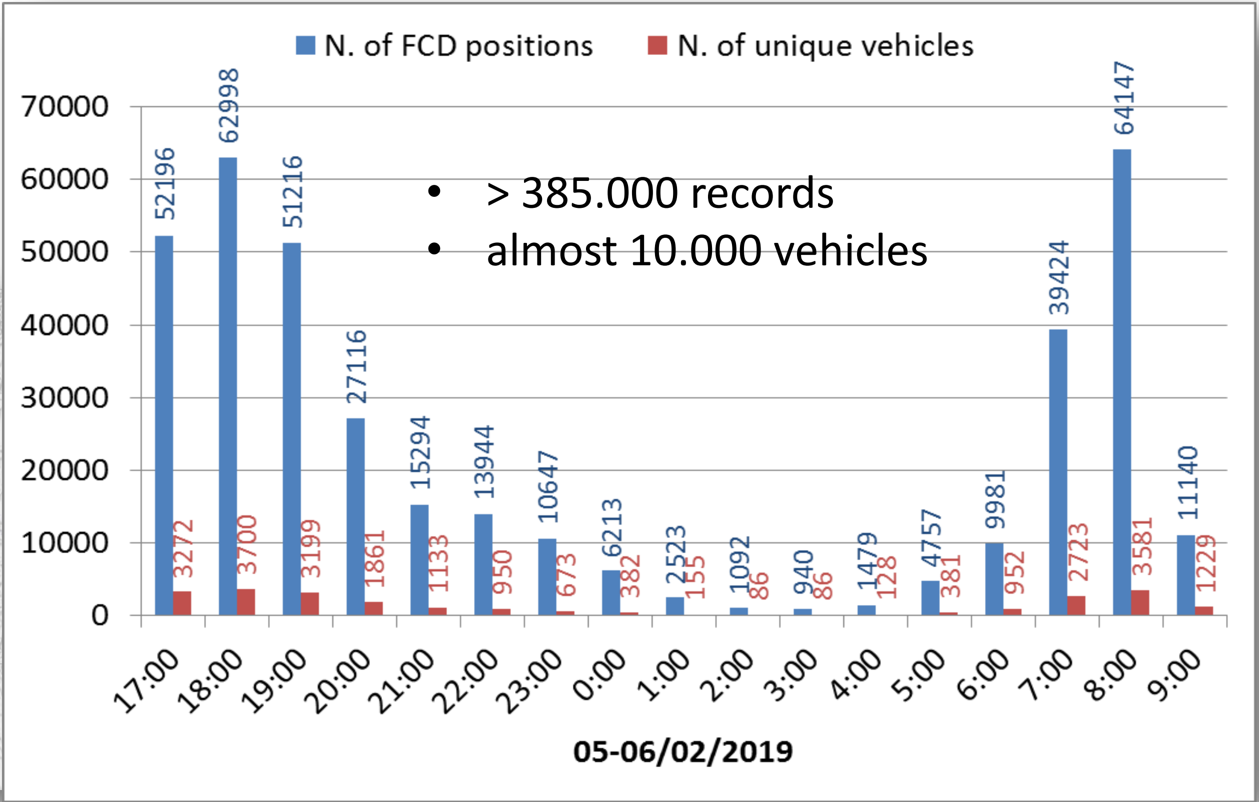
- geographical distribution
- inhomogeneity
- minor roads coverage
- costs
- …





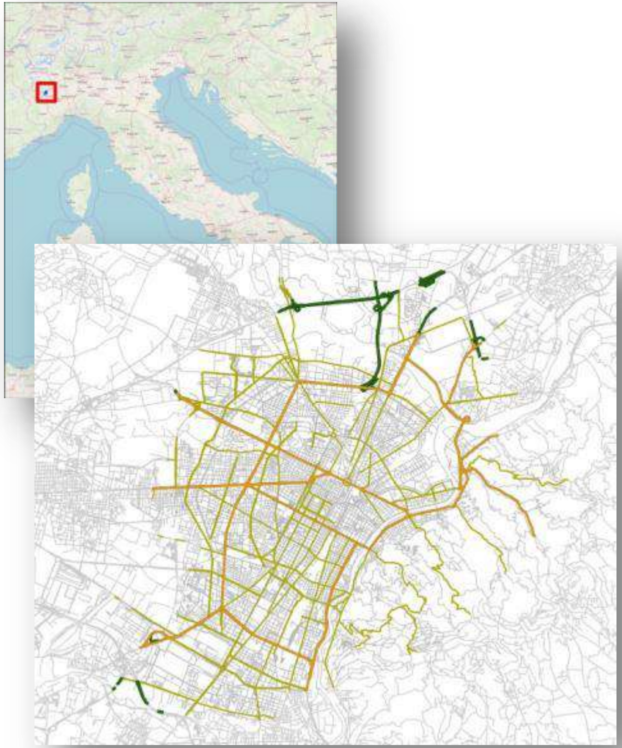
Torino use case

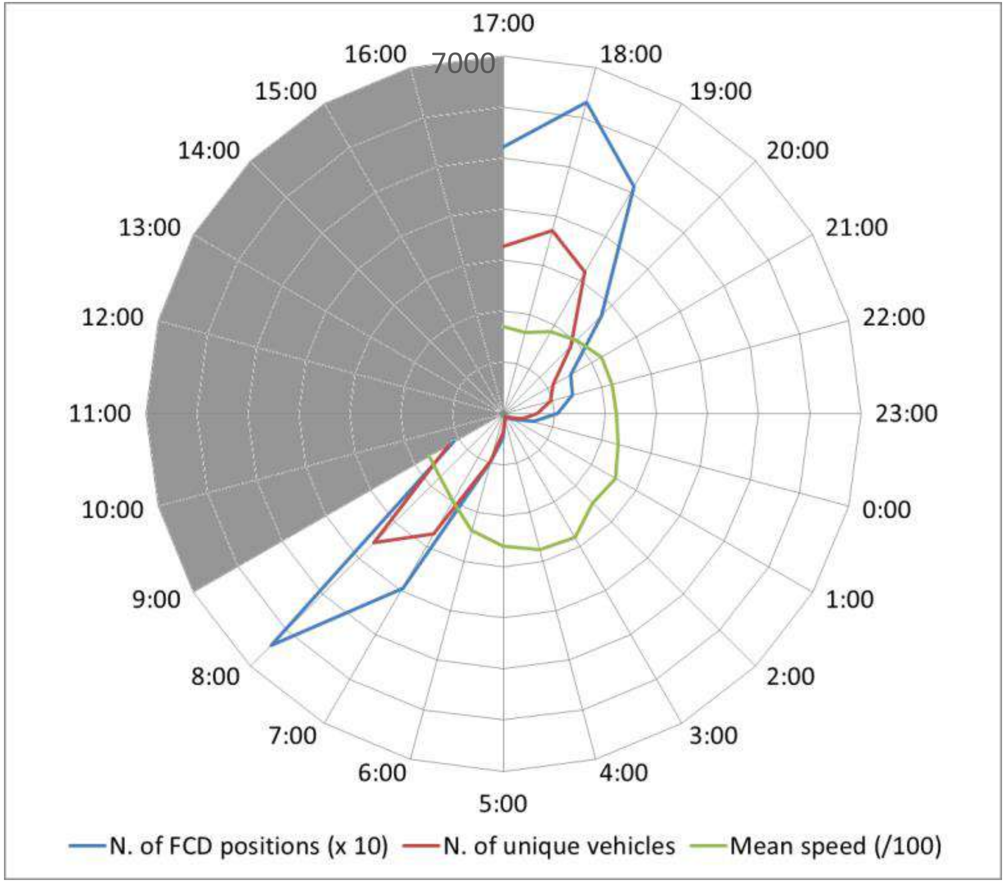




- > 385.000 records
- almost 10.000 vehicles

Torino use case

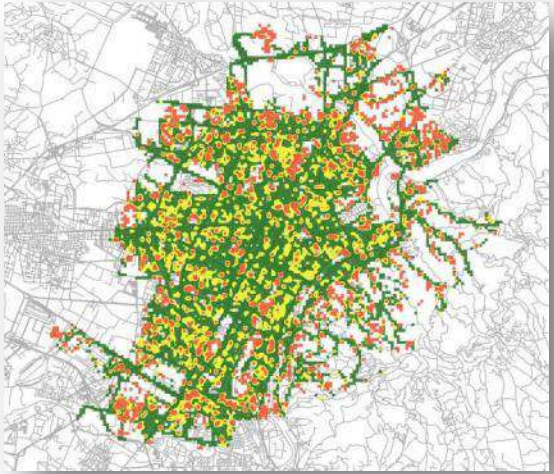




FCD processing

- Open Transport Map (**OTM**) used as reference network dataset
- FCD positions uniquely assigned to OTM elements by **proximity**

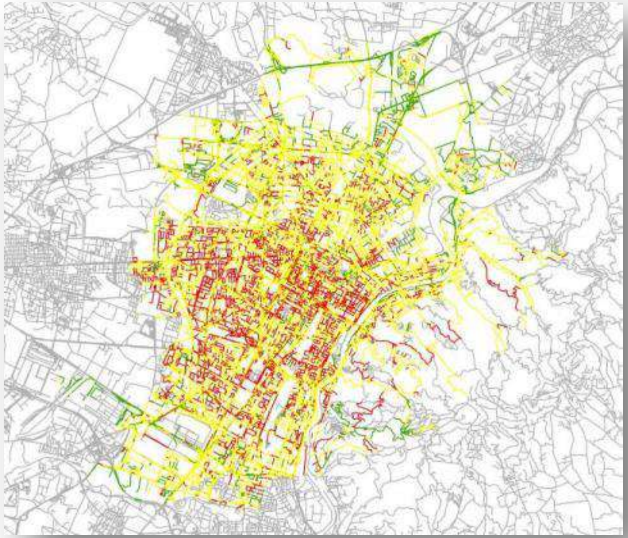
Parameter	m
Minimum	0.00
Maximum	471.70
Mean	6.80
St. Dev.	13.21

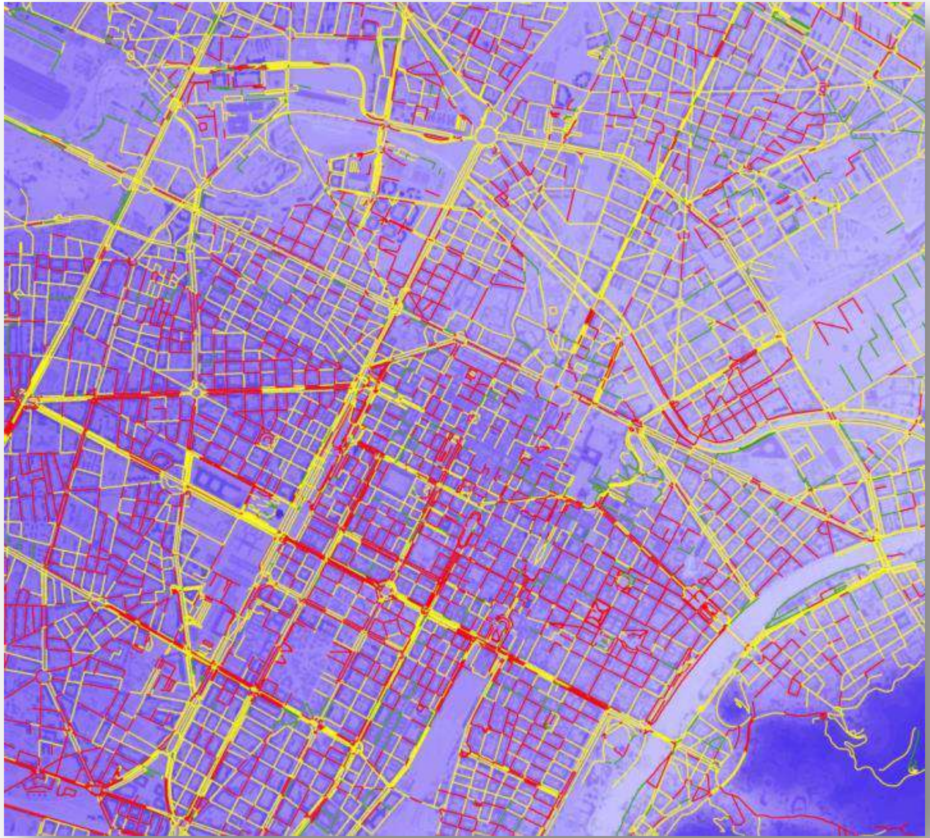


Min. FCD positions	OTM elements covered
1	22,259 (73%)
10	9,867 (32%)
50	1,632 (5%)

HDOP patterns

- Horizontal Dilution Of Precision
- Street canyons affect GPS positioning -> shadowing and multipath effects





Comparison with traffic sensors

Freely available data from 124 sensors (out of the 3,400 installed in the municipality)

Representativeness of the FCD sample

Comparison with traffic sensors

Freely available data from 124 sensors (out of the 3,400 installed in the municipality)

Representativeness of the FCD sample

Time interval	N. of vehicles		
	Loop sensor	FCD	%
17:00-18:00	93841	1033	**1.1**
18-00-19:00	96121	1353	**1.4**
19:00-20:00	85507	1067	**1.2**
20:00-21:00	59688	506	**0.8**
21:00-22:00	36584	319	**0.9**
22:00-23:00	32866	242	**0.7**
23:00-24:00	27272	216	**0.8**
17:00-24:00	431879	4736	**1.1**

Comparison with traffic sensors

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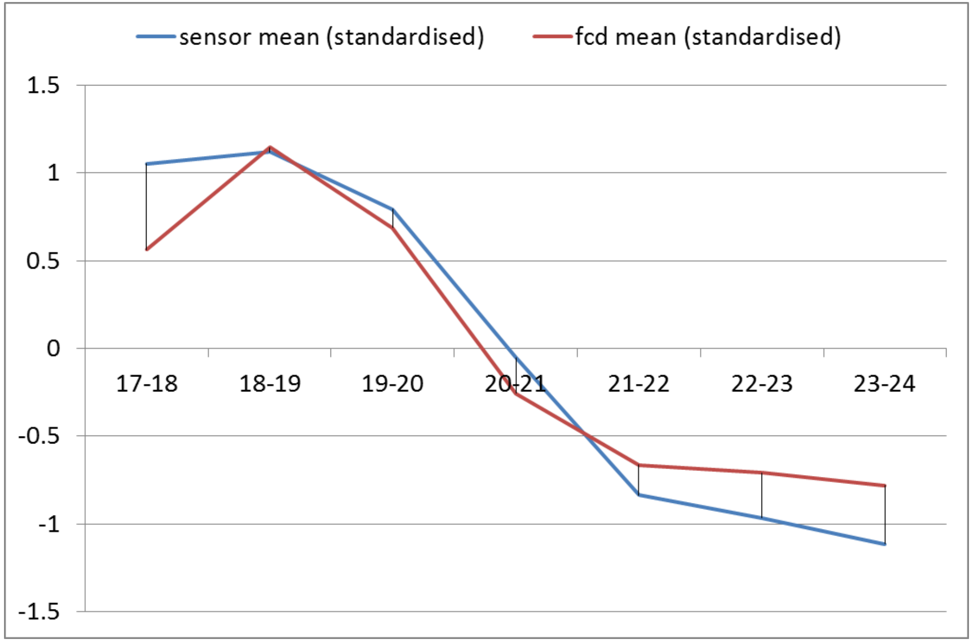
Representativeness of the FCD sample



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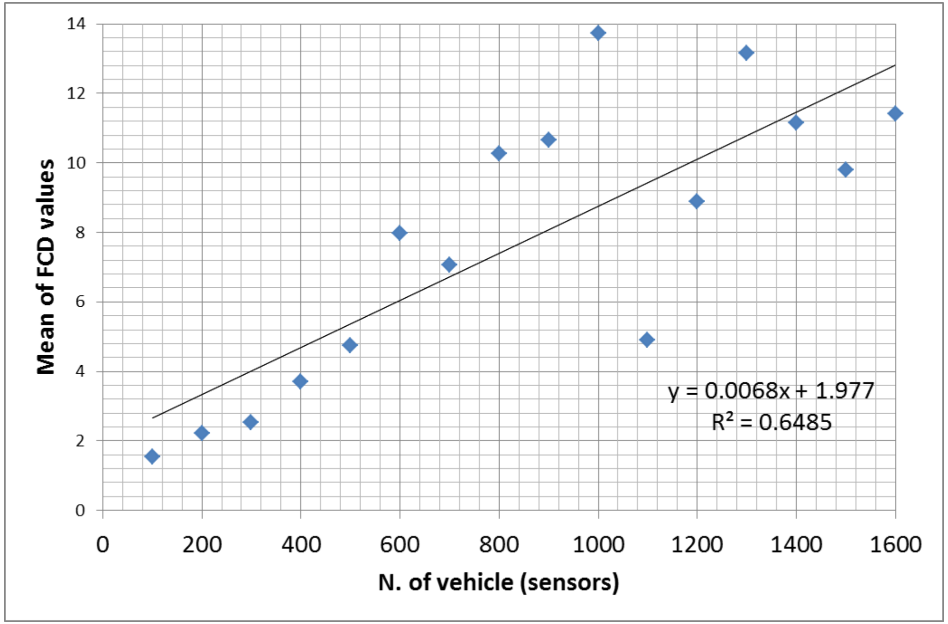
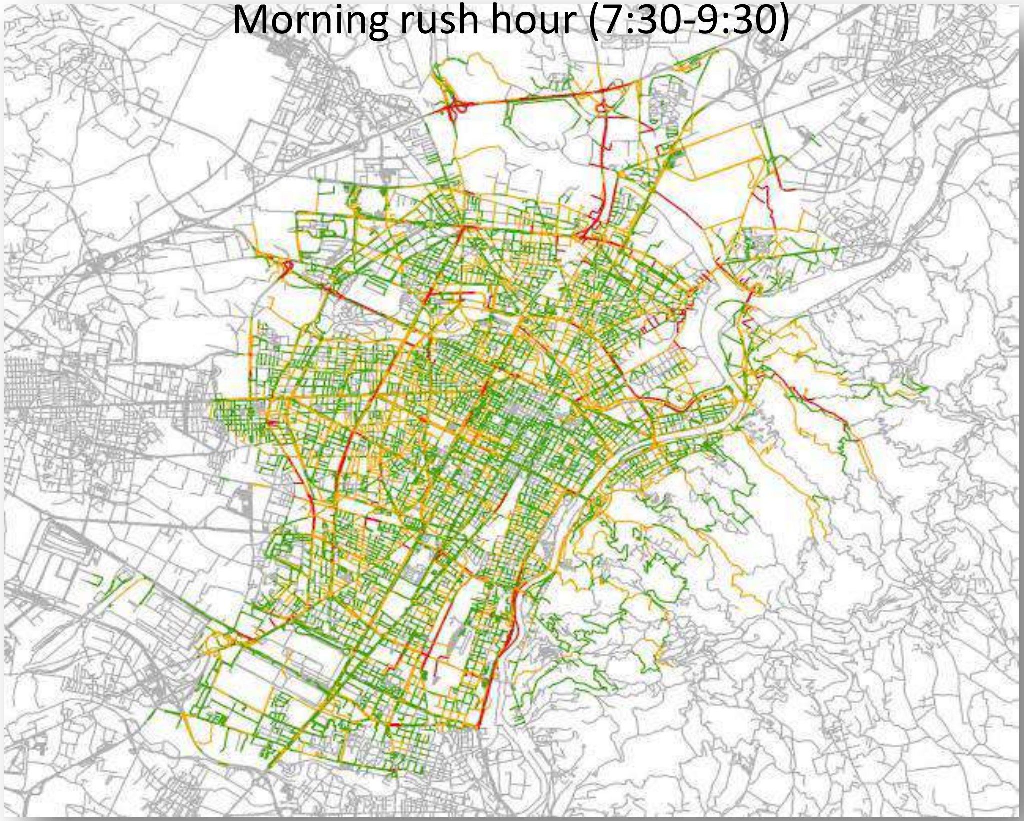
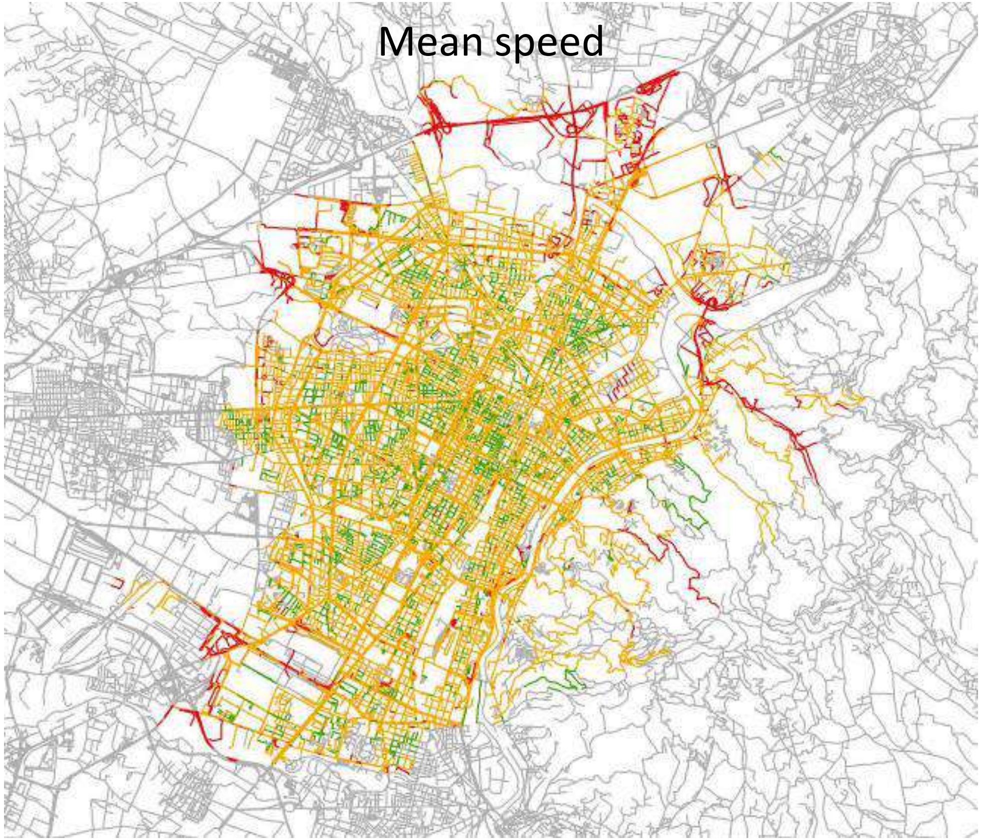


Number of vehicles



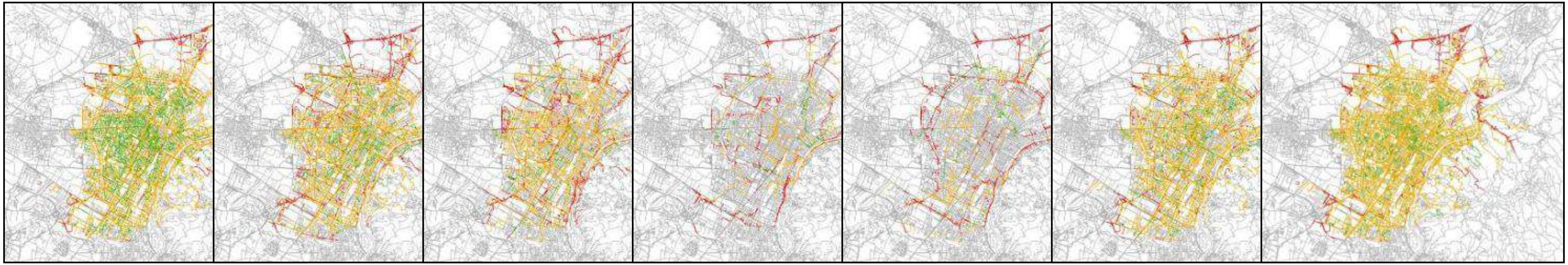
Road network elements classified in function of the **number of** unique **vehicles** that travelled on each specific road element in the morning rush hour

Mean speed



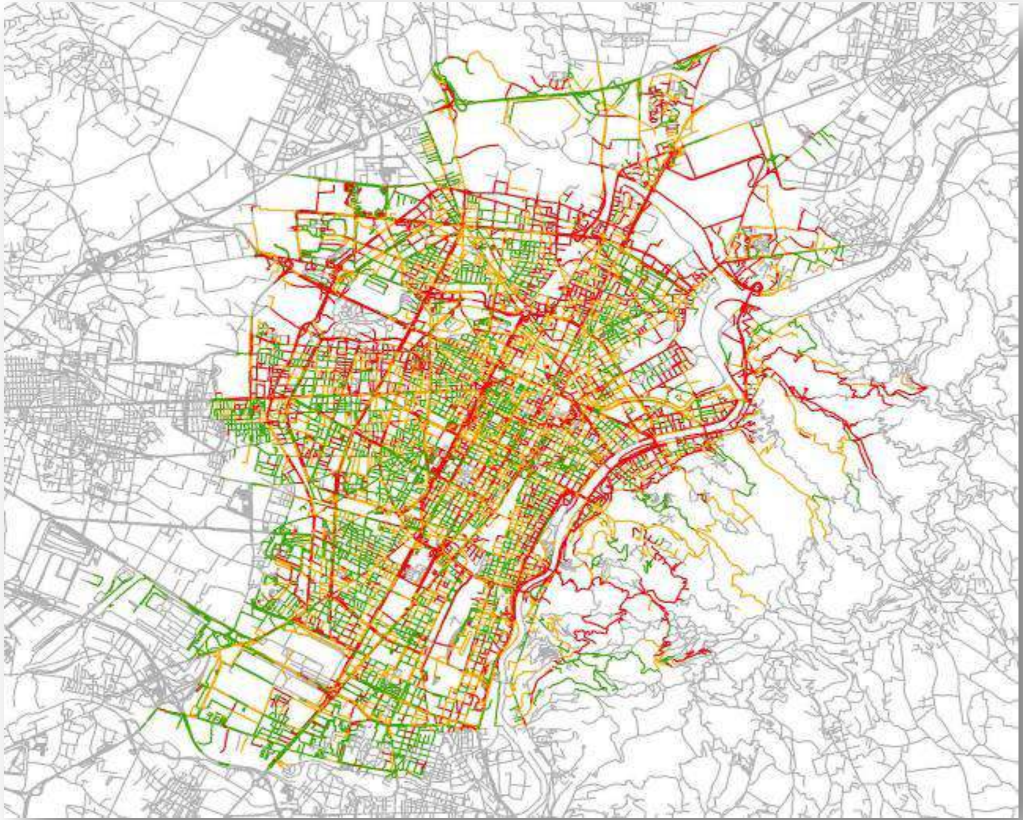
Mean speed value, considering all records available in the FCD sample, clearly highlight **main roads and local roads**

Travel times

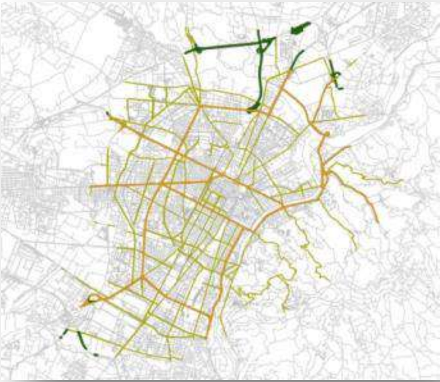


The use of the timestamp associated to FCD data allows to calculate **mean speeds in the different moments of the day**, useful for estimating **dynamic travel times**

Travel distances

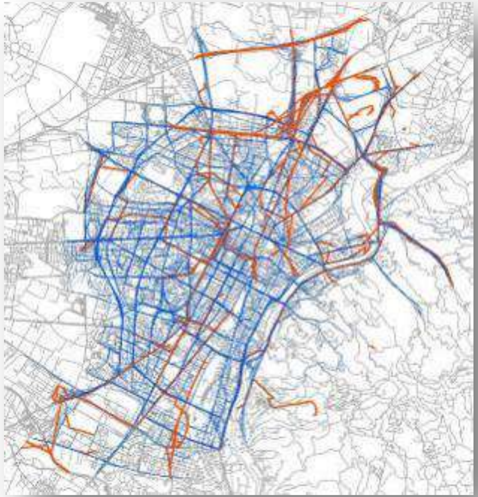


- FCD is in its nature trip -> extracting paths is an important step towards **travel time estimation**
- traffic that travels along **major roads** (crossing the city NNE to SSW and WNW to ESE) normally travels **longer distances**

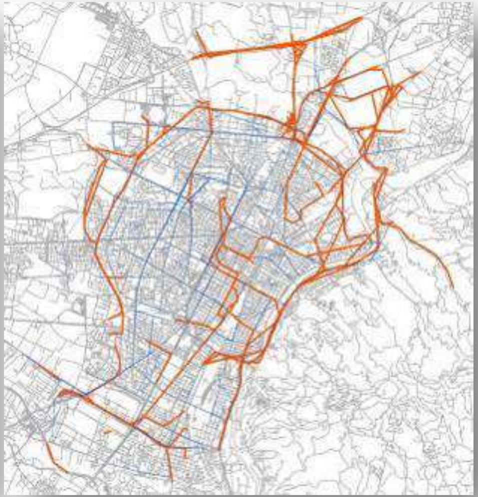


Travel behaviors

Private cars vs. fleets



19:30 to 00:30

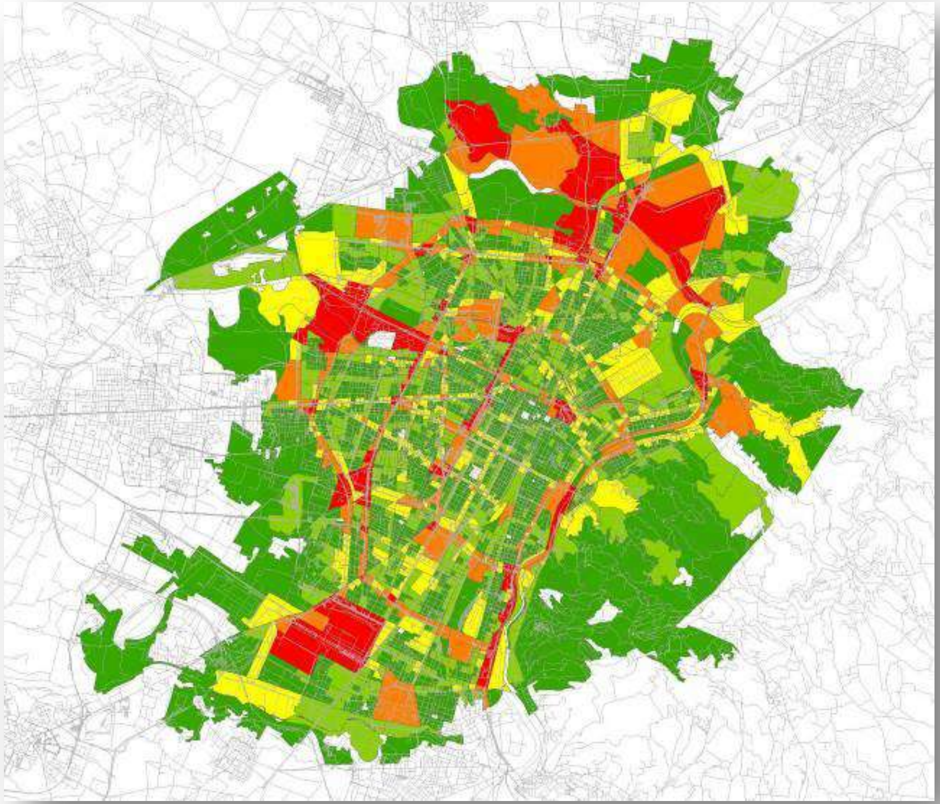


00:30 to 05:30

- Based on **attribute identifying the type of vehicle** (private car or fleet)
- dominance of **private cars** in **evening hours**
- dominance of **fleets** during the **night and early morning hours**

Travel behaviors

- Based on the **total length of path** crossing each census area
- Identification of the **census areas** hosting **higher traffic flows**
- major **crossing census areas** also identified



Conclusions

Cons:

- sample representativeness (~2% in Italy, according to FCD provider)

Pros:

- overcoming some physical sensors limitations
- mobility patters detectable

Next research steps:

- more robust **road elements assignation** (uncertainties)
- **representativeness** to be further investigated
- reanalysis based on a **longer time series**
- **compare analysis results with authoritative ones**

Geomatics for Mobility Management

A comprehensive database model for Mobility Management

Introduction

Urban transport has a large impact on the socio economic growth and in general on the quality of life of citizens.

SUSTAINABLE TRANSPORT

Concept promoted by the European Commission

Mobility management is a key factor
to provide integrated and real-time information

Data integration as key strategy
Better managing to better inform

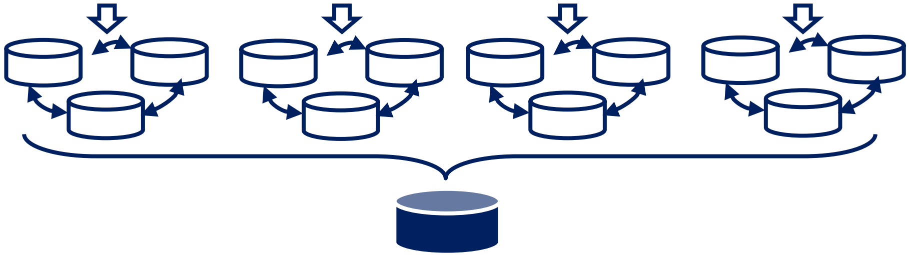
SPATIAL INTEGRATION

GIS as a solution to integrate the separated and vertical vision in a **spatial** and **horizontal** ones

Introduction

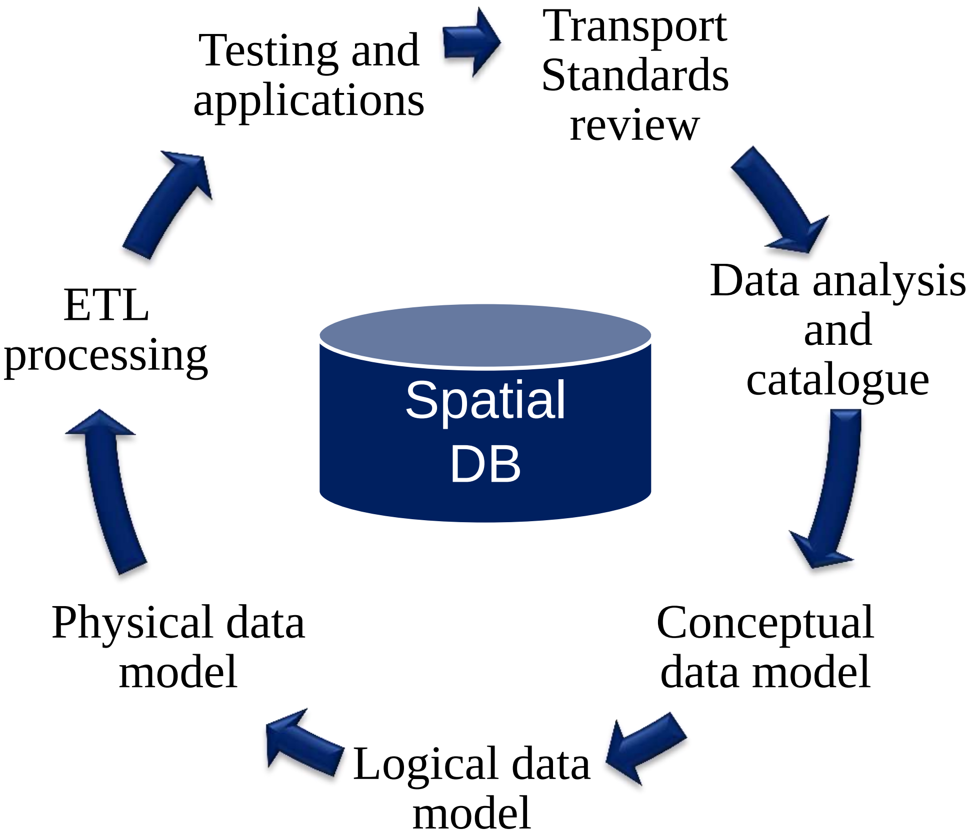
Design a comprehensive spatial data model for mobility management

as base for multi-thematic analysis
and as a tool for decision support system



- It is possible to build a spatial data model independent by used ITS technologies? It can be reusable by different companies?
- Can the transition between ITS and GIS be automated?
- How a comprehensive spatial data model can enable transport data integration?

Methodology

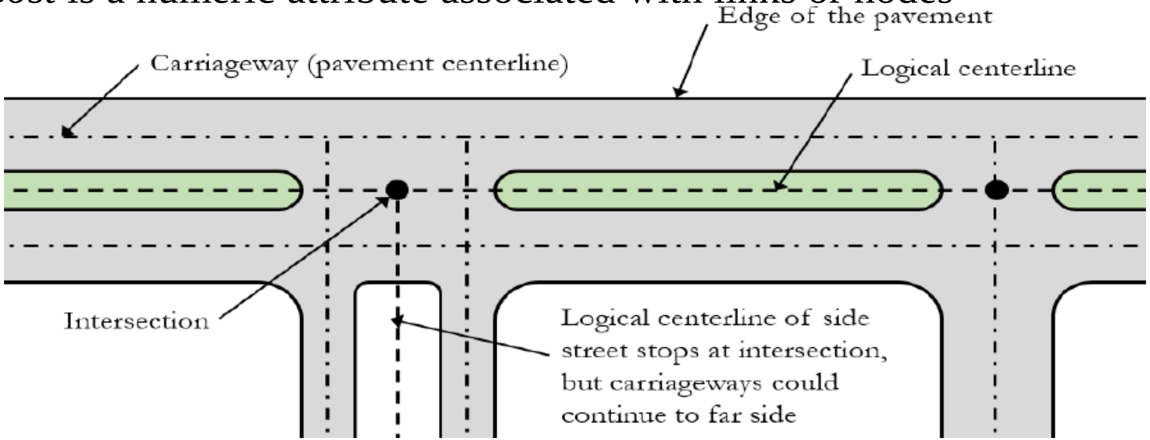


Mobility data issues

In transport management approach the network infrastructure defines the transport supply

Graph model is the most used way to represent transport supply as it allows to solve most common network and routing problems.

- *Node* represents an object of interest
- *Link* represents a relationship between two nodes
- *Path* is an alternating sequence of nodes and links
- *Cost* is a numeric attribute associated with links or nodes



Static mobility data

Traffic detectors

- Fixed traffic detectors (Induction loops, Microwave sensors, Ultrasound sensors, Doppler Radar, Wireless magnetic field)
- Urban Traffic Control (UTC) system (loops + stations + traffic lights)
- Cameras
- Floating Car Data (FCD)

Informative panels

- Fixed/mobile
- Specific purposes (VMS-T, VMS-Z, VMS-P, VIA)

Points of interest and other objects

- Bollards
- Restricted Access Area Gates
- Autovelox
- Parking areas
- Public Transport Stops, Stations and Depots, bike and car sharing stations
- Weather Stations

Dynamic mobility data

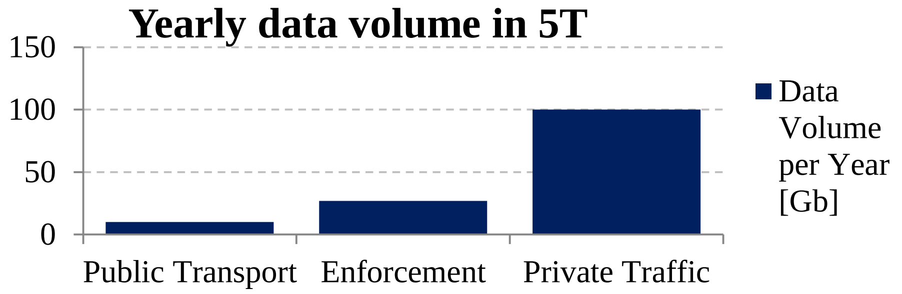
Dynamic and real-time data

Raw measures

Flow, speed, vehicles count, travel time, vehicle positions
Temporal range: 1/5/15 minutes
Sources: fixed detectors (loops and cameras)and FCD

Aggregated measures

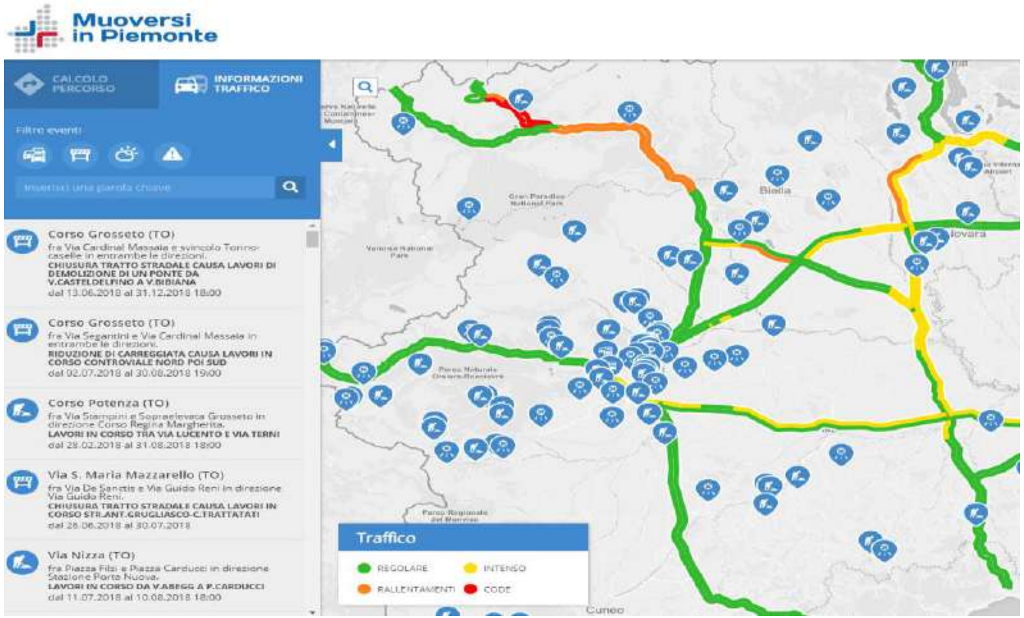
Mean Flow, Mean speed, Mean Travel Time, Level of Service – realtime and forecasted
Temporal range: 5/15/30/45/60 minutes
Sources: Regional and Metropolitan Supervisor software

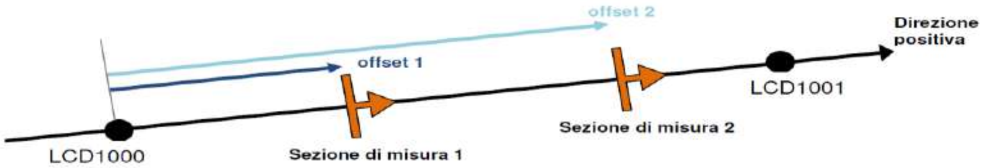


Dynamic mobility data

Traffic events

- Protocols for information exchange between agencies;
- XML encoding format;
- Complex system of categorization;





Linear referencing techniques for the correct positioning of an event.

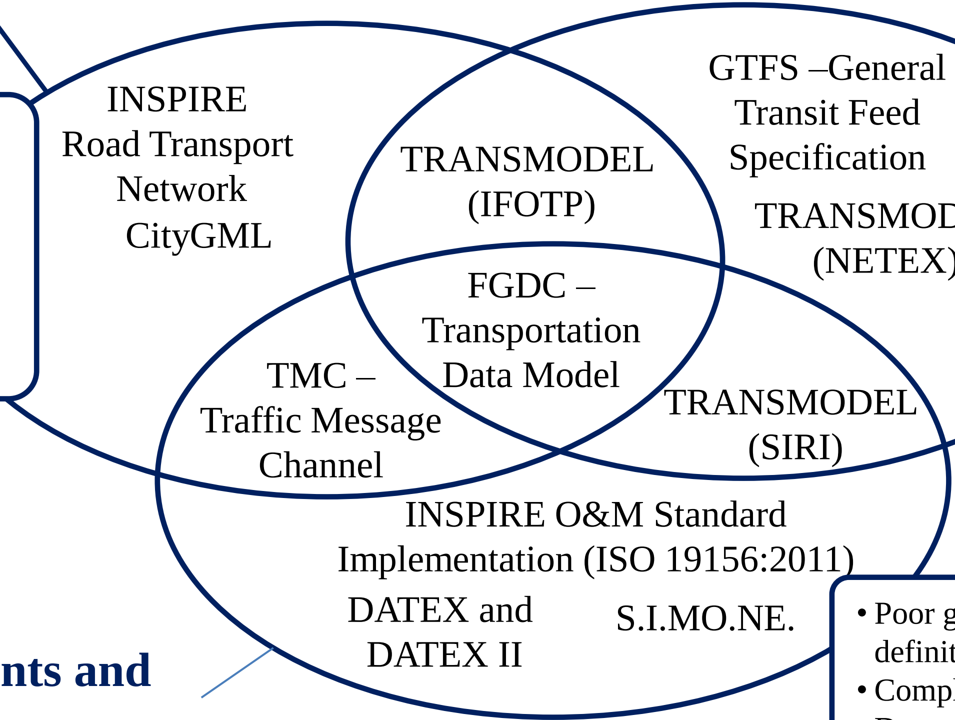
Transport Standard

Private Transport Network

- Strong geometric and topological definition
- Dictionaries of elements
- Lacks of ancillary elements definition

Public Transport

- Variable geometric and topological definition
- Inconsistencies between dictionaries
- Several temporal aspects



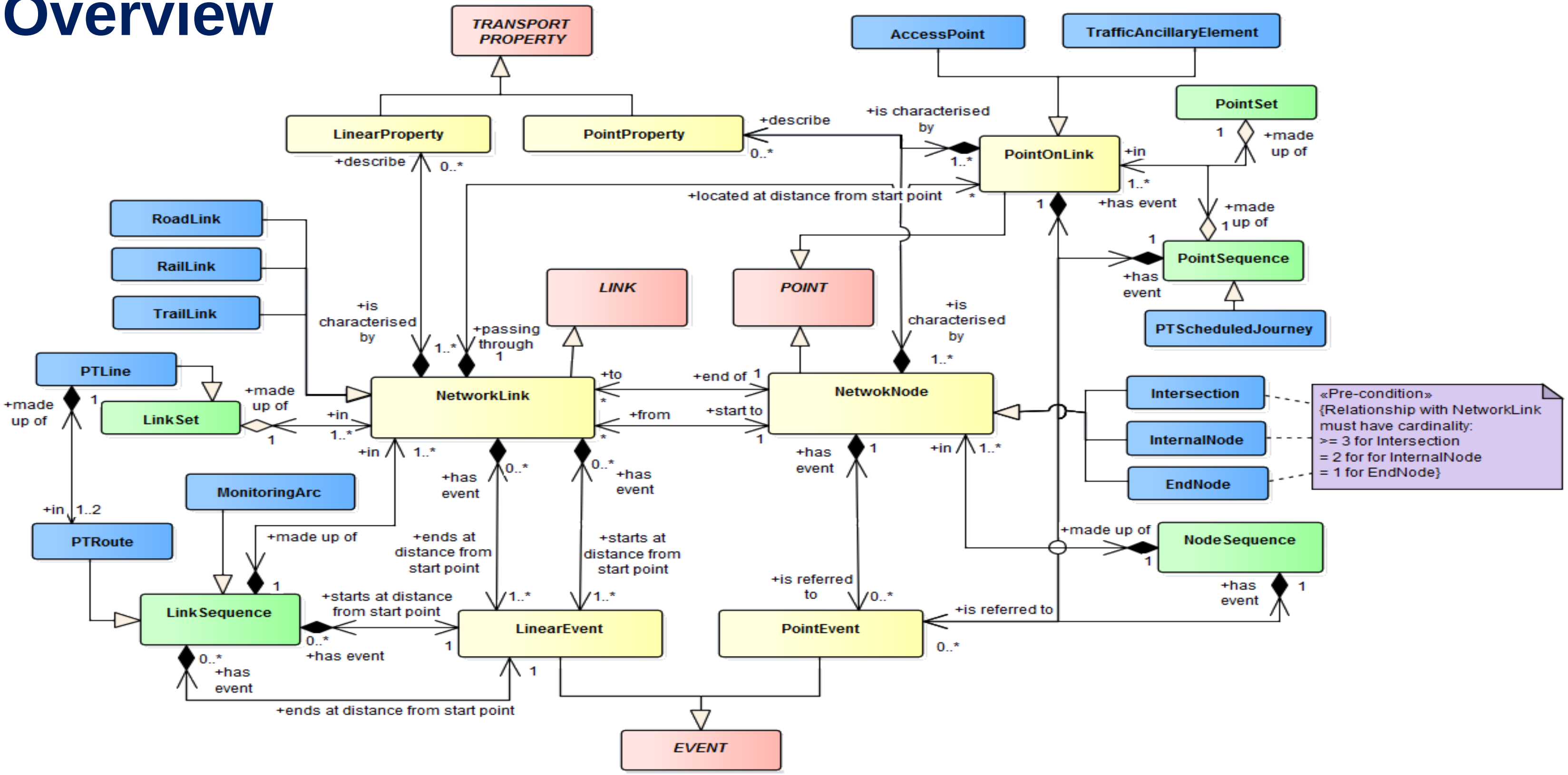
Traffic Events and Measures

- Poor geometric and topological definition
- Complex category dictionary
- Deep temporal defintion

Data modelling

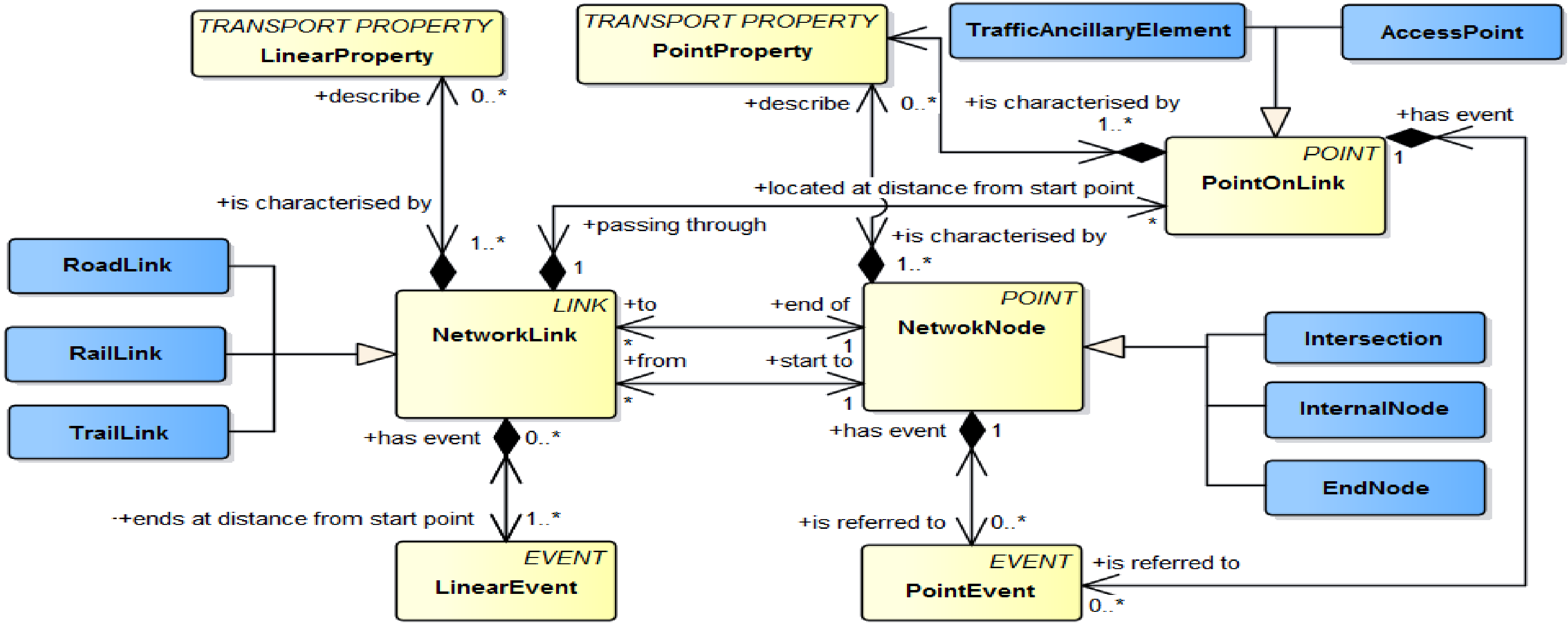
The conceptual data model

Overview

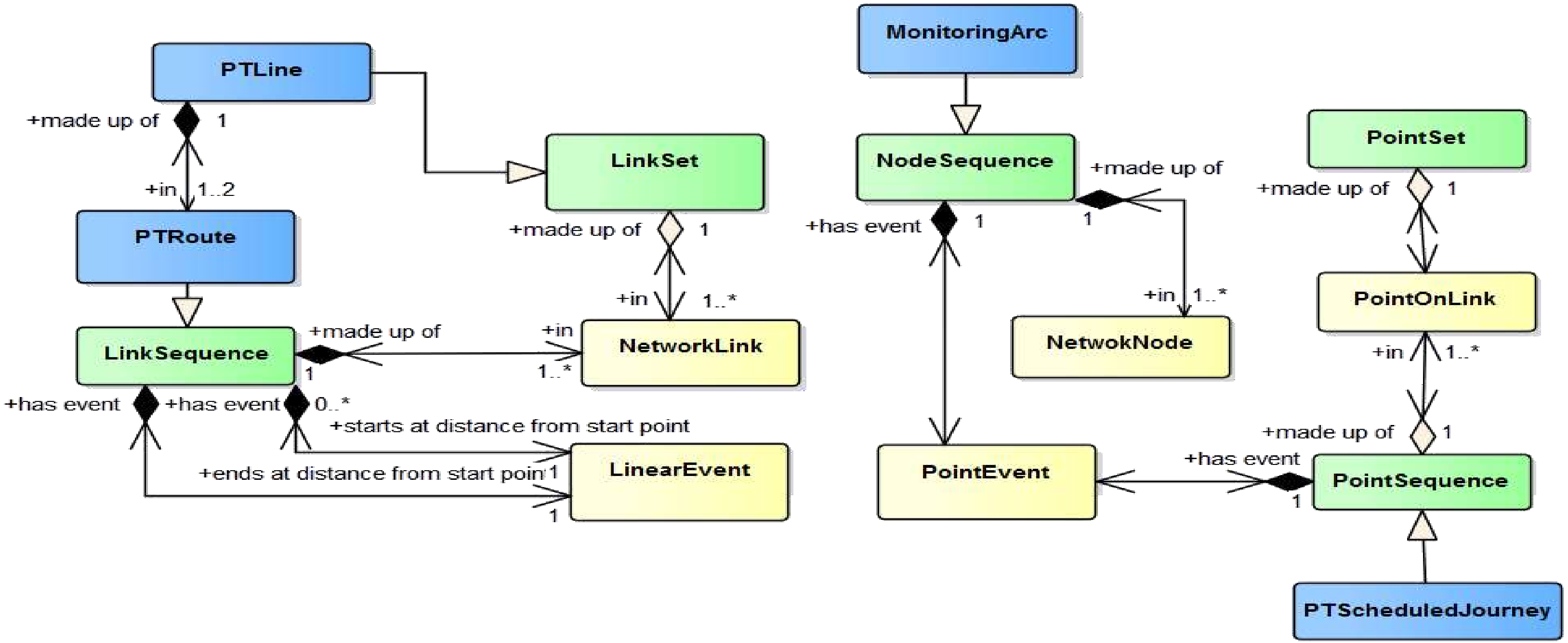


Data modelling
The conceptual data model

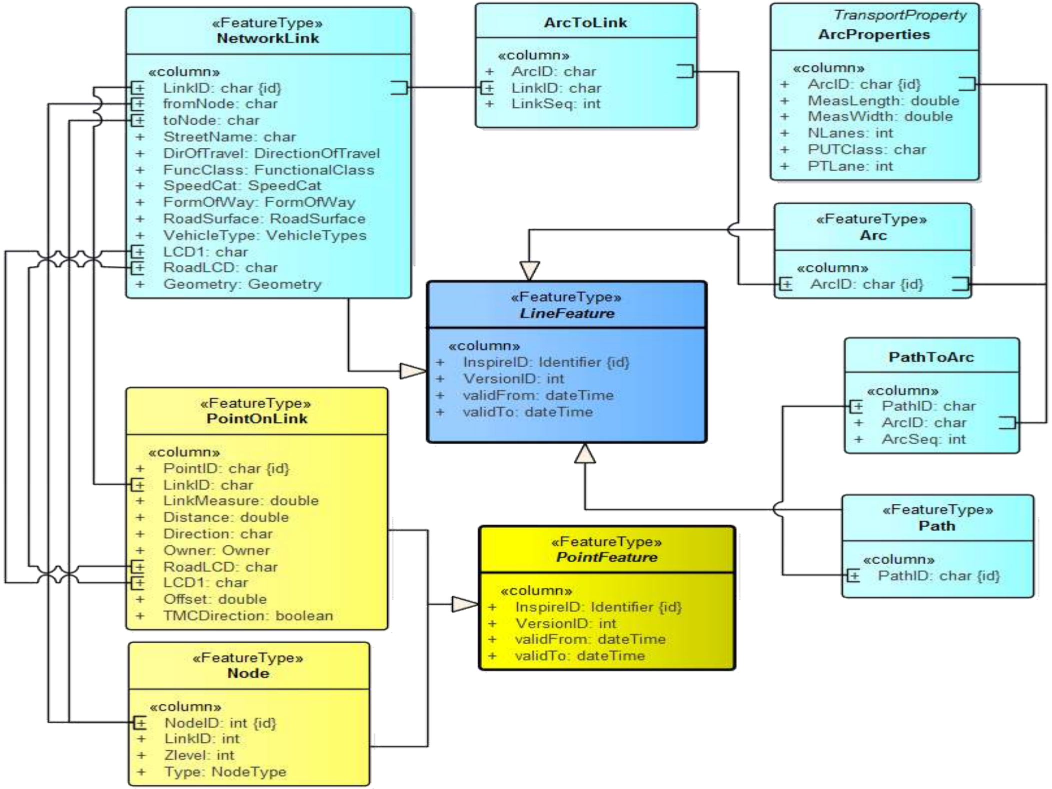
Main elements



Aggregations and compositions



Data modelling
The logical and physical data model
Road Network elements - logical



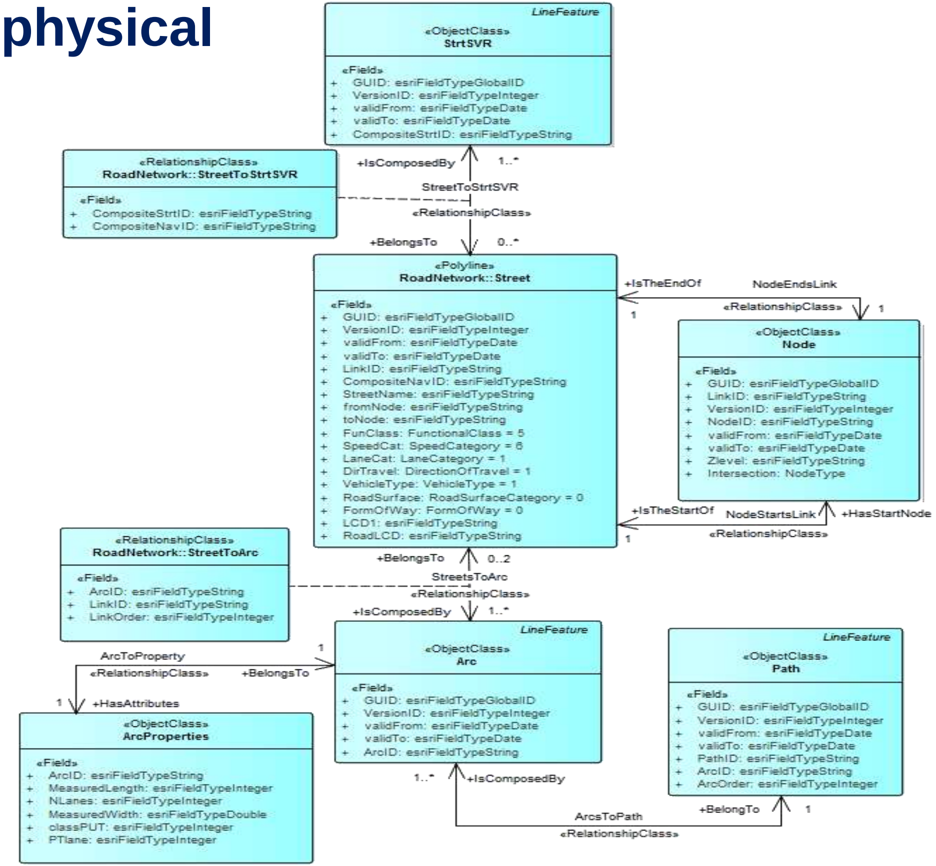
- Abstract classes with a set of common attributes (from INSPIRE)
- Relationships defined at attribute level (primary and foreign key)
- Grouping of network links
- Explicit topological relationships
- Attributes for linear referencing
- Code lists (from INSPIRE)

Data modelling

The logical and physical data model

Road Network elements - physical

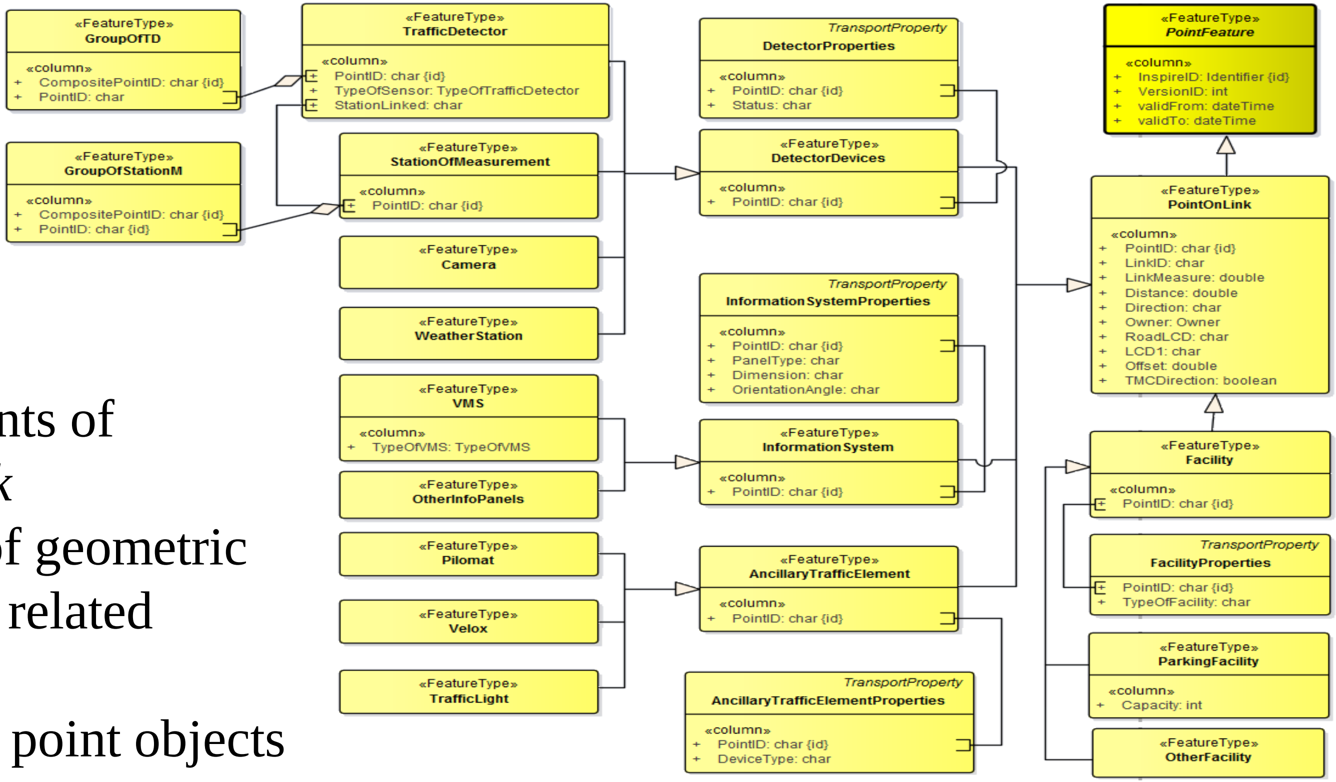
- Abstract classes with a set of common attributes (from INSPIRE)
- Attribute data type definition + default values
- Explicit relationships classes
- Tailored on 5T data (specific attributes and objects)
- Attributes for linear referencing
- *Street* as the only spatial feature object



Data modelling

The logical and physical data model

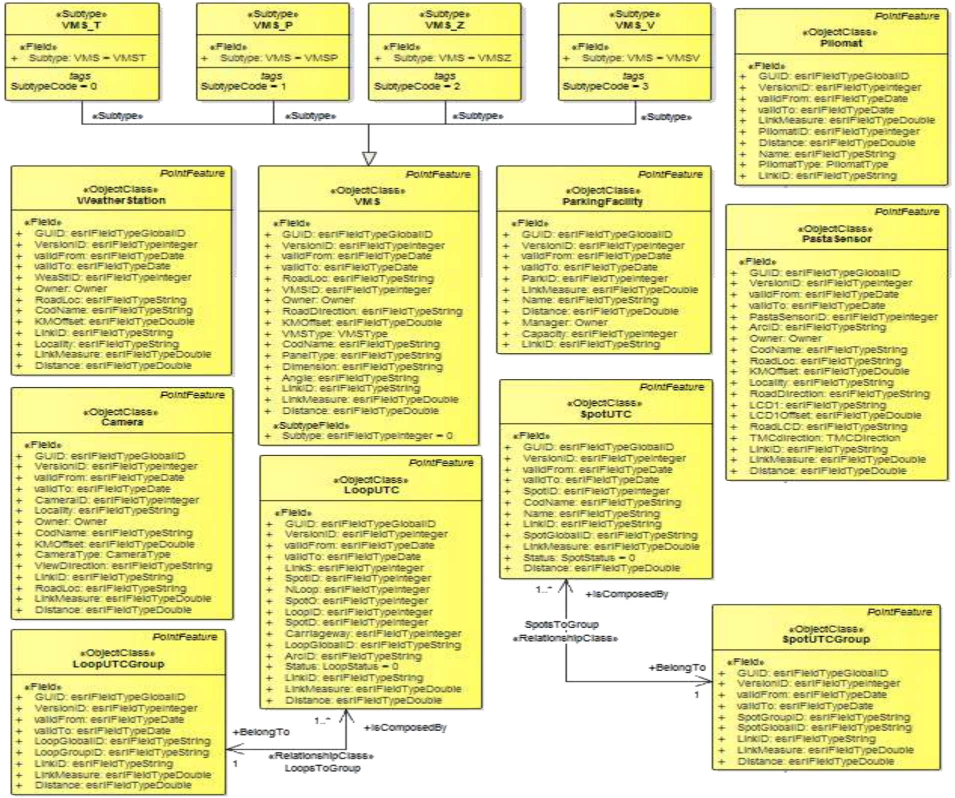
Ancillary traffic elements – logical



- Child elements of *PointOnLink*
- Separation of geometric features and related properties
- Grouping of point objects

Data modelling
The logical and physical data model

Ancillary traffic elements – physical



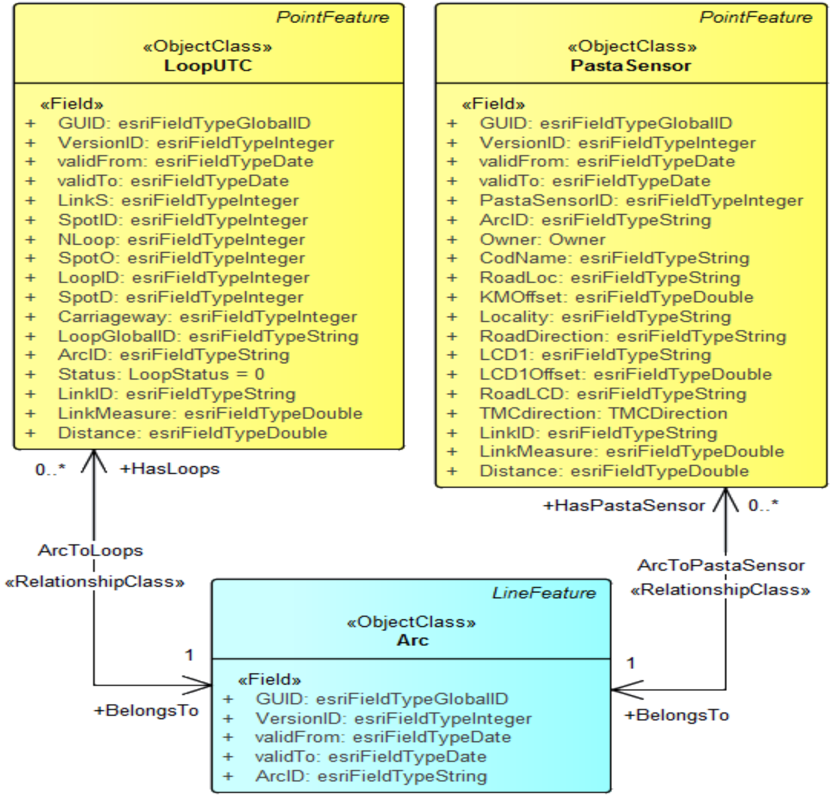
- Definition of specific traffic detectors types of 5T
- Use of subtypes
- Relationship classes define grouping of point objects

Data modelling

The logical and physical data model

Ancillary traffic elements relationships – physical

- Relationship classes to link traffic detectors and arcs
- Specific attributes for linear referencing (both TMC and ArcGIS engine)

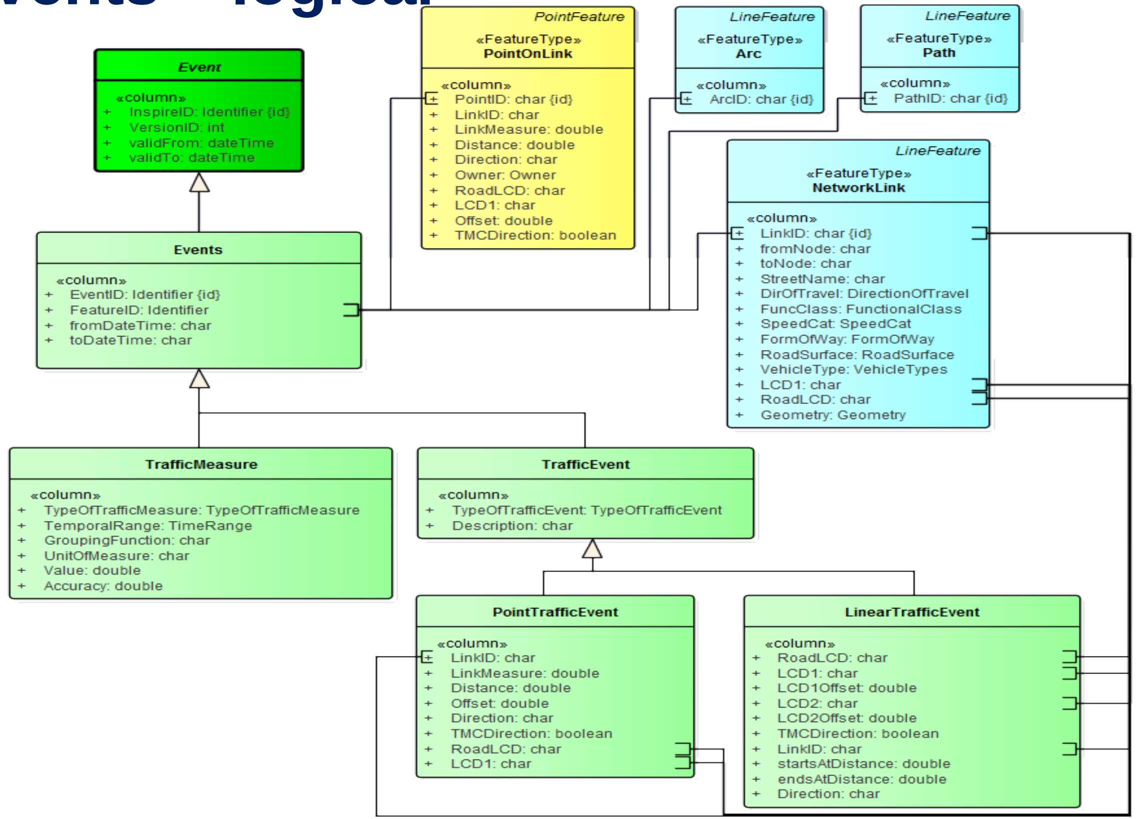


Data modelling

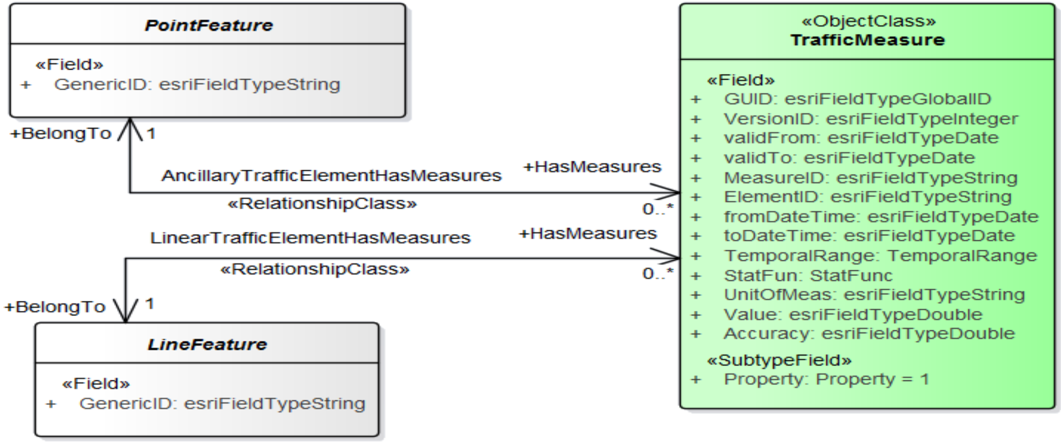
The logical and physical data model

Measures and events – logical

- Temporal and measures types attributes derived from O&M standard
- TMC linear referencing attributes for traffic events
- Types of traffic events derived from DATEX



Traffic Measures – physical

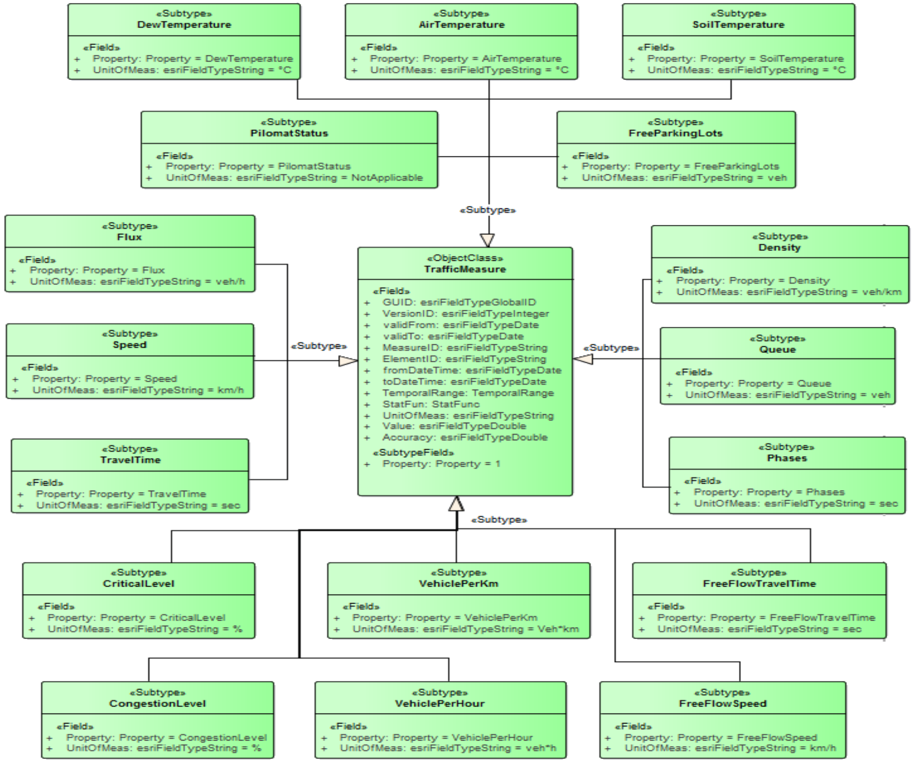


- Generic relationships classes to define the relationship between measures and abstract spatial objects, as a generic template for specific measure extraction

Data modelling

The logical and physical data model

Traffic Measures – physical

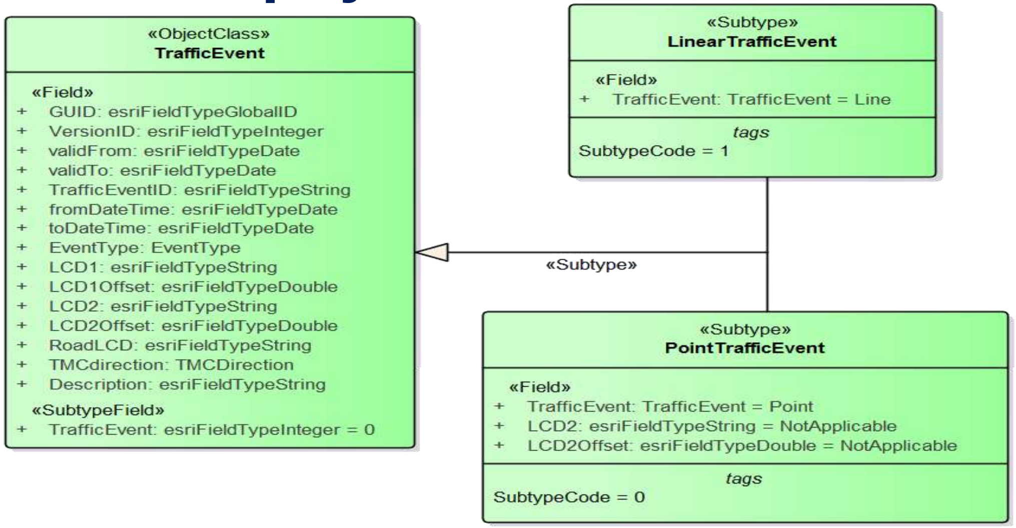


- Use of subtypes to define traffic measures types and default values for unit of measure

Data modelling

The logical and physical data model

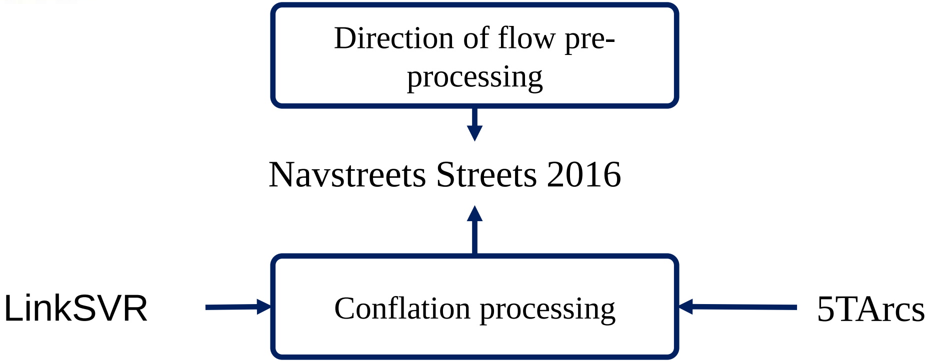
Traffic Events – physical

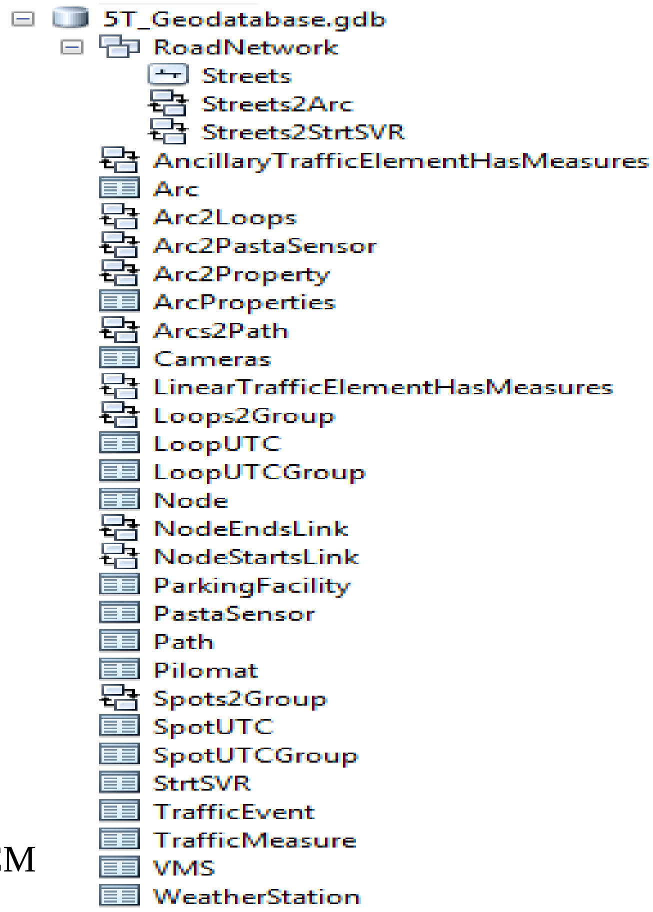


- Reference to spatial objects defined only by attributes
- Use of TMC location referencing system, implemented in ArcGIS through a custom script

Data pre-processing and ETL

Road Network





Ancillary Traffic Elements

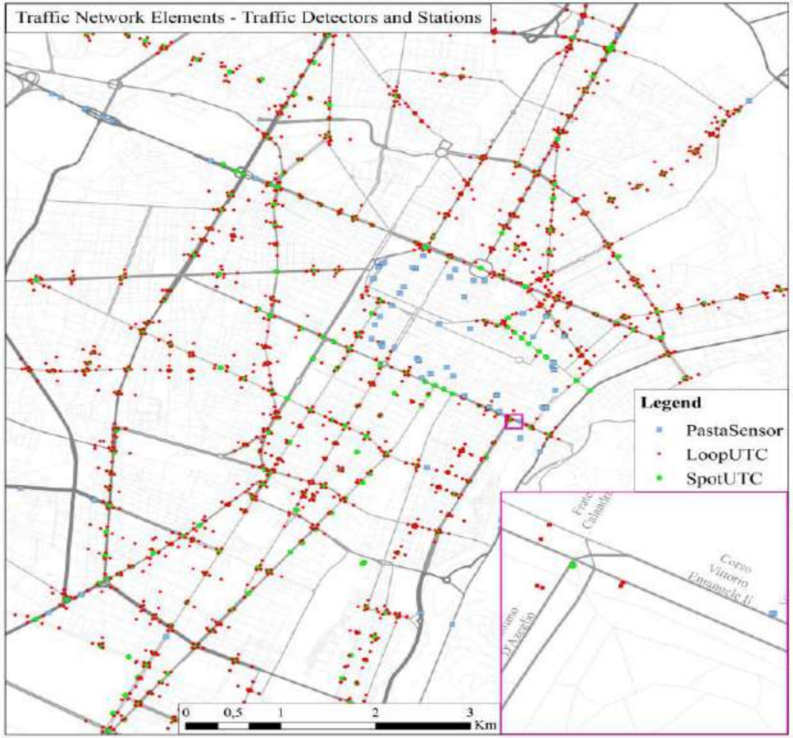
- Composite primary key creation
- Attribute matching between values and code lists
- Linear referencing with ArcGIS

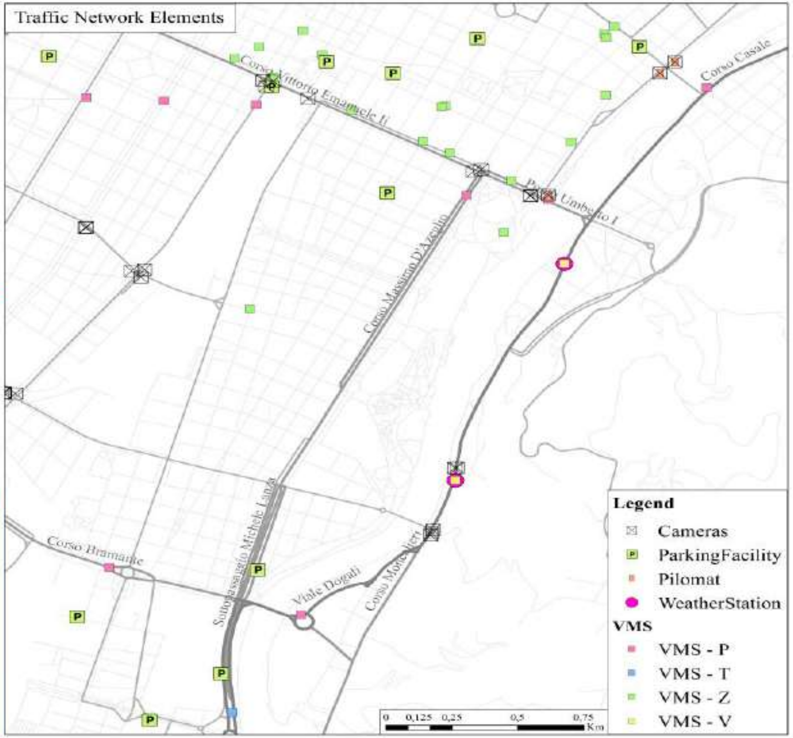
Measures and Traffic Events

- Measures extraction scripts (“group by” queries)
- ArcGIS custom script for traffic events linear referencing on TCM locations

Applications
Elements visualisation

Visualisation and queries of fixed ancillary traffic elements

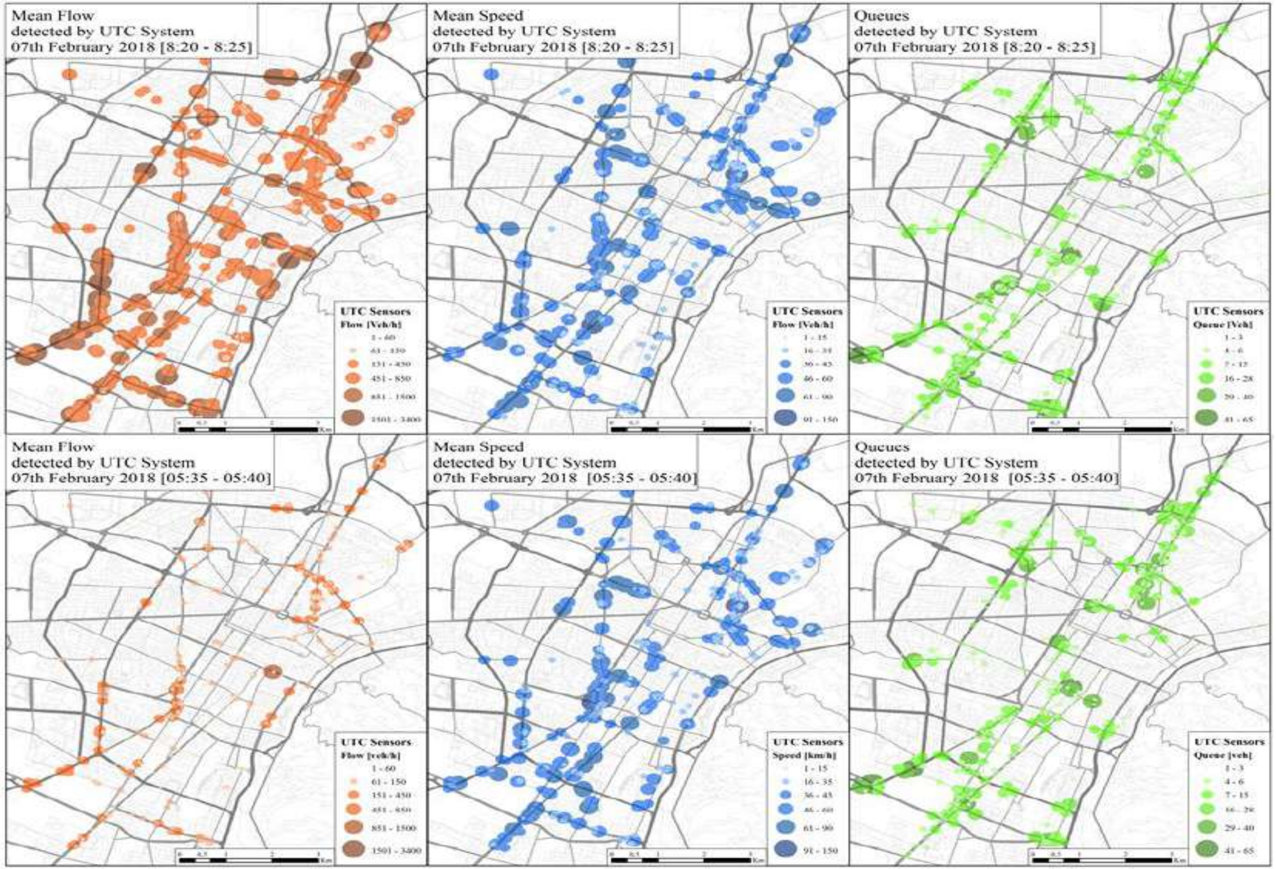




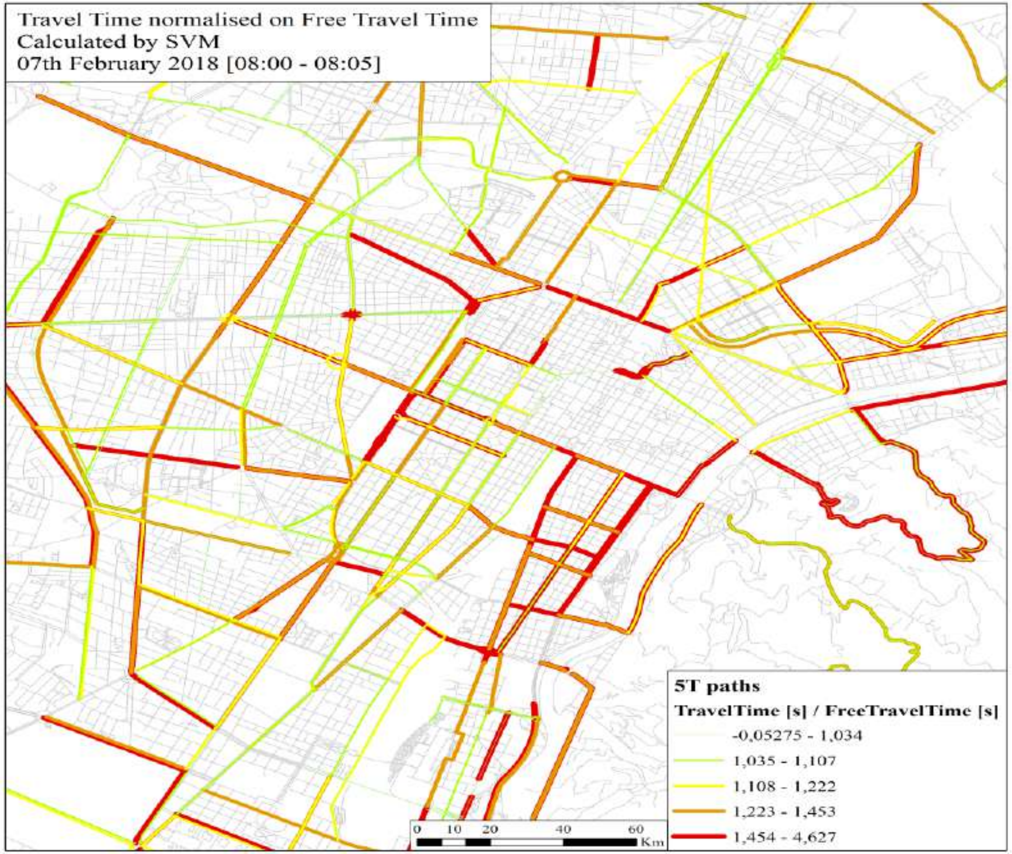
Applications

Measures visualisation

UTC measures at peak and non-peak hour (flow, speed, queues)



Applications
Measures visualisation

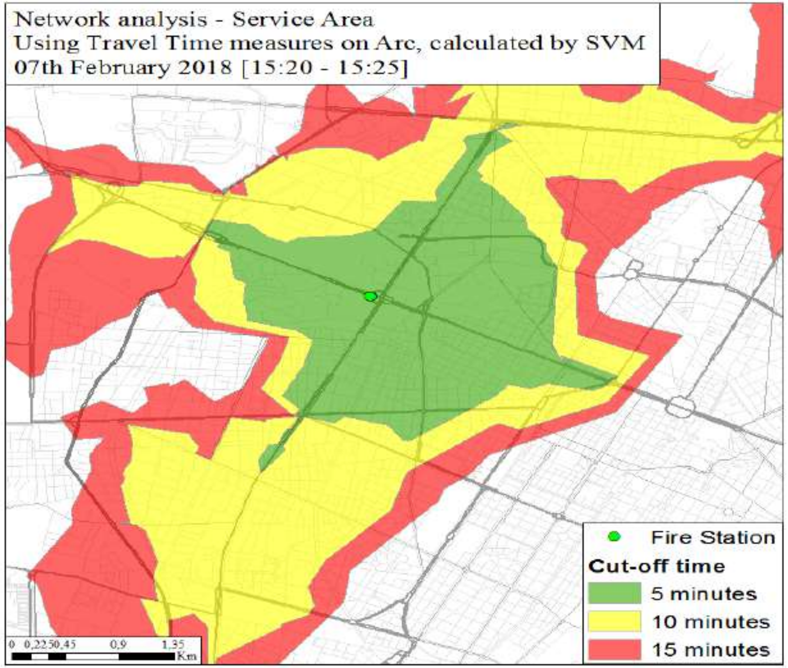


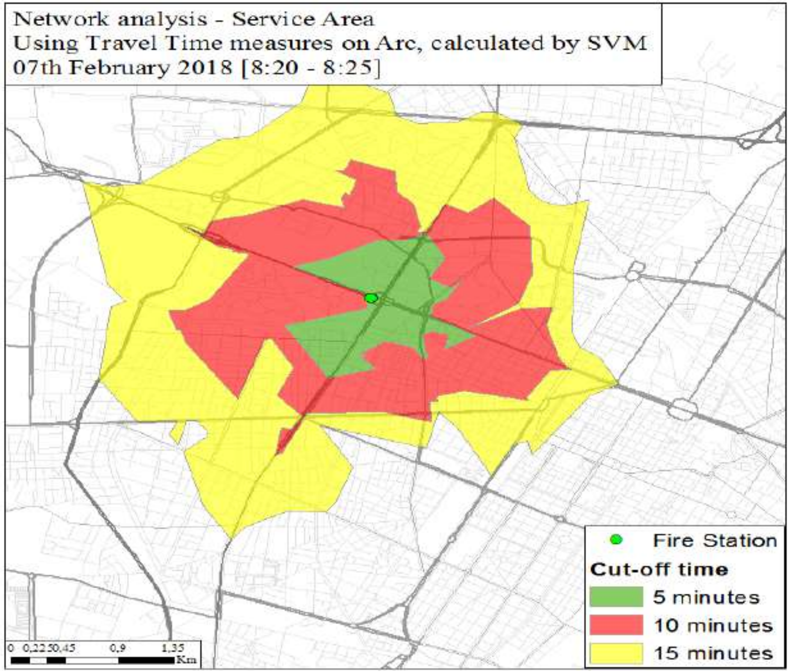
Measures from Metropolitan Supervisor, travel time normalised at peak hour

Applications

Network analysis with real impedances

Service areas at peak and non-peak hour

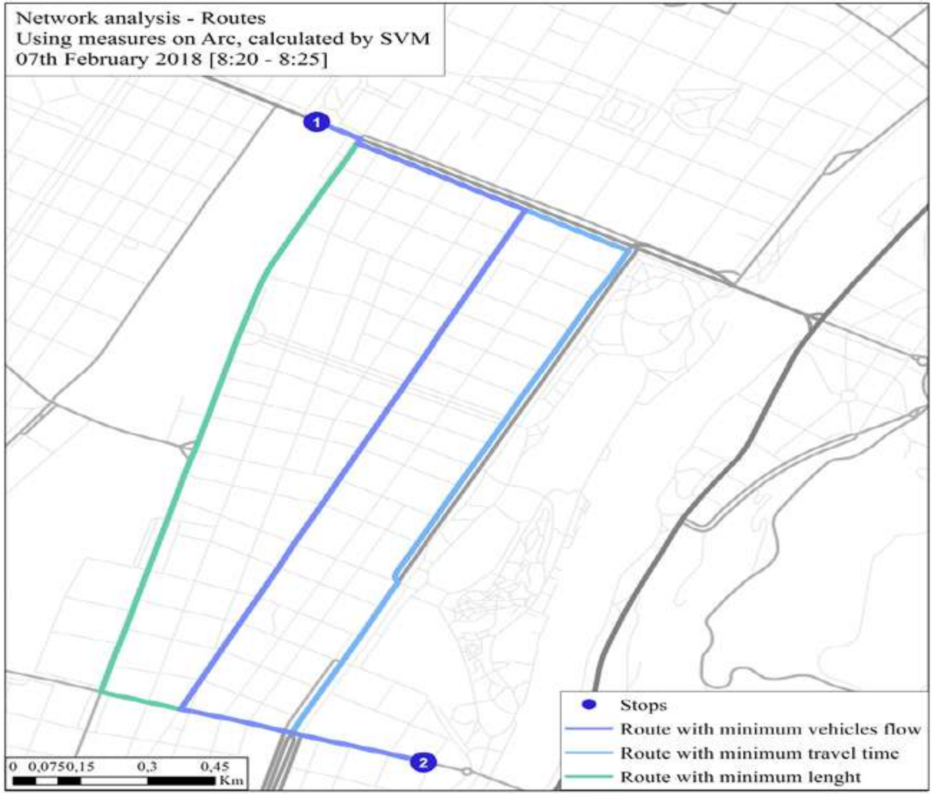




Applications

Network analysis with real impedances

Best route calculation using different types of impedances (flows, travel time, length)



Conclusions
Results

Comprehensive spatial data model

- A concrete proposal of <u>dictionary and relationships for ancillary traffic data</u> (generally poor in transport standards)
- Good basis for reports and analysis, not suitable for operational activities

Data and model reuse

- Possibility to reuse a various types of measures and events and good performance thanks to ad hoc queries extraction and measure aggregations
- Logical data model can be adapted for other agencies and other DBMS (technology independent)
- Physical data model and ETL script highly dependent from the ITS technology

ITS to desktop GIS data transition

The process cannot be automated and reused in different contexts, but good practices and general procedures can be defined

Conclusions
Further developments

Additional elements for spatial data model

- Operational and management aspects of ancillary traffic elements (status, connection types, diagnostics, IP…)
- Real time and complex type data (as cameras outputs, VMS messages…)
- Integration of travel demand (O/D matrix)
- Most sophisticated network analysis as “what if” scenarios
- Specification of public transport components and measures (defined only at conceptual level)
- Integration of slow and sharing mobility elements (bicycles paths, bike and car sharing stations)
- Adoption of DATEX II dictionary and OpenLR location system for traffic events

Thank you for your attention!

Road network comparison and matching techniques

A workflow proposal for the integration of Traffic Message Channel and Open Source network datasets

Introduction

ITS & Geo Big Data

<u>Research goals:</u>

- Conflate different road network
- Locate and manage traffic measure in a GIS environment
- Reuse of traffic measures

Road Network Data

Road Network Data

Comparison and quality assessment of Open Source Road Network Data Sets

- Spatial Completeness
- Attribute Completness
- Topology Correctness

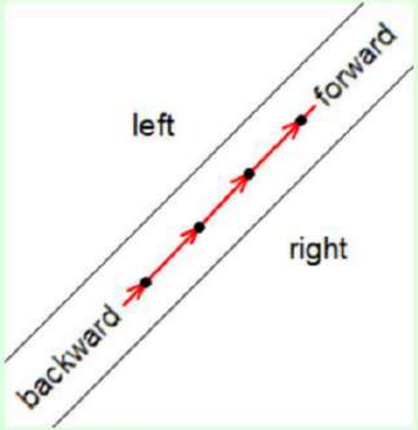
Open Street Map

Street as a vector

A one-way residential street, tagged as highway=residential + name=Clipstone Street + oneway=yes

```
<way id="5090250" visible="true" timestamp="2009-01-19T19:07:25Z" version="8" changeset="816806" user="Blumpsy" uid="64226">
  <nd ref="822403"/>
  <nd ref="21533912"/>
  <nd ref="821601"/>
  <nd ref="21533910"/>
  <nd ref="135791608"/>
  <nd ref="333725784"/>
  <nd ref="333725781"/>
  <nd ref="333725774"/>
  <nd ref="333725776"/>
  <nd ref="823771"/>
  <tag k="highway" v="residential"/>
  <tag k="name" v="Clipstone Street"/>
  <tag k="oneway" v="yes"/>
</way>
```

Feature : Forward & backward, left & right



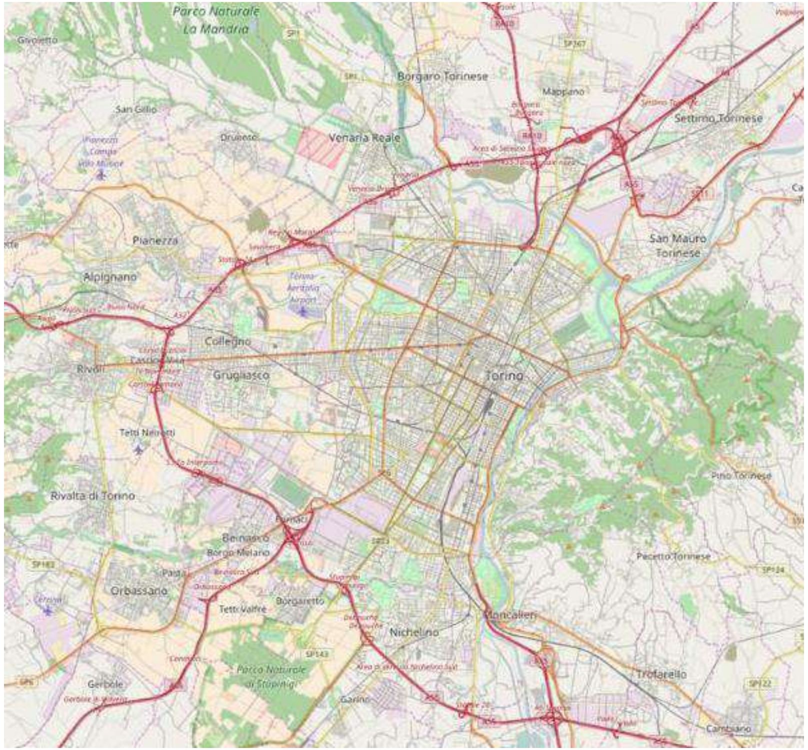
Description

Used to describe position or direction relative to a way.

Tags

:forward=, *:backward=*, *:left=*, *:right=*

Open Transport Map



<<table>>
TrafficVolume

+ID: Identifier
+roadLinkID: Identifier = RoadLink.inspireID
+trafficVolume: NumberOfVehiclesCrossingTheSegmentInTimePeriod
+trafficVolumeTimePeriod: TimePeriodValue
+fromTime: DateTime
+toTime: DateTime
+vehicleType: VehicleTypeValue

1

<<featureType>>
RoadLink

+inspireID: Identifier = DatasetSource_ID
+beginLifeSpanVersion: DateTime
+endLifeSpanVersion: DateTime
+validFrom: DateTime
+validTo: DateTime
+fictitious: Boolean
+centerLineGeometry: GM_Curve
+direction: LinkDirectionValue
+fromRoadNode: Identifier = RoadNode.inspireID
+toRoadNode: Identifier = RoadNode.inspireID
+RoadName: GeographicalName
+nationalRoadCode: CharacterString
+functionalRoadClass: FunctionalRoadClassValue
+formOfWay: FormOfWayValue
+roadSurfaceCategory: roadSurfaceCategoryValue
+speedLimit: SpeedLimitValue
+capacity: NumberOfMaximalTrafficVolumeValue
+maximumHeight: Float = meters
+maximumTotalWeight: Float = meters
+maximumWidth: Float = meters
+vehicleType: VehicleTypeValue

<<codeList>>
VehicleTypeValue

all vehicle
bicycle
car with trailer
delivery truck
emergency vehicle
employee vehicle
facility vehicle
farm vehicle
high occupancy vehicle
light rail
mail vehicle
military vehicle
moped
motorcycle
passenger car
pedestrian
private bus
public bus
residential vehicle
school bus
snow chain equipped vehicle
tanker
taxi
transport truck
trolley bus
vehicle for disabled person
vehicle with explosive load
vehicle with other dangerous load
vehicle with water polluting load

<<codeList>>
FormOfWayValue

bicycleRoad
dualCarriageway
enclosedTrafficArea
entranceOrExitCarPark
entranceOrExitService
freeway
motorway
pedestrianZone
roundabout
serviceRoad
singleCarriageway
slipRoad
tractor
trafficSquare
walkway

<<codeList>>
FormOfRoadNodeValue

enclosed traffic area
junction
level crossing
pseudo node
road end
road service area
roundabout
traffic square

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RoadSurfaceCategoryValue

paved
unpaved

<<codeList>>
LinkDirectionValue

bothDirections
inDirection
inOppositeDirection

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FunctionalRoadClassValue

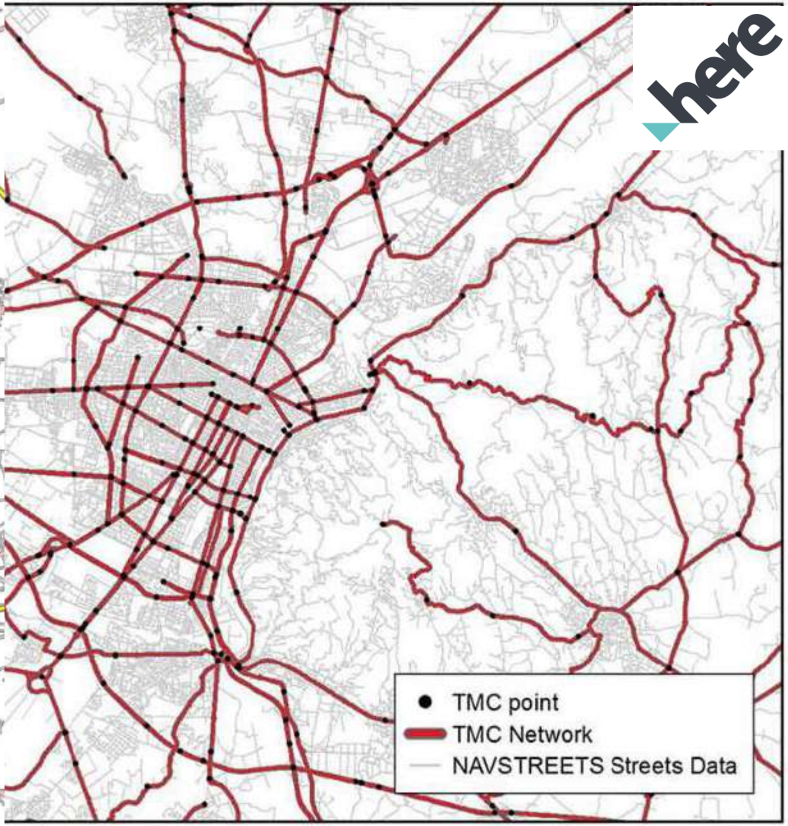
mainRoad
firstClass
secondClass
thirdClass
fourthClass
fifthClass

<<codeList>>
TimePeriodValue

hour
day
monday, ..., sunday
weekday
weekend
week
month
year

HERE - NavStreetData

Streets	
LINK_ID	PRIVATE
ST_NAME	FRONTAGE
FEAT_ID	BRIDGE
ST_LANGCD	TUNNEL
NUM_STNMES	RAMP
ST_NM_PREF	TOLLWAY
ST_TYP_BEF	POIACCESS
ST_NM_BASE	CONTRACC
ST_NM_SUFF	ROUNDABOUT
ST_TYP_AFT	INTERINTER
ST_TYP_ATT	UNDEFTRAFF
ADDR_TYPE	FERRY_TYPE
L_REFADDR	MULTIDIGIT
L_NREFADDR	MAXATTR
L_ADDRSCH	SPECTRFIG
L_ADDRFORM	INDESCRIB
R_REFADDR	MANOEUVRE
R_NREFADDR	DIVIDERLEG
R_ADDRSCH	INPROCDATA
R_ADDRFORM	FULL_GEOM
REF_IN_ID	URBAN
NREF_IN_ID	ROUTE_TYPE
N_SHAPEPNT	DIRONSIGN
FUNC_CLASS	EXPLICATBL
SPEED_CAT	NAMEONRDSN
FR_SPD_LIM	POSTALNAME
TO_SPD_LIM	STALENAME
TO_LANES	VANITYNAME
FROM_LANES	JUNCTIONNM
ENH_GEOM	EXITNAME
LANE_CAT	SCENIC_RT
DIVIDER	SCENIC_NM
DIR_TRAVEL	FOURWHLDR
L_AREA_ID	COVERIND
R_AREA_ID	PLOT_ROAD
L_POSTCODE	REVERSIBLE
R_POSTCODE	PHYS_LANES
L_NUMZONES	EXPR_LANE
R_NUMZONES	CARPOOLRD
NUM_AD_RNG	VER_TRANS
AR_AUTO	PUB_ACCESS
AR_BUS	LOW_MBLTY
AR_TAXIS	PRK_AVLBT
AR_CARPOOL	PRIORITYRD
AR_PEDEST	SPD_LM_SRC
AR_TRUCKS	TRANS_AREA
AR_TRAFF	DELVRY_RD
AR_DELIV	SUPGEO_BIT
AR_ENERVEH	CONF_LVL
PAVED	



Data comparison and assessment

Data pre – processing

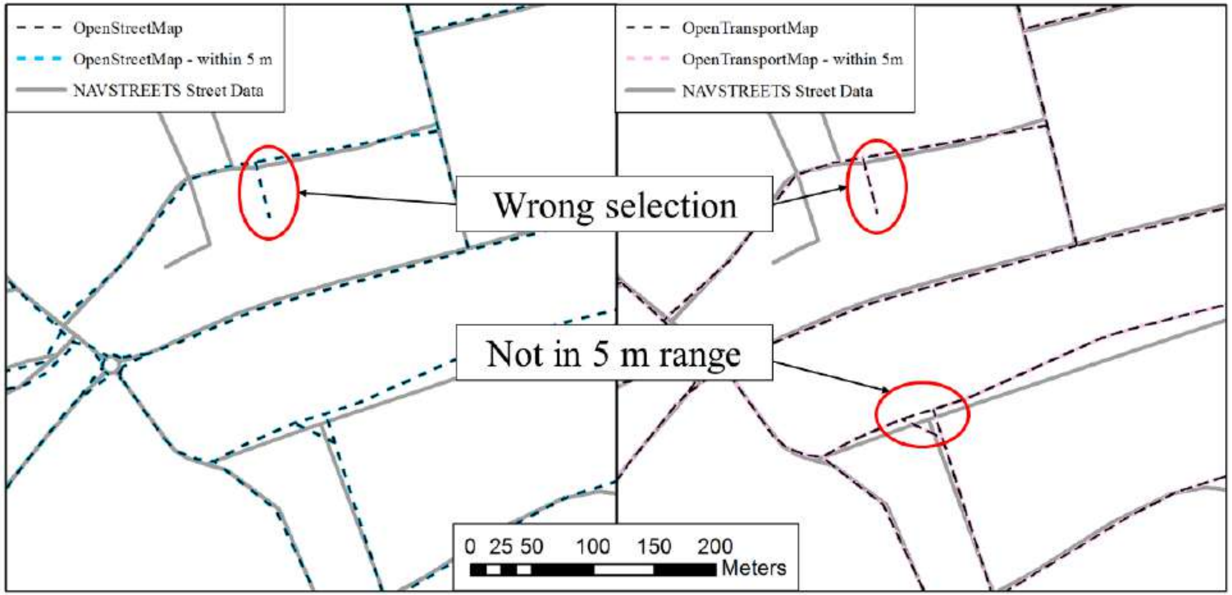
- Spatial processing:
  - Selection of OSM&OTM roads within 5, 10 and 30 meters of distance from the HERE Navstreet Data
- Attribute processing:
  - Exlusion of cycleways, pedestrian path and unpaved roads

GOAL → 1:1 correspondance at object level

Data comparison and assessment

	Total km	Features count
NAVSTREETS Street Data	48.935,19	406.291
OpenStreetMap 5m	66.052,86	203.304
OpenStreetMap 10 m	67.454,18	210.398
OpenStreetMap 30 m	69.335,58	220.199
OpenTransportMap 5 m	81.406,44	498.966
OpenTransportMap 10 m	83.259,50	514.430
OpenTransportMap 30 m	85.847,40	534.555

Data comparison and assessment

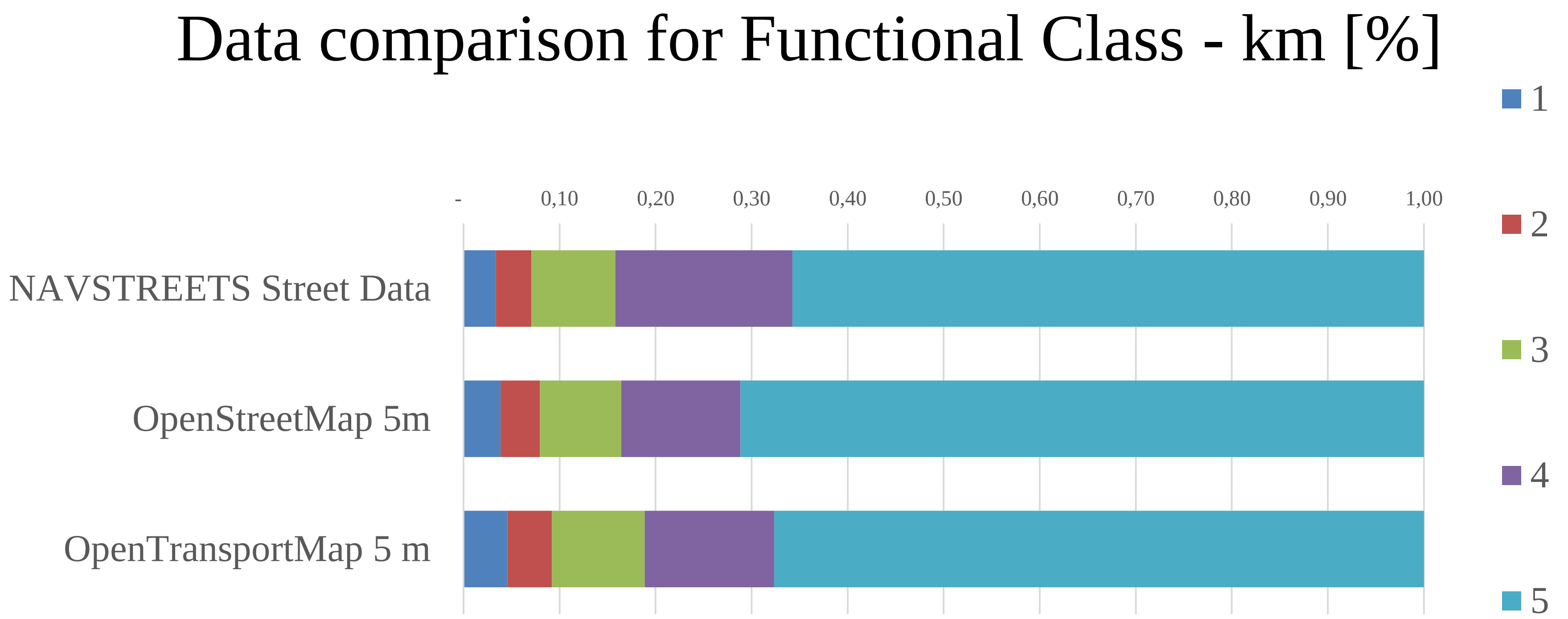


Data comparison and assessment

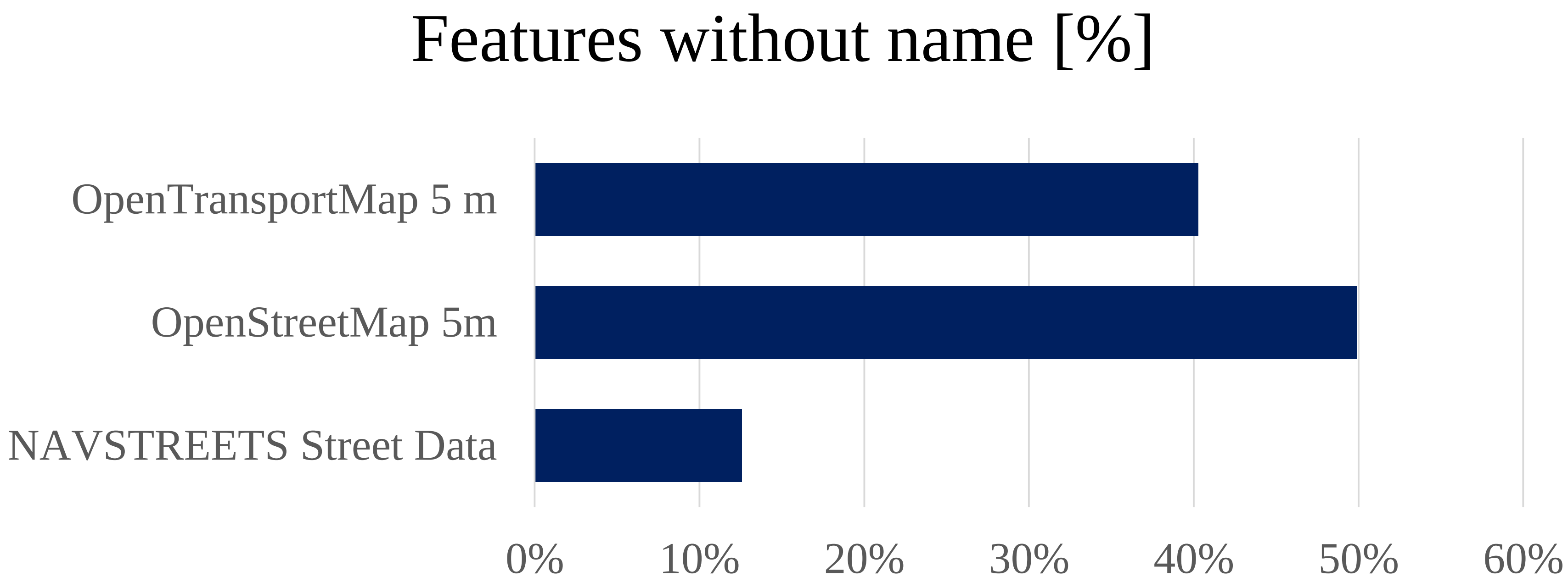
Functional classification

NAVSTREETS	OSM	OTM
1	motorway, motorway_link, trunk, trunk_link	mainRoad
2	primary, primary_link	firstClass
3	secondary, secondary_link	secondCLass
4	tertiary, tertiary link	thirdClass
5	all other values	fourthClass and fifthClass

Data comparison and assessment



Data comparison and assessment



Data comparison and assessment

Topology	Feature Mean Length	N° of Features	Must Not Self-overlap	Must not Self-intersect
NAVSTREETS Street Data	0,127	406.291	0	0
OpenStreetMap	0,331	255.984	44	74
OpenTransportMap	0,183	609.952	5	15
OpenStreetMap - FeatureToLine	0,170	481.524	0	0

Traffic measures Open Data

Not secure | opendata.5t.torino.it/get_fdt

Apps Gmail Calendar ITHACA Products Copernicus in-situ... » Other bookmark

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 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
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 14T03:11:00+02:00" start_time="2019-06-14T03:05:00+02:00" end_time="2019-06-14T03:10:00+02:00"
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  </location_reference>
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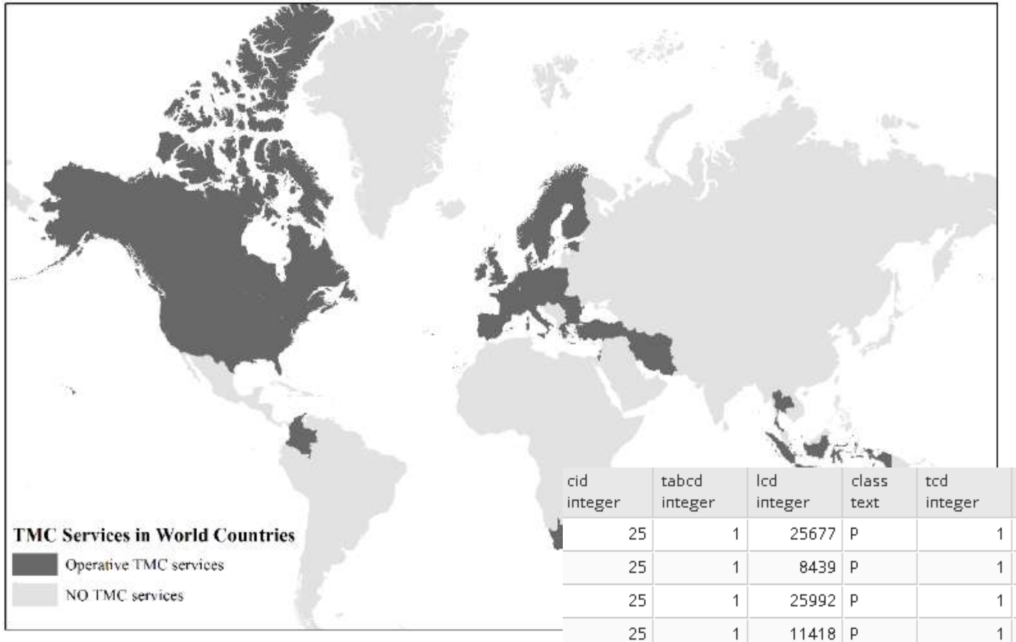
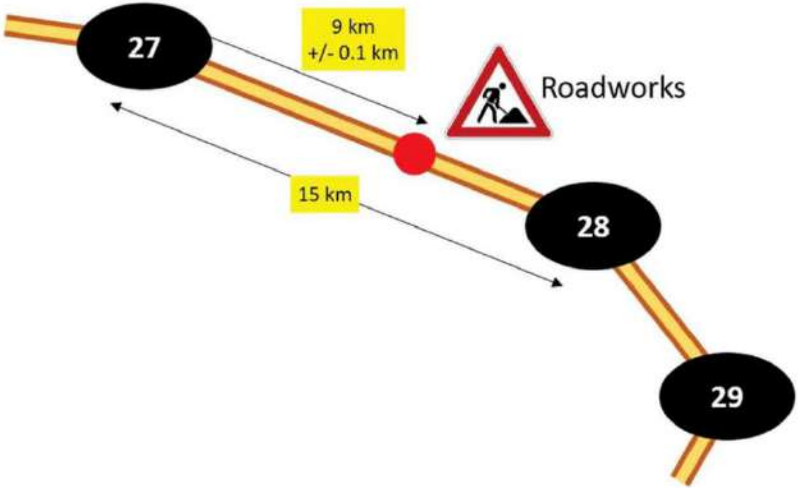
S.I.Mo.Ne Italian Standard
(DATEX I Implementation)

- Protocol to exchange dynamic traffic information between traffic management operators
- Location encoded using:
  - WGS 84 coordinates;
  - **TMC location referencing**

Traffic Message Channel





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25	1	25677	P	1	11	[null]	8524	7222	[null]	62	[null]	[null]	25674
25	1	8439	P	1	11	[null]	59476	44102	[null]	90	[null]	[null]	586
25	1	25992	P	1	11	[null]	62538	59928	[null]	55	[null]	[null]	25987
25	1	11418	P	1	11	[null]	45134	10716	[null]	71	[null]	[null]	885
25	1	30024	P	1	11	[null]	37734	57328	[null]	113	[null]	[null]	30022
25	1	38909	P	1	11	[null]	31154	5040	[null]	123	[null]	[null]	38905
25	1	11811	P	1	11	[null]	6500	15996	[null]	55	[null]	[null]	925
25	1	[illegible]	P	1	11	[null]	[illegible]	[illegible]	[null]	[illegible]	[null]	[null]	[illegible]

Data conflation procedure

Transferring TMC attibutes to OTM road network

Achieved using PostGIS&PGRouting functions

2 Main steps:

1. Matching between OTM nodes (intersections) and TMC Location Point
2. Routing between two consecutives points on the OTM network

Data conflation procedure

One TMC point can be related to one or more OTM points:

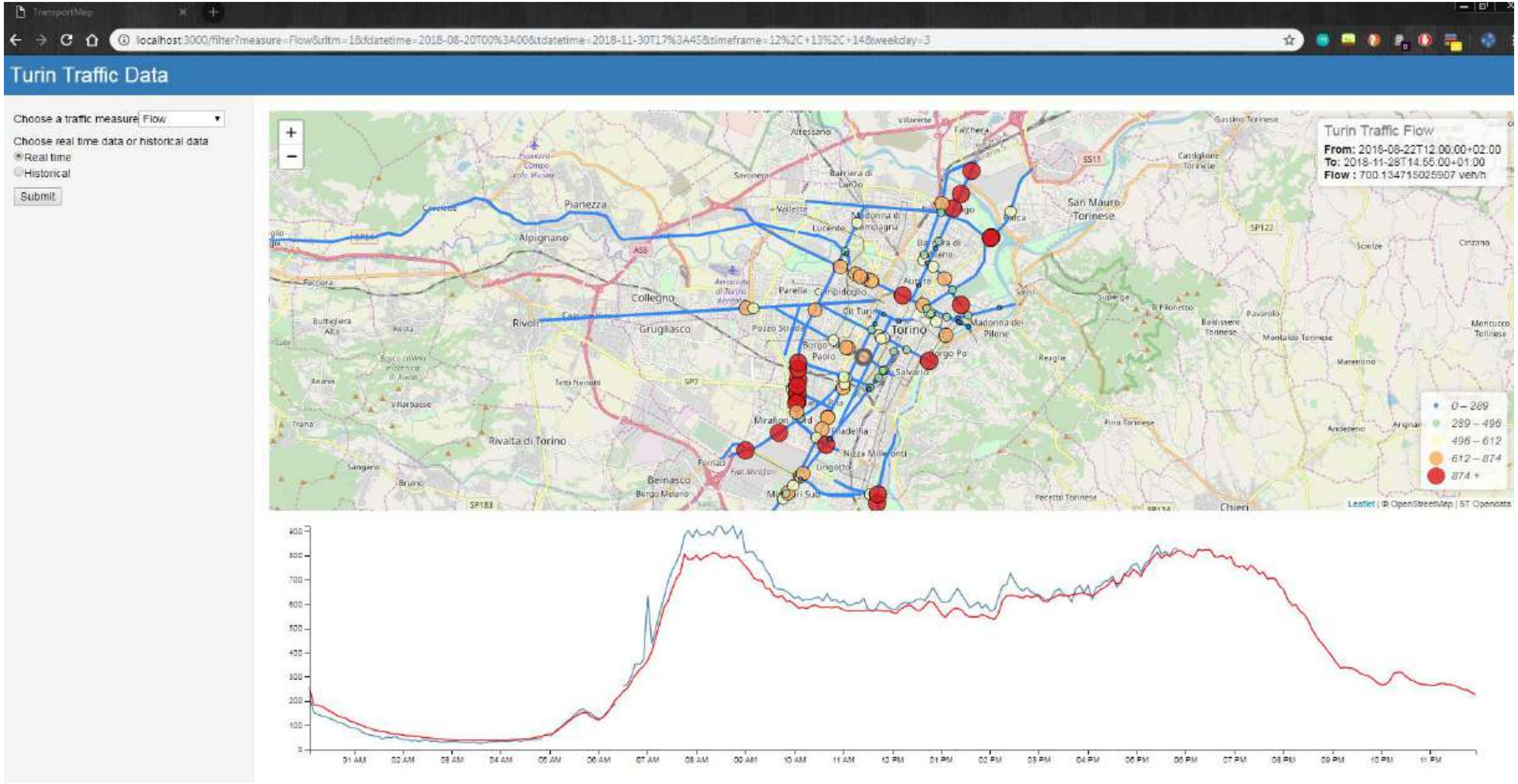
1. Selection of OTM points representing a crossing (grade of the node > 2)
2. Association of the names of the roads to the OTM crossing nodes
3. Selection of the OTM nodes to be associated with TMC points through: proximity and similarity of the associated names (Levenstain index)

At the end of this process we still don’t know if the OTM points selected are the right one – in particular we don’t know if the node is the one in the correct direction of flow (valid for double digitised roads)

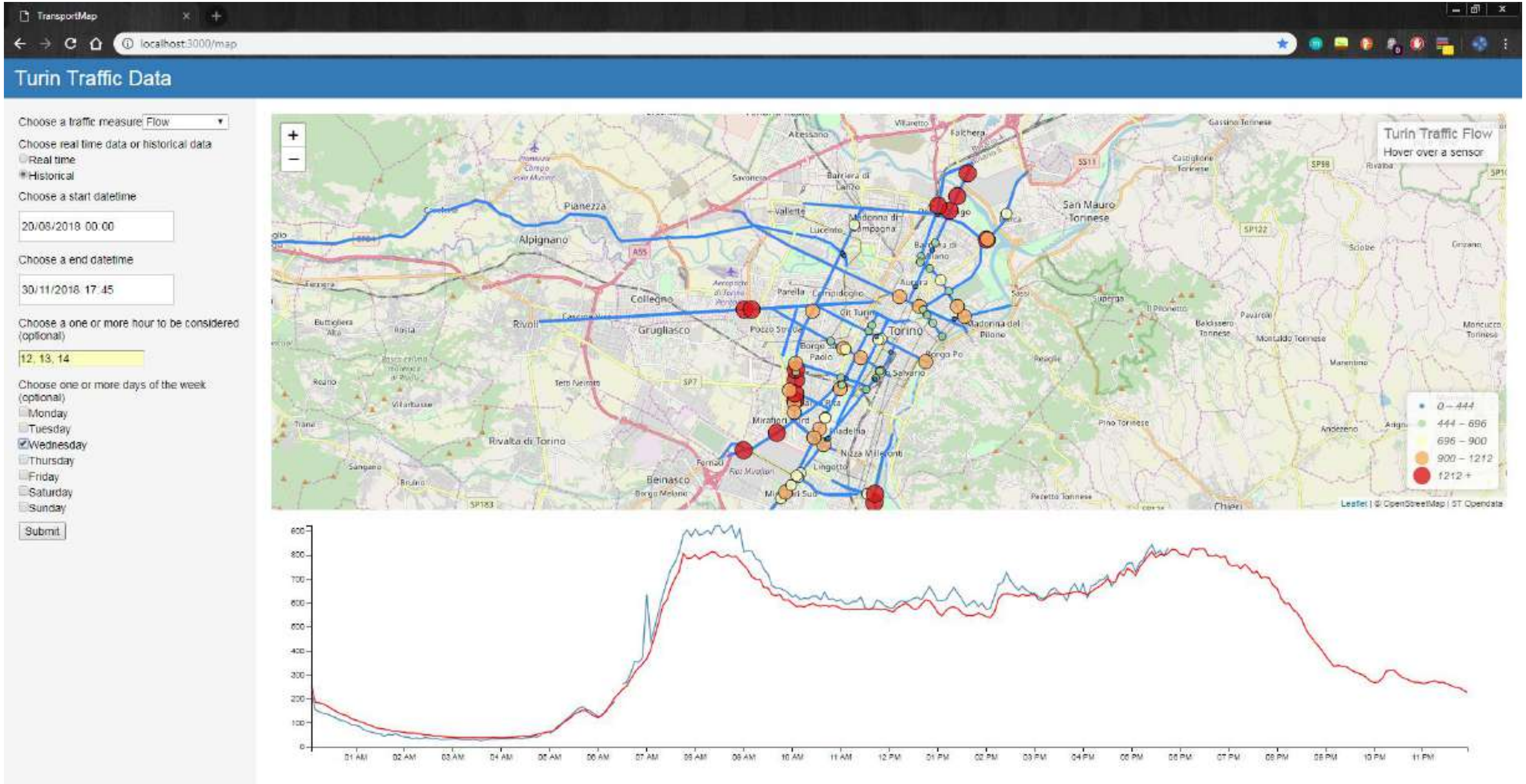
Data conflation procedure

- A routing algorithm using PostgisRouting has been set up (selection of preferential roads…)
- Find the route between two couples of OTM points following the rules of connection defined in the TMC
- Between multiple solutions only the ones with the minimum distance and minimum number of turns has been considered
- The resultant paths have been associated to the OTM network, adding an attribute which identify a TMC road in negative or positive direction)
- *Results is correct for 83% of the considered TMC roads: in some cases the solution found was incorrect or no solution has been found by the routing algorithm → a manual revision is always needed!*

Data visualisation



Data visualisation



Conclusions

The procedure may be applied in future for the whole Italian network

Testing cities	Turin	Milan	Padua	Rome	Naples
Rates of correctly located TMC roads	83%	78%	53%	79%	59%

The use of TMC is indeed encouraged by the Italian Smart Road Initiative.

The result is a first step to overcome the use of commercial road data, in car navigation systems, public adminstrations and Traffic Operation Centers

Further developments:

- Visualising a set of linear traffic events
- Using processed data for traffic perturbation analysis during particular events
- Methods and strategies to efficiently store and query these Geo Big Data

Thank you for your attention!

UPDATING A ROAD NETWORK DATASET EXPLOITING THE RESULTS OF SEMANTIC SEGMENTATION TECHNIQUES APPLIED TO STREET-LEVEL IMAGERY

A. Ajmar [1], E. Arco [2], P. Boccardo [2], F. Giulio Tonolo [3], Janine Yoong [4]

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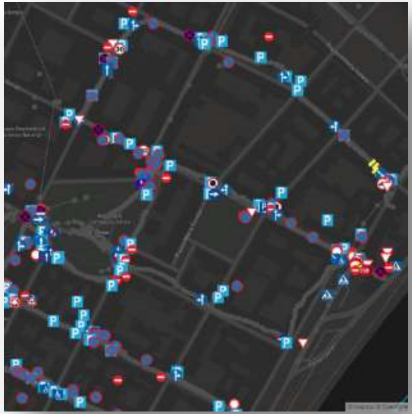
2 Politecnico di Torino – DIST, Torino, Italy – (emere.arco, piero.boccardo)@polito.it
3 Politecnico di Torino, Department of Architecture and Design, Italy - fabio.giuliotonolo@polito.it
4 Mapillary Inc.. 134 North 4th Street, Brooklyn NY 11249-3296, USA - janine@mapillary.com

Outline

1. Traffic signs inventories: issues and opportunities
2. Traffic signs automatic recognition
3. Operational exploitation of traffic signs datasets
4. Conclusions

Traffic signs inventories

- While setting up a **road network**:
  - speed limits
  - restricted access
  - breakthrough prohibition signs
  - …



- Support road concessionaires during **installation and maintenance**
  - in 2006, the Torino municipality issued a special contract specification document for traffic signs ordinary maintenance for a total value of 530.000 €

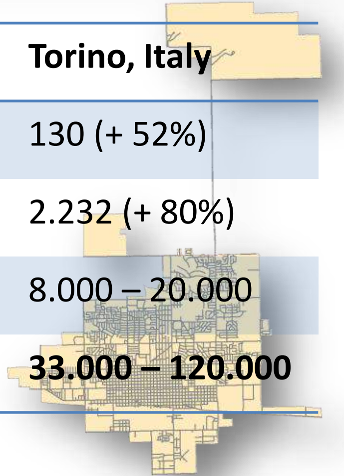
Traffic signs inventories

Inventories are rarely existing and their generation is highly demanding

	Clovis, New Mexico, USA	Torino, Italy
Area (km^2)	62	130 (+ 52%)
Urban roads (km)	441	2.232 (+ 80%)
Traffic signs	4.000	8.000 – 20.000
Iventory cost (€)*	14.000 – 21.000	**33.000 – 120.000**

* 4-6 US$ per traffic sign

Clovis, New Mexico, USA

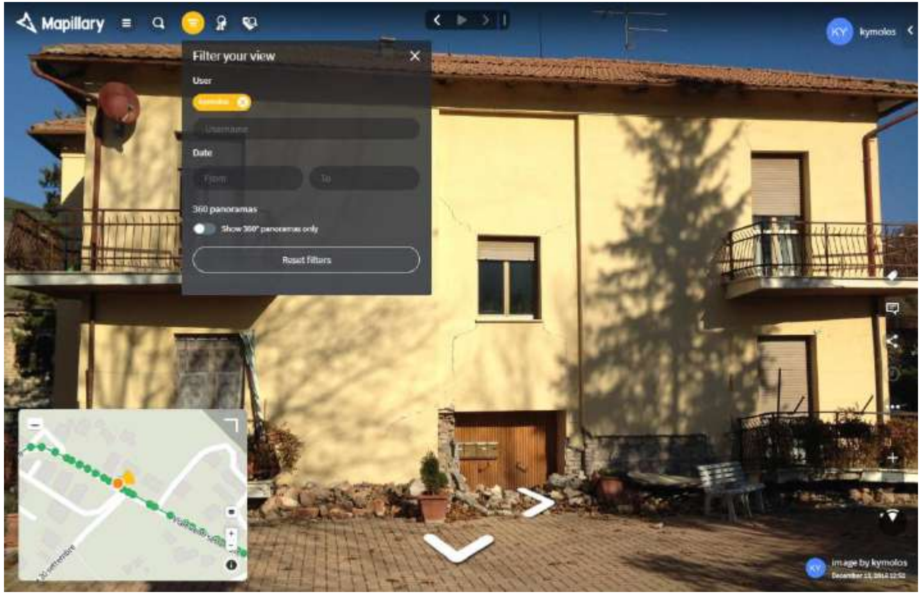


Torino, Italy

Street-level images

Mapillary

is a **street-level imagery** acquisition, storage and pubblication platform



Street-level images

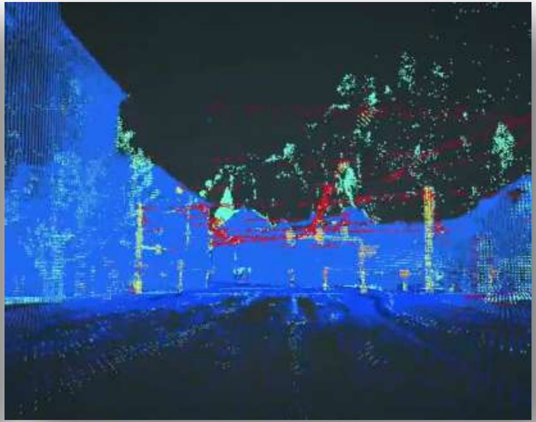
Mapillary

supports **organizations** to easily create and share street-level imagery and automatically extracted data to keep maps and geospatial datasets up to date

Semantic segmentation

Mapillary

adopt the well-established photogrammetric algorithm Structure from Motion (SfM) to create and reconstruct surfaces in 3D



Semantic segmentation

Mapillary

runs semantic segmentation to recognise features on images

Pixel-wise labeling with 97 classes

Traffic sign recognition

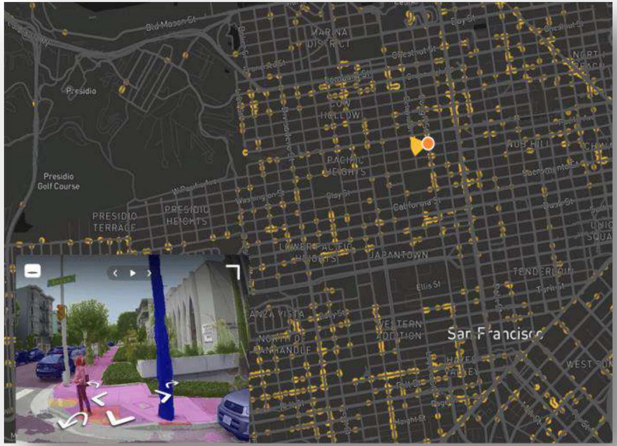
Over 1500 signs in 100 countries

Semantic segmentation

Mapillary

Mapillary

semantic segmentation together with 3D reconstruction enables to extract 3D coordinates of the detected objects



Traffic signs recognition

Main issues:

- signs in the same class don’t all look the same
  - a traffic sign taxonomy is needed to organize the different traffic signs into semantic classes over different countries

Traffic signs recognition

Main issues:

- signs in the same class don’t all look the same
  - a traffic sign taxonomy is needed to organize the different traffic signs into semantic classes over different countries
- can be visually similar to other objects

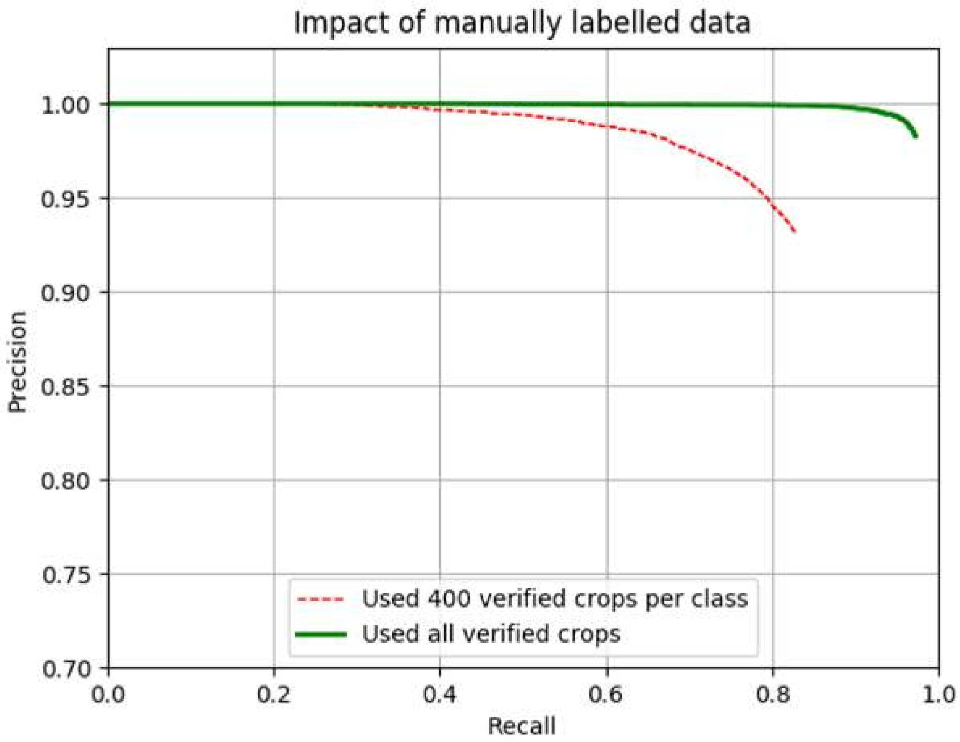
Traffic signs recognition

Main issues:

- signs in the same class
  - a traffic sign taxonomy
    different traffic signs in
    different countries
- can be visually similar

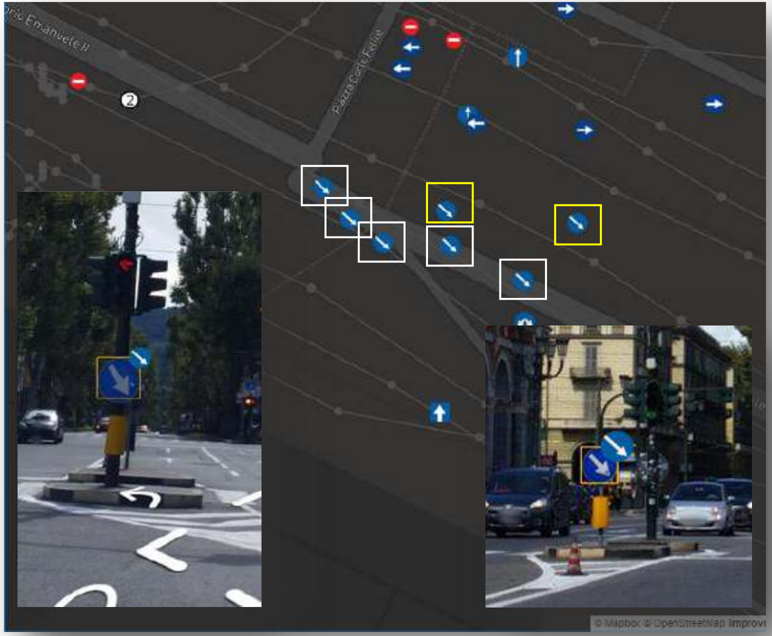
Verification by Mapillary community

members contributed in verifying 1,000,000 traffic signs, leading to significant improvements in recognition accuracy



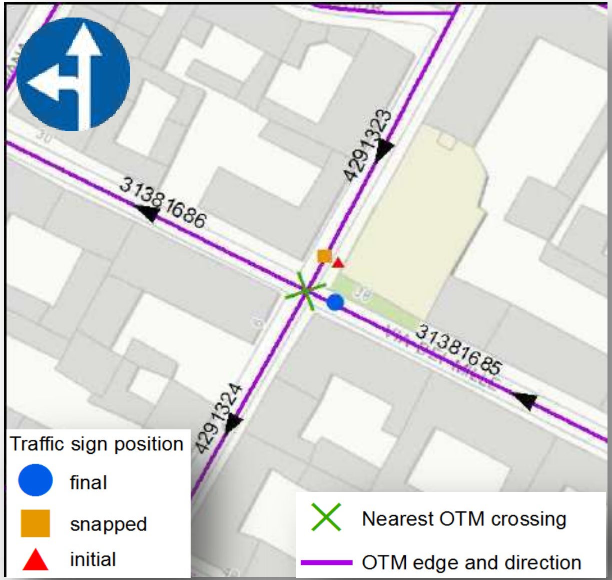
Operational exploitation

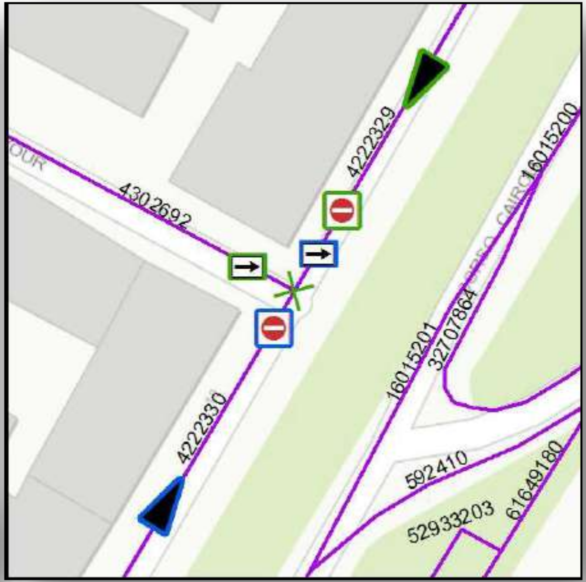
Issue	Countermeasure
Duplication of traffic sign features	Use track direction



Operational exploitation

Issue	Proposed solution
Duplication of traffic sign features	Use track direction
Positional accuracy	Postprocessing based on existing road networks





Operational exploitation

Issue	Proposed solution
Duplication of traffic sign features	Use track direction
Positional accuracy	Postprocessing based on existing road networks
National and local traffic signs	Increase the coverage of different country-specific traffic sign sets in the recognition process

Impact on maintenance and authorization

Incorrect interpretation

Operational exploitation

Issue	Proposed solution
Duplication of traffic sign features	Use track direction
Positional accuracy	Postprocessing based on existing road networks
National and local traffic signs	Increase the coverage of different country-specific traffic sign sets in the recognition process

Recognition even with unfavourable geometry acquisition settings

Low sensitivity

Conclusions

Mapillary traffic sign recognition process is an interesting and unique dataset that can be further improved by:

- taking **track directions** of the processed frames into consideration
- benchmarking error margins of the output data using a **variety of devices** compared against data with known accuracy standards
- increase the **quality of input data** (e.g. dual frequency GPS, better image sensors in sub-optimal conditions, training/education on the best set-up/operational procedures)

DSM AND DTM FOR EXTRACTING 3D BUILDING MODELS: ADVANTAGES AND LIMITATIONS

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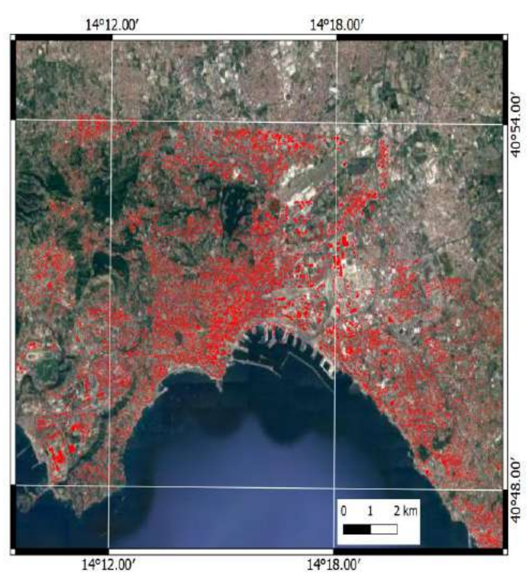
SUMMARY

Using multiple sources of 3D information over buildings to go from building footprints (LOD0) to higher LODs in CityGML models is a widely investigated topic. In this investigation we propose to use a very common 2.5D product, i.e. digital terrain and surface models (DTMs and DSMs), to test how much they can contribute to improve a CityGML model. The minimal information required to represents a 3 dimensional space in an urban environment is the combination of a DTM, the footprints of buildings and their heights; in this way a representation of urban environment to define LOD1 CityGML is guaranteed. In this paper we discuss the following research questions: can DTMs and DSMs provide significant information for modelling buildings at higher LODs? What characteristics can be extracted depending on the ground sampling distance (GSD) of the DTM/DSM? Results show that the used DTM/DSM at 1 m GSD provides potential significant information for higher LODs and that the conversion of the unstructured point cloud to a regular grid helps in defining single buildings using connected component analysis. Regularization of the original point cloud does loose accuracy of the source information due to smoothing or interpolation, but has the advantage of providing a predictable distance between points, thus allowing to join points belonging to the same building and provide initial primitives for further modelling.

STUDY AREA

The metropolitan city of Naples with a population of over three million people is the third metropolitan Italian city by number of inhabitants, while it is first in population density. The entire metropolitan area covers an area of 1,171 km² and includes 92 municipalities.

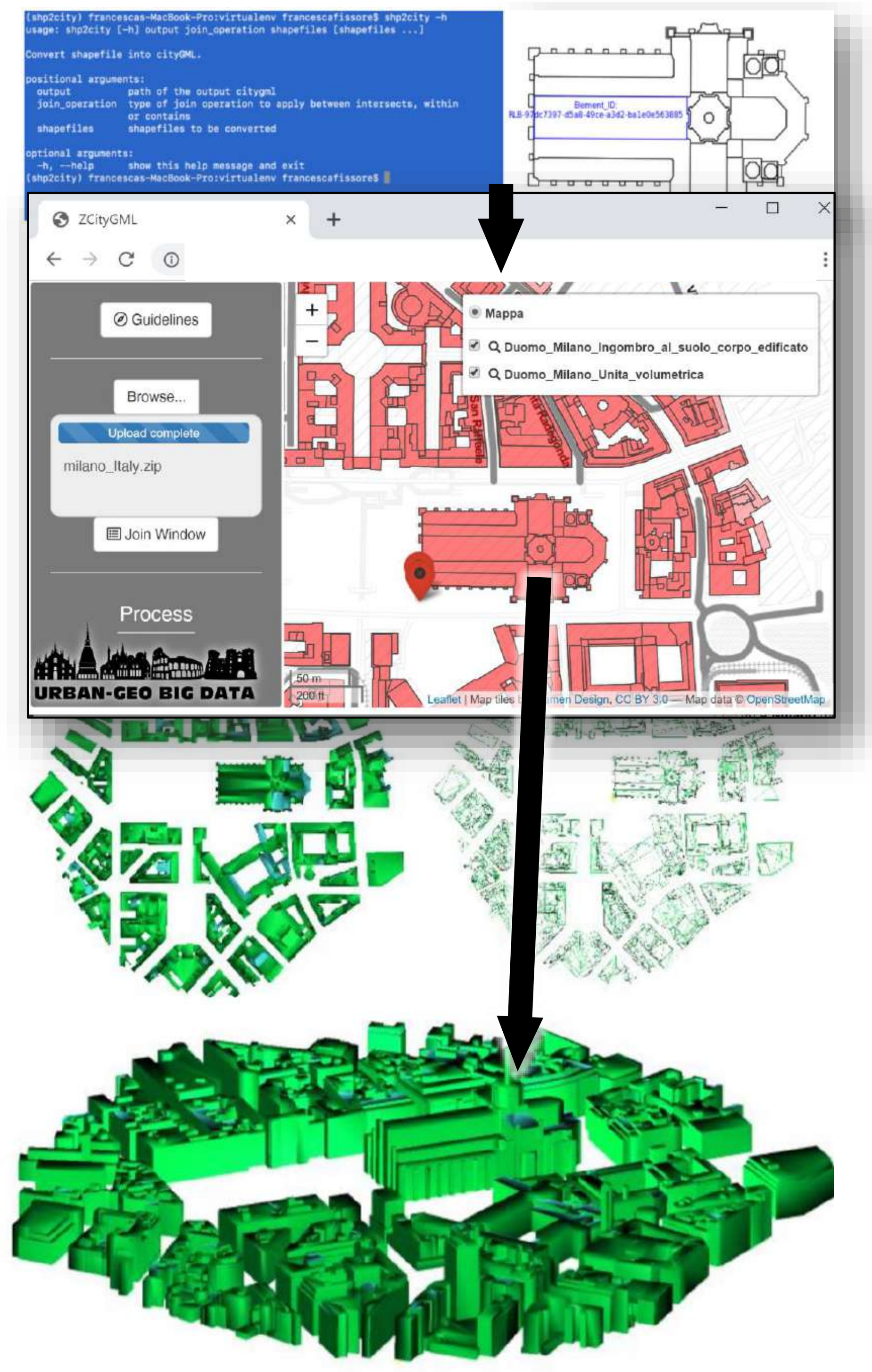


RESULTS

A total of ~11 million points, i.e. cell centers, overlap building footprints. Residuals between from lidar-derived raster height models and heights of buildings from cartographic shapefiles attributes are shown in Figure 4 below. It was calculated by finding the lowest roof-point in each polygon representing the building footprint, and subtracting it from the building absolute height at heave, derived from adding building height at heave to Z value of polygon to get height above sea level. LiDAR heights are referred to geoid height above mean sea level. Results show differences in all buildings analysed (15000 buildings). Distribution of residuals between cartographic building heights and LiDAR-derived heights have an average of -1.3 m and a standard deviation of 4.15 m. This result is in line with accuracy that is expected from the 1:10000 scale, considering higher residuals due to errors defining the lidar point in the roof that represents heave heights.

THE PROJECT

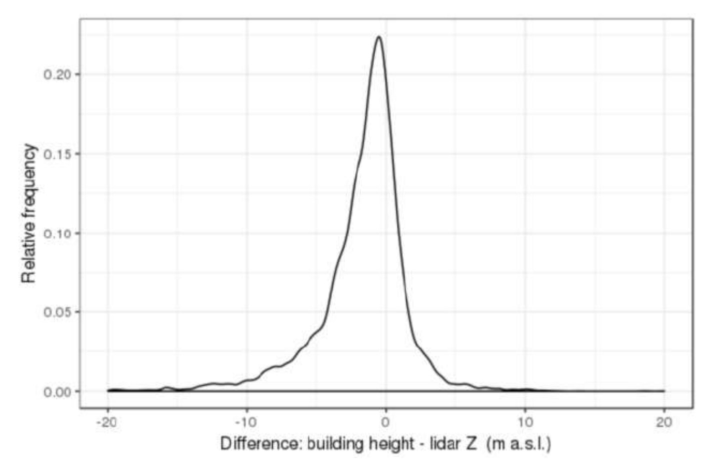
Within the Urban-Geo Big Data project (Brovelli et al., 2017) an Italian project of national interest (PRIN 2015), a large amount of cartographic data related to some of the main Italian cities was collected. Amongst the targets of the project, there is a need to identify standards for the extract transform and load (ETL) process of conversion from cartographic vector models to 3D CityGML models.



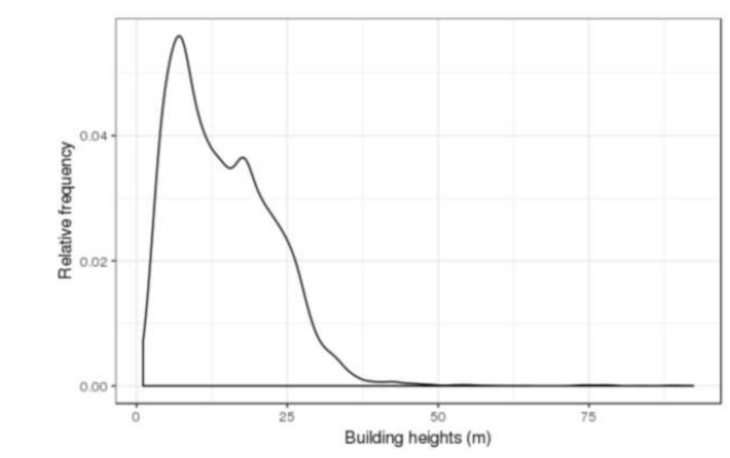
METHODS

The LiDAR data are converted to a regularly spaced point cloud representing the center of a 1 m x 1 m cell. Each building roof will therefore have a number of height values depending on the area of the roof.

Intersecting each point grid with the polygons described in the cartographic dataset, that represent the footprint of buildings, we obtain both a distribution of height values at heaves for each building - using the lowest points inside the polygon – and the distribution of heights that represent the roof shape. These values can be used to (i) obtain values of building elevation in the cartographic dataset (ii) carry out statistical surveys aimed at estimating the type of roof (main objective of this work), and (iii) analyse residuals and discuss applicability of assigning building height from lidar-derived raster height models.



Frequency of building heights as recorded in cartographic sources



Residuals frequency distribution calculated by adding building height to ground height above sea level and subtracting lidar height

CONCLUSIONS

The work described shows that significant information is present in commonly used LiDAR-derived products, i.e. dense DTMs and DSMs. Conversion of the unstructured point cloud to a regularly spaced grid helps in providing space-related information to support removing isolated parts that do not belong to roofs. The point sets have an id related to the building footprint thanks to spatial intersection and are thus available for further modelling of roofs to CityGML schema, and support LOD2 object creation. This last step is not the focus of this work, but several investigations are available in literature. Added value of LiDAR surveys over urban areas is a known fact, and this work further supports the idea that dense DTM/DSMs can be very important for urban city modelling.

ACKNOWLEDGMENTS AND REFERENCES

This research is supported by the Italian Ministry of Education through the project of national interest (PRIN) Urban-Geo Big Data (project code: 20159CNLW8 - PE10).

Brovelli, M., Boccardo, P., Crespi, M., Lanari, R., Pirotti, F., 2017. URBAN GEO-BIG DATA - URBAN GEOmatics for Bulk Information Generation, DAta assessment and Technology Awarness http://www.urbangeobigdata.it/