URBAN-GEO BIG DATA

POLITECNICO MILANO 1863

Services and innovation for mobility

PRIN PROJECT: *URBAN GEOmatics for Bulk Information Generation, Data Assessment and Technology Awareness*

MIUR

MINISTERO DELL'ISTRUZIONE DELL'UNIVERSITÀ E DELLA RICERCA

ITS Definition

Intelligent Transport Systems (ITS) are the control and information systems that use integrated communications and data processing technologies for the purposes of:

- **improving the mobility** of people and goods
- **increasing safety, reducing traffic congestion and managing incidents effectively**
- **meeting transport policy goals and objectives** – such as demand management or public transport priority measures

The definition covers a broad array of techniques and approaches that may be achieved through stand-alone technological applications or through **integration of different systems** to provide new (or enhancements to) existing transport services. ITS provides the tools to transform mobility and improve safety – and is particularly relevant in the context of road network operations.

ITS Function

ITS aims to serve the user of the transport system by providing– for the individual – more reliability and comfort for individual mobility and – for the operator of the transport system – more effective operations and decision making. The overall function of ITS is to **improve the operation of the entire transport system** (often in real-time) for transport network controllers, travellers, shippers and other users.

ITS deployment is influenced by commercial interests and policy initiatives at the international, national, regional and local level – which impact on the business practices of stakeholders in the public or private sector.

ITS provides a **flexible approach** to addressing common transport problems – one that emphasises the **use of information, optimal decision-making and a high level of system adaptability**. This compares with the more traditional approach of building additional road infrastructure and adding physical capacity. ITS offers alternatives to meeting future travel demand in situations where conventional approaches may not work – for example in heavily built-up locations or in areas subject to stringent environmental regulations.

More specifically, ITS includes a variety of tools, such as **sensing, communications, and computing technologies** – which can be applied in an integrated way to the transport system to improve its efficiency, safety, sustainability and the resilience of network operations in the events of serious disruption.

ITS and network operations

Many ITS applications have a role to play in effective road network operations – the aims of which include:

- **making best use of the capacity** available on the road network
- ensuring that the road network operates in the **most efficient, safe, and sustainable way possible**

In general, ITS applications that are designed to improve the efficiency, safety and/or sustainability of road networks are the applications most frequently adopted. Examples include:

- systems for managing traffic and travel demand – such as traffic control, incident management, electronic payment, travel demand management, parking management and control
- traveller information systems applications that allow road users to make informed decisions on their travel choices – such as driver information and route guidance

The concept of connected autonomous vehicles is becoming feasible and gaining support which will have major implications for road network operations – which will need full evaluation

ITS benefits

All road users, including drivers and their passengers, pedestrians and cyclists – across all modes of road transport, including **private cars, buses, coaches and commercial vehicles** – can benefit from greater use of ITS.
For example, ITS applications support:

- commercial vehicle operations of commercial operators, regulatory and tax agencies and road users – providing benefits such as electronic administrative processes and automated roadside safety inspections
- public transport from the perspective of both operators and travellers – providing benefits such as improved observance of time-tables, optimised operations, improved security on-board vehicles and at terminals – and a higher standard of service by providing real-time schedule information to travellers

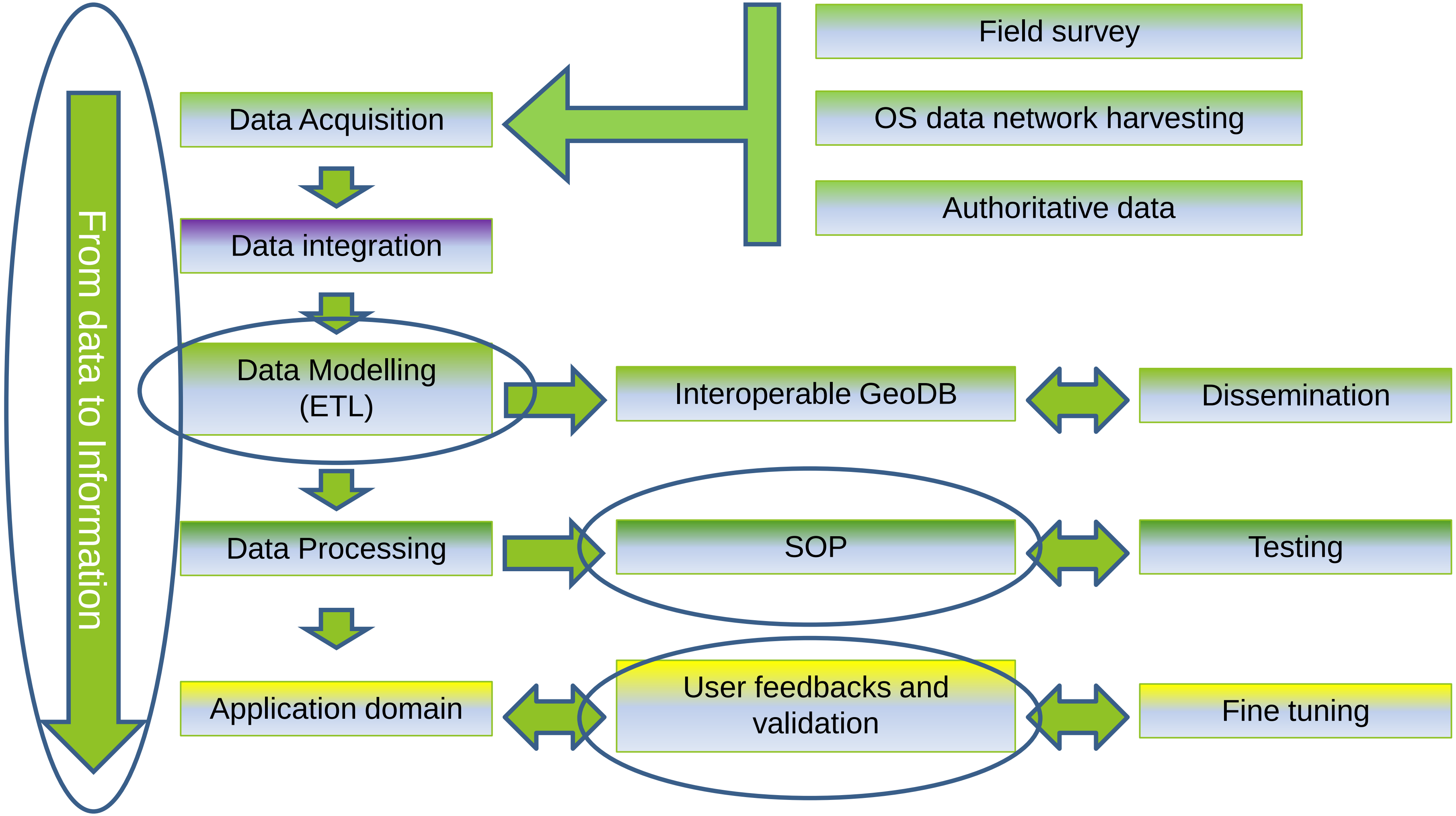
ITS services

A decade or so ago the means for disseminating information to travellers were rather limited (such as Dynamic Variable Message Signs, Highway Advisory Radio, Television, and phone systems). Today, with the almost universal market penetration of smart phones and other mobile devices, it is much easier to reach travellers with the correct information.

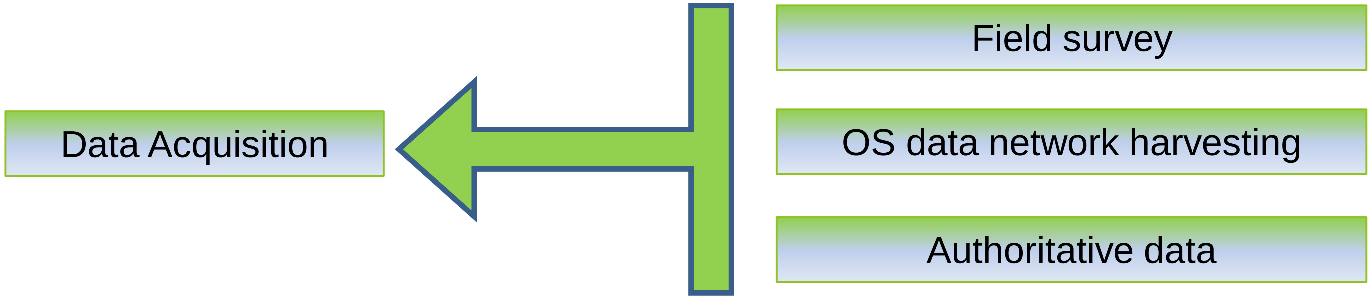
Recent years have witnessed a renewed and increased interest in the topic of connected and autonomous (self-driving) vehicles – which can be regarded as the latest phase in the evolution of ITS. Third and fourth generation digital mobile telecommunications have enabled higher levels of connectivity between vehicles and the infrastructure, coupled with greater automation within vehicles. This may radically change the way that motor vehicles are driven and the way that road traffic is managed.

A different Geomatics paradigm (classification flowchart)

In order to fully implement our project, the main effort should be devoted to the application of a different approach described below:

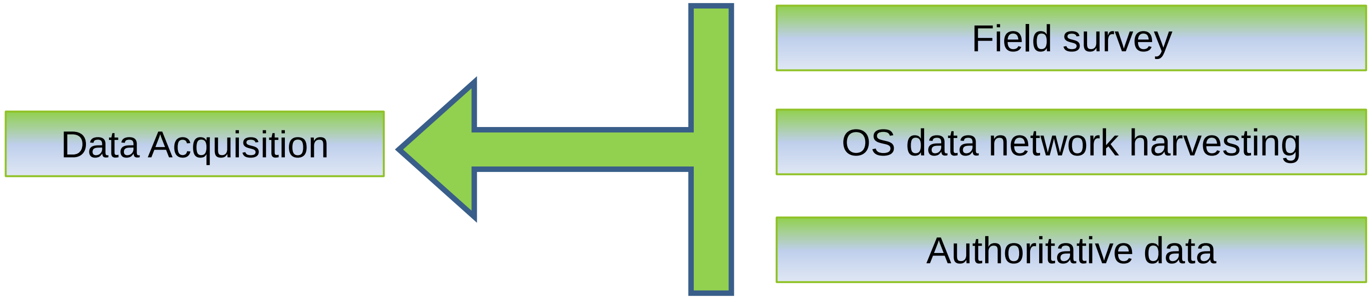


The classification flowchart: analysis of the different components



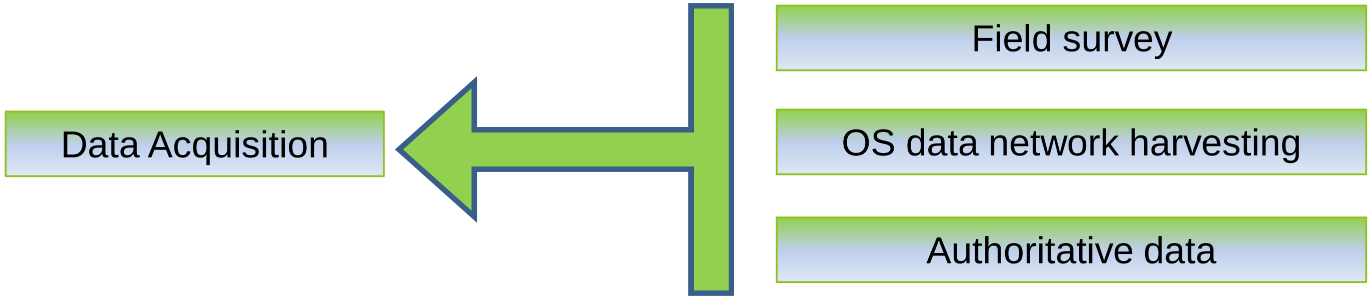
A prerequisite for many ITS services is the collection of timely, accurate and reliable information about traffic flow and road conditions. Traffic data falls into three classes: point traffic stream data (e.g. average speed); individual vehicle data (e.g. vehicle type); and link traffic data (e.g. average travel time).

For many years, traffic surveillance has been achieved by **inductive loop detectors,** which can sense the presence of a vehicle. A single loop buried under the lane pavement can perform vehicle counting. Double loops in the same lane separated by a fixed distance can measure vehicle speed. As vehicle speed slows below a certain threshold, loop detectors can indicate traffic congestion. Other types of traffic sensors, e.g. **ultrasonic, radar, and infrared traffic sensors**, are installed on overhead gantries, making their installation and maintenance less disturbing to traffic flow than loop detectors. However, these sensors may not be as reliable as inductive loops in bad weather conditions. In addition, like loop detectors, these sensors work only as single-zone traffic detectors.



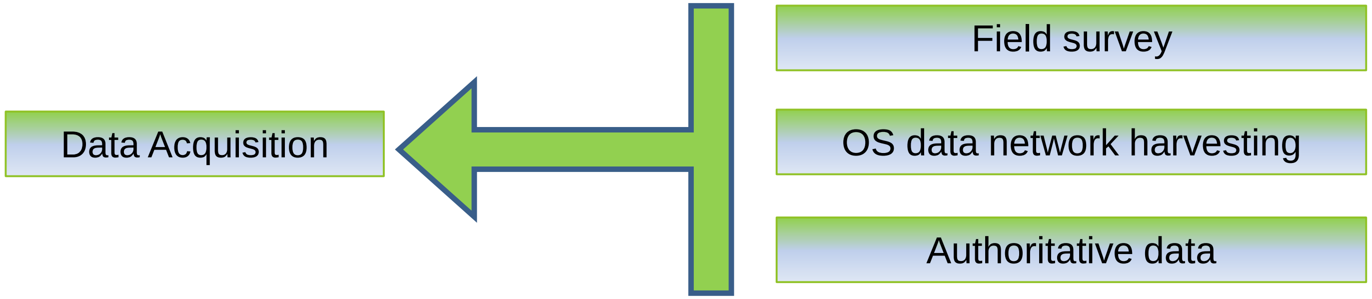
While traffic sensors can provide many attributes of traffic flow, directly or indirectly, there is nothing better than **live video images** to help the traffic centre operator monitor complicated traffic situations and make appropriate decisions. Visual images from closed circuit television (CCTV) are therefore obtained by the traffic management centre to complement the traffic detectors. Even with a combination of traffic detectors and video traffic surveillance, additional inputs from police patrols, helicopter reporters, road maintenance departments, the meteorological office, taxi fleets and increasingly cell phone call-ins from drivers on the road, are used for traffic information and management. For example, additional inputs can come from sensors measuring the freezing point of the road surface, enabling network managers to calculate the required amount of de-icing chemicals, and resulting in road safety improvement as well as substantial cost savings.

Through image processing are one of the more recent technologies to be applied to traffic detection. Images acquired by video cameras in VID are processed to obtain vehicle presence, speed, lane occupancy, lane flow rate, etc. Multiple detection zones can be defined within the field of view of the video camera, thus providing multiple lane coverage by a single camera. Multiple cameras can be connected to one processor unit providing wide area coverage and, coupled with computer software, can reduce the problems caused by shadows, occlusion, and direct sunlight shining on the cameras. This domain of application should be further investigated in the framework of actual legislation.

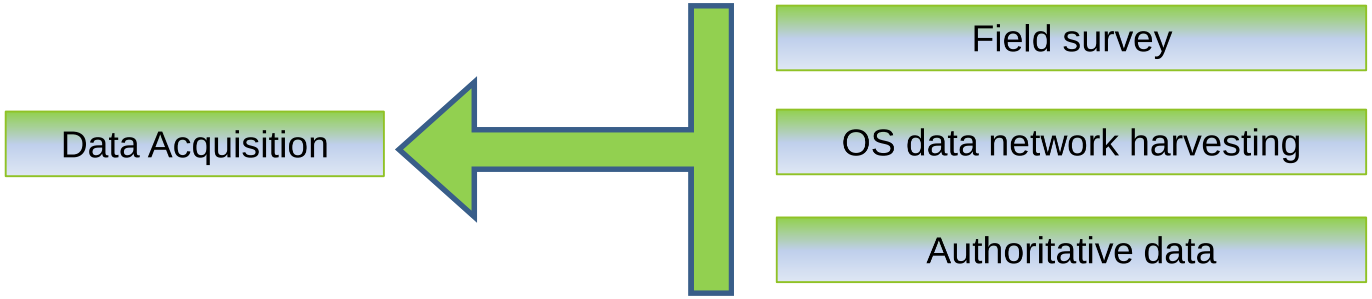


On the vehicle side, data regarding vehicle conditions such as speed, fuel level, oil pressure, engine temperature, etc. are familiar to all drivers. Acquisition of these data through **in-vehicle sensors** is important for vehicle operation and maintenance. From the perspective of road maintenance, surveillance of vehicle weight is also important. It is estimated that one overloaded truck axle causes more road damage than half a million cars. In recent years, surveillance of commercial vehicle weights through weigh-in-motion (WIM), an ITS technology based on load cell, bending plate, piezoelectric or similar principles designed to catch over-weighted trucks without requiring all trucks to stop, has produced substantial time saving benefits to both truck drivers and road authorities in many countries.

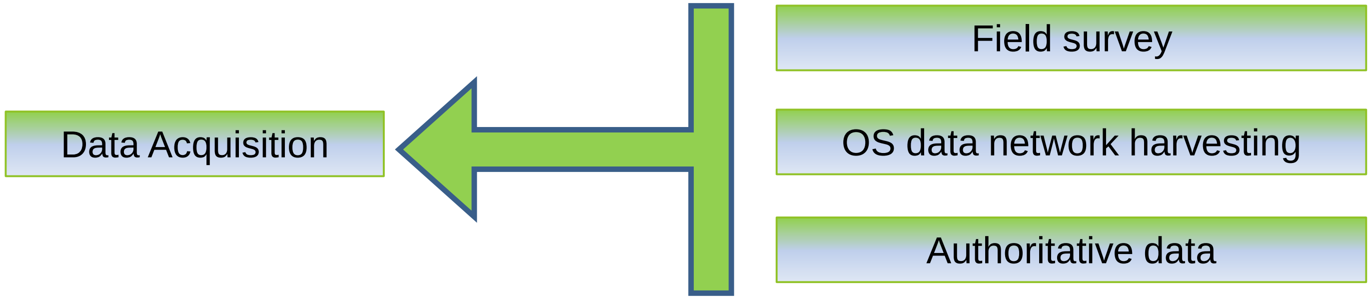
Measurement of vehicle dimensions by ITS technologies is also needed for some functions in traffic management. For example, over-height detectors (based on the cutting beam principle) can warn the drivers as they approach a tunnel. Bus detection can also be achieved by the use of vehicle length detectors or **automatic vehicle classification (AVC)** techniques. The combination of automatic vehicle identification and classification is needed for **electronic toll collection**.



In ITS, information about vehicle location is important for both the individual driver who wants to know where he or she is in order to navigate or to obtain location-relevant information, and for the fleet operator who wants to track vehicles for fleet management purposes. Vehicle location is invaluable for public agencies to locate a vehicle in trouble for rescue purposes, or to find stolen vehicles or vehicles transporting hazardous materials. Moreover, when the locations of a moving vehicle are known on a link at two different times, the travel time on the link (or link time) can be measured directly. A vehicle used for this purpose is known as a “probe vehicle” or a “floating vehicle,” and the corresponding technology, “vehicle probes,” is described below. In addition, tyre slippage on an icy road and moisture on the windshield can also be detected and reported by the vehicle along with its location to the traffic centre. In this case, the vehicle serves as a “probe” for both traffic and road/weather conditions. In South Korea, a national automatic vehicle number identification system is used by the police for traffic law enforcement and vehicle crime prevention. Automatic Vehicle Identification involves equipment installed on the infrastructure. Vehicle probes based on AVI requires installation of appropriate equipment on the infrastructure (either roadside beacons where passing vehicles are equipped with a tag or transponder that can be recognised or camera-based licence plate readers which rely on image processing techniques). The same function may be performed by cooperative probe vehicles providing travel time directly to the traffic centre through wireless communications. The concept of vehicle probe technology can also be applied without equipment on the road side, and thus applicable anywhere in the world, by using Automatic Vehicle Location (AVL) based on global navigation satellite systems (GNSS).

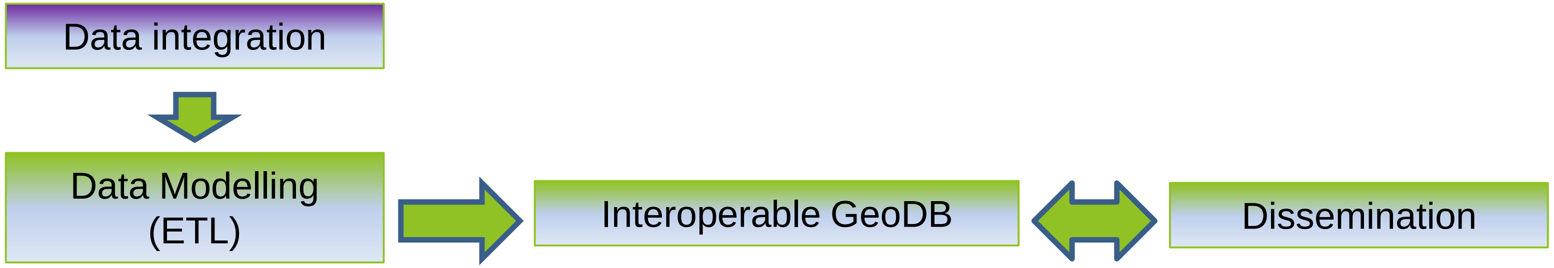


In addition to the data from traffic and vehicles, a considerable investment is needed in data concerning the transport networks themselves. The basis for ITS in many cases are detailed and reliable databases of network links, inter-connections and other features, supported by a location referencing system. Capturing data on transport networks is very labour-intensive, involving detailed reference to maps and plans, aerial photographs, and on-site surveys. Videoing the network from a moving vehicle is often used to reduce the amount of time spent on the ground. Viewing these video images is an effective form of desk-based data capture. The images can be studied frame-by-frame if detail is required, whereas the fast forward control allows unimportant sections to be skipped. At the time of data capture careful attention must be given to the way the database will be used, since at some future occasion someone will have to interpret the data. Numerical codes, grid references, and latitude and longitude coordinates do not convey any meaning in themselves. Network features need to be described in terms which the user will easily comprehend, including local place names, landmarks, and other descriptions.



With the advent of hand-held **GNSS receivers and vehicles equipped with AVL** the business of accurately locating network features like intersections, freeway merge and diverge points, bridges, tunnels, access points to properties, transit stops, etc. has become much easier. Without an inventory of stop locations, for example, it is not possible to offer point-to-point journey planning for public transport. Similarly for road information, reliable coding of the network is needed for emergency response, incident reporting and other location based services. **The degree of precision in location referencing is especially important**. Nothing is worse than having mis-located a feature in the event of an emergency, for example an error which puts the vehicle on the wrong carriageway.

Vehicle probes are becoming more important, because public agencies realise the comparatively **higher costs of conventional traffic sensors** on the road infrastructure for widespread ITS applications. A good example is the **floating vehicle data (FVD)** system used by 5T to extend the TOC to the whole Regional area.



In order to fully take advantage of input data (authoritative, OS and crowdsourced), the most important task is to **implement a proper data integration strategy** that should deliver a **proper data model**, implemented in a **geodatabase** considered as the primary source of **data to be disseminated**.

Different data integrity analysis, data models to possibly adopt and interoperable geoDB, will be further described in second part of the presentation.

Data Processing → SOP ↔ Testing

Traffic information can be obtained in many ways and from many sources at the same time. Thus, at the traffic or transportation management centre, there is a need to process the data, verify their accuracy, reconcile conflicting information, put them into compatible formats, and combine them with data from other agencies (e.g. transit management centre, highway maintenance organisation, police department, etc.) This process is known as data fusion. One of the important data processing applications is to provide the user service of current traffic information and/or predictive travel times (PTT). This involves the fusion of travel information from relevant sources, both public and private; for predictive information, data fusion would also include time variability depending on time of departure, roadworks, weather, events, incident reports, etc. Additional factors taken into account in PTT could include vehicle types (car, bus, truck), driver types (neutral, passive, aggressive) as well as specific time (current, or any time within the next 48 hours). A variety of approaches to PTT can be found in the literature, ranging from the use of analytical algorithms, artificial neural network, to traffic simulation, or a selective combination of these methods.

The predicted travel time may be displayed not only on Dynamic Message Signs (DMS), but also through the media, In-Vehicle Units (IVU), or handheld devices. Access to PTT through the latter would help travellers make decisions on departure time and/or mode choice (between driving and public transit) in pretrip planning.

Data Processing → SOP ↔ Testing

Automatic incident detection (AID) is another important data processing technology on the infrastructure side. This is accomplished through computer processing, based on sophisticated algorithms applied to traffic data obtained from a variety of detectors, sub-surface and above-ground detectors. To determine whether an incident has occurred, the input data from the detection system are tested against an algorithm. The algorithms that have been developed include a number of methodologies such as comparative, statistical forecasting of traffic behaviour, and others, where loop occupancy for more than a set interval indicate stationary or slowmoving vehicles. In general, AID technology is not designed to replace the traffic centre operator but to alert him or her of traffic patterns resembling those in an incident. Human confirmation through CCTV or site visits is still needed. The use of portable AID and CCTV equipment around highway work zones and other temporary high risk locations is especially valuable.

Data Processing → SOP ↔ Testing

On the vehicle side, data processing is needed for navigation. The basic technology for determining vehicle location is the same as that for determining ship or aeroplane locations. Since all satellite navigation systems require the observation of at least four satellites to function, vehicle location needs complementary systems that still work while the vehicle is in a tunnel, under trees, or in an “urban canyon” surrounded by tall buildings. Coverage can be bridged with map matching, the basic component of popular in-vehicle navigation systems. These take advantage of the fact that vehicle location is usually restricted to the road network except during temporary deviations when the vehicle is in a parking lot or on a ferry. As the name implies, map matching uses a highly accurate digital map on the vehicle and heuristic algorithms to deduce where the vehicle is located on the map. Another approach to navigation is dead reckoning, which uses a gyroscope or related inertial guidance principles to deduce vehicle location in reference to a known starting point. However, dead reckoning cannot function alone since the cumulative error needs to be corrected from time to time, preferably automatically.

Nevertheless, GPS correction should be taken into account when referring to services where submetric precision is needed (traffic restriction areas, parking, etc.)

Application domain ⟷ User feedbacks and validation ⟷ Fine tuning

The principal applications of ITS – that contribute to road network operations are:

- **traffic and road network management**
- **traveller information systems**
- **public transport systems**
- **commercial vehicle applications**
- **vehicle safety applications**
- **maintenance and construction management applications**
- **emergency management**
- **archived data management**

A real case experience

	Regional Authorities	Cities	Service providers
Traffic	Regional Traffic Operations Centre	Urban and Metropolitan Mobility and Infomobility Operations Centre	Signal priority for public transport
Public transport	Regional Traffic Information Centre		Trip planner and real-time information
Infomobility	Regional Ticketing System		Tools for PT planning and management
Ticketing			Ticketing system

Traffic and road management

A common feature of ITS – when applied to traffic and road network management – is the **use of real-time, conventional and historic data sources to produce information on the existing and future status of the road transport system.**

ITS applications play an important part in the way road networks are managed to improve the efficiency and reliability of transport operations and reduce negative environmental and energy consumption impacts.

Traffic and road **management**

Coordinated traffic control within a large urban or regional area is handled by the traffic management centre, where traffic information is usually projected on a large display panel, supplemented by multiple CCTV screens that can be switched to any camera in the field. Colour code can be used on the traffic display panel to indicate the degree of congestion or occurrence of incidents. The operators watch all the information and can operate dynamic message signs (DMS), traffic lights, etc. through graphical user interfaces. In these interfaces, the road network, control elements (such as DMS), detectors, etc. are displayed on two-dimensional maps with several zoom levels. Operators also maintain voice communications with traffic patrols and operators in other centres, which is particularly important during emergency situations as timely, accurate, and interactive information acquisition is required for coordinated rescue operations.

While information technologies in ITS help the driver today to make strategic decisions through traffic information, navigation and route guidance on a minute-by-minute basis, control and sensor fusion technologies may in the future allow some degree of longitudinal and lateral vehicle control assistance to the driver. The most common sensors now being used for longitudinal control are radar and laser devices that provide relative vehicle spacing by measuring the distance from the vehicle ahead, gapclosing rate between vehicles, and by detecting obstacles on the roadway. Sonic and ultrasonic sensors are also used for blind spot and back-up warning. Recent progress in both hardware and software has been achieved to implement adaptive cruise control (ACC).

These systems automatically reduce vehicle speed, which has been set by the driver through cruise control, to keep a safe headway from the vehicle ahead and to resume the set speed when the headway is sufficiently long.

Traffic

Taking into account the Traffic Operation Centre in Torino metropolitan area:

- **330** (out of 600) controlled intersections to regulate the cycle time of a traffic light
- over **1,500** inductive loops for real-time traffic flow measurement
- **36** above-ground sensors
- **71** cameras on 23 intersections
- Integration of FCD (Floating Car Data)

ITS Enabling Technologies	Infrastructure Side	Vehicle Side
Location Referencing	Digital maps Geographical Information Systems Transport network databases	Mobile phone location Global Navigation Satellite Systems Automatic Vehicle Location
Data Acquisition	Traffic detectors Weather monitoring Automatic Incident Detection	Automatic Vehicle Identification Vehicle probes
Data Processing	Data dictionaries Data fusion Data exchange	On-board computers Digital map matching
Communications	Fixed microwave links Optical fibre networks Beacons (DSRC) Cellphone networks	DAB receiver Cellphone receivers Highway Advisory Radio, RDS-TMC Transponders
Information Distribution	Dynamic Message Signs Internet Kiosks	Handsets and Personal Digital Assistants In-vehicle units
Information Utilisation	Incident detection Demand management Congestion monitoring	Route guidance Advanced Driver Assistance Systems

Enforcement systems

Management of enforcement systems in order to manage mobility demand and increase road safety:

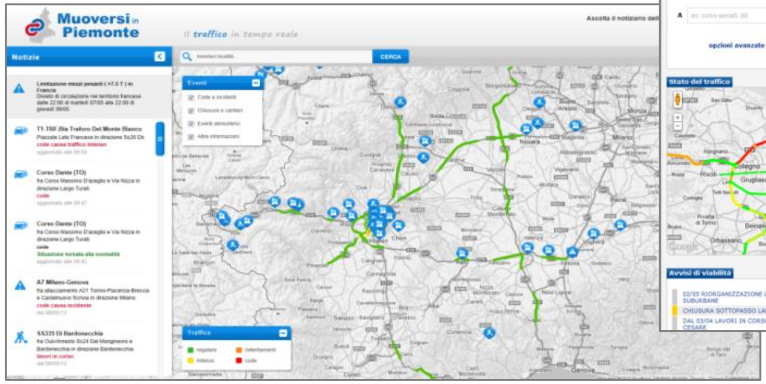
- **2 speed control systems** (in 2 main urban roads)
- **Limited Access Area** (in the city centre: 2,5 sq. km): **36 electronic gates** and **36 information panels** providing access information
- **ZTL**: 15,000 transits per day including 4% non-authorised transits

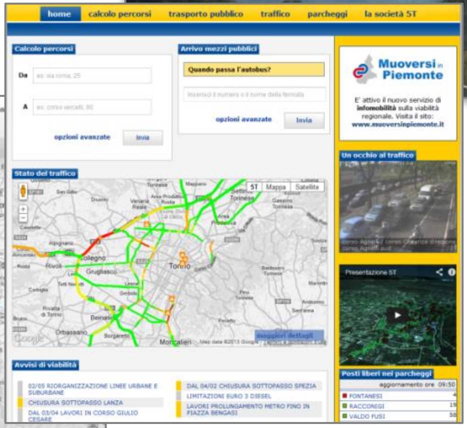
ITS Enabling Technologies	Infrastructure Side	Vehicle Side
Location Referencing	Digital maps Geographical Information Systems Transport network databases	Mobile phone location Global Navigation Satellite Systems Automatic Vehicle Location
Data Acquisition	**VIDEO CAMERAS**	Automati ehicle Ide fication Vehic s
Data Processing	**OCR AND DEEP LEARNING**	On-boar Digital ma
Communications	Fixed microwave links Optical fibre networks Beacons (DSRC) Cellphone networks	DAB receive Cellphone Highway RDS-TMC Transp
Information Distribution	Dynamic Message Signs Internet Kiosks	Handsets d Person Digital Assistants In-vehicle units
Information Utilisation	**ACCESSIBILITY**	Route guidance Advanced Driver Assistance Systems

Road traffic information

Management of road traffic information services in real-time:

- 26 above-road VMS
- 20 parking info VMS for 26 parking lot structures
- 18 extra-urban displays
- 36 limited traffic area displays
- www.5t.torino.it for real-time information in the metropolitan area
- www.muoversinpiemonte.it for real-time information in the Piemonte region





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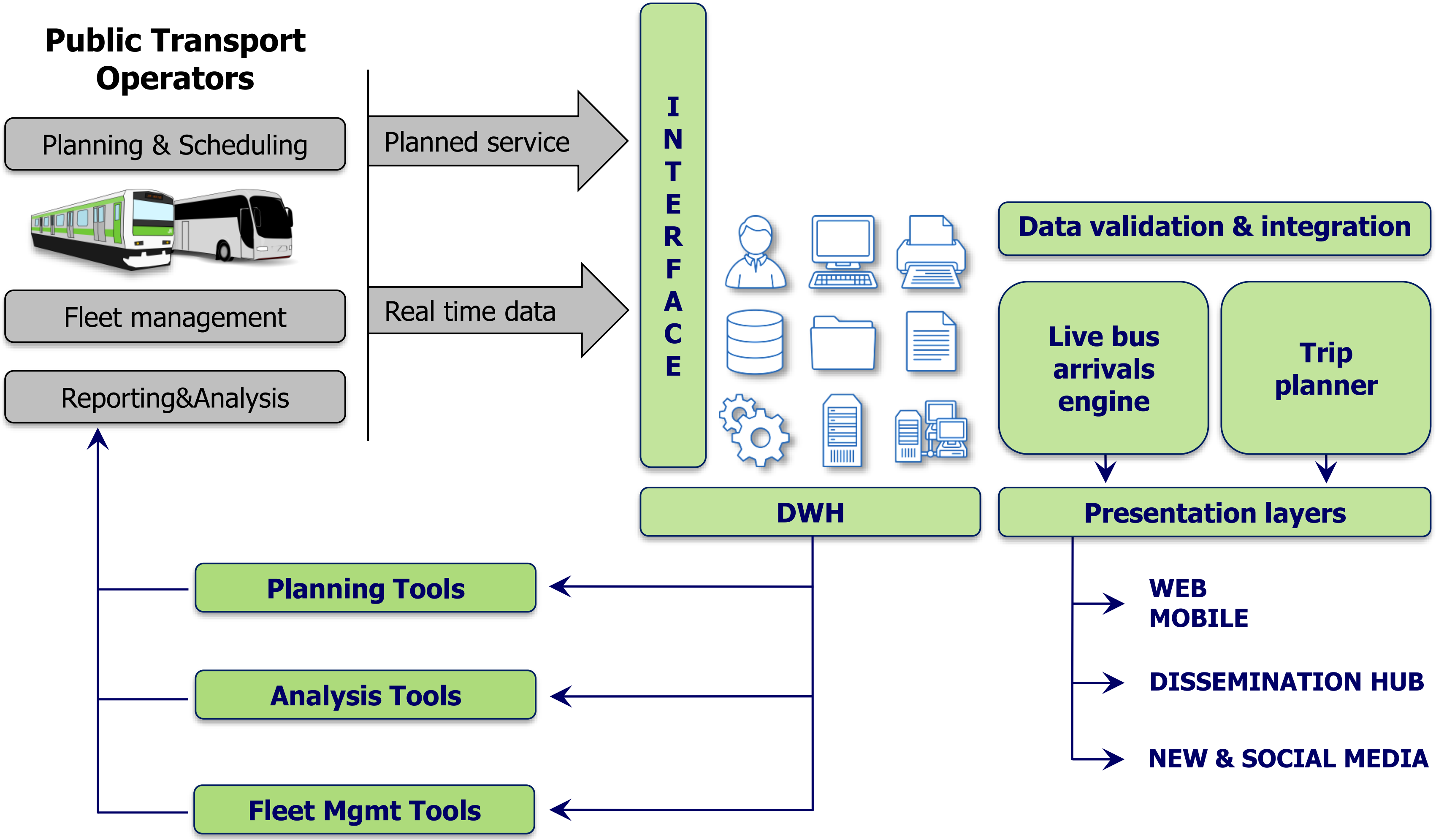
Information Utilisation	**BY PORTALS AND/OR APPS**	Route guidance Advanced Driver Assistance Systems

Public Transport

We provide support tools and travellers information services for Public Transport operators



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The Regional Mobility Centre

Implementation and operations related to the Regional Mobility Centre of Piemonte Region and all the related systems and services

Area: 25,387.07 km²
Inhabitants: 4,406,860

1 - Traffic Operation Centre

Managing of the Traffic Operation Centre (TOC), one of the most advanced in Europe in terms of geographical extent and exhaustiveness: Regional Supervisor, network of sensors, floating car data, dangerous goods

2 - Ticketing Management Centre

The BIP is the best expression of electronic ticketing system in Italy. Implementation and managing of the Regional Service Centre and is the technology manager of the BIP project

3 - Infomobility Centre

Implementation and managing of traffic monitoring and information services about traffic conditions in the region and public transport (www.muoversinpiemonte.it)

ITS Enabling Technologies	Infrastructure Side	Vehicle Side
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Data Acquisition	Traffic detectors Weather monitoring + FDV Automatic Incident Detection	Automatic Vehicle Identification Vehicle probes
Data Processing	Data dictionaries Data fusion Data exchange	On-board computers Digital map matching
Communications	Fixed microwave links Optical fibre networks Beacons (DSRC) Cellphone networks	DAB receiver Cellphone receivers Highway Advisory Radio, RDS-TMC Transponders
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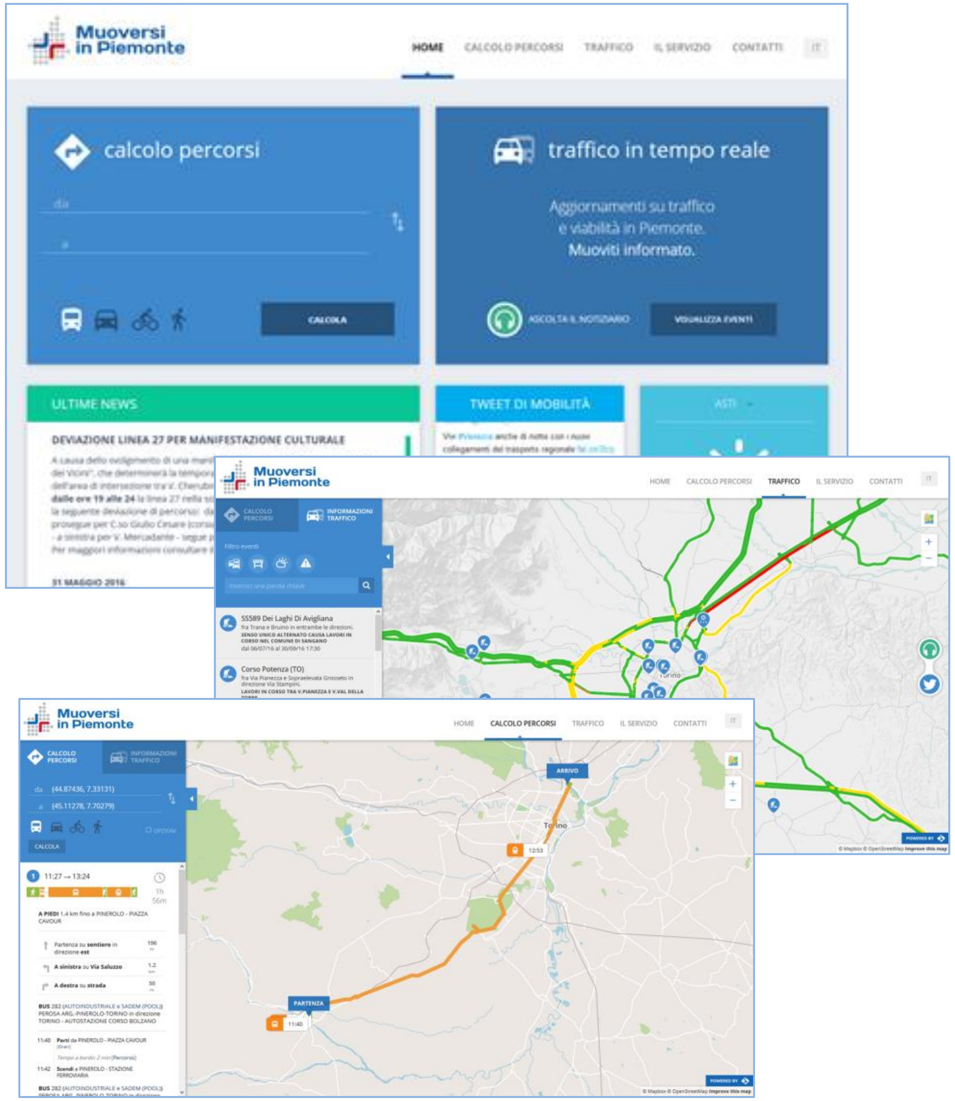
Regional infomobility service

One-stop-shop infomobility service ***Muoversi in Piemonte*** with traffic and public transport information delivered through multiple channels:

- Web www.muoversinpiemonte.it
- Journey planner
- Radio bulletins
- Twitter @MIPiemonte



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Ticketing - the BIP project

BIP - (Piemonte Integrated Ticket):

- 100 public transport companies
- 3,400 buses
- 15,000 bus stops
- 300 railway stations

BIP Card integration with:

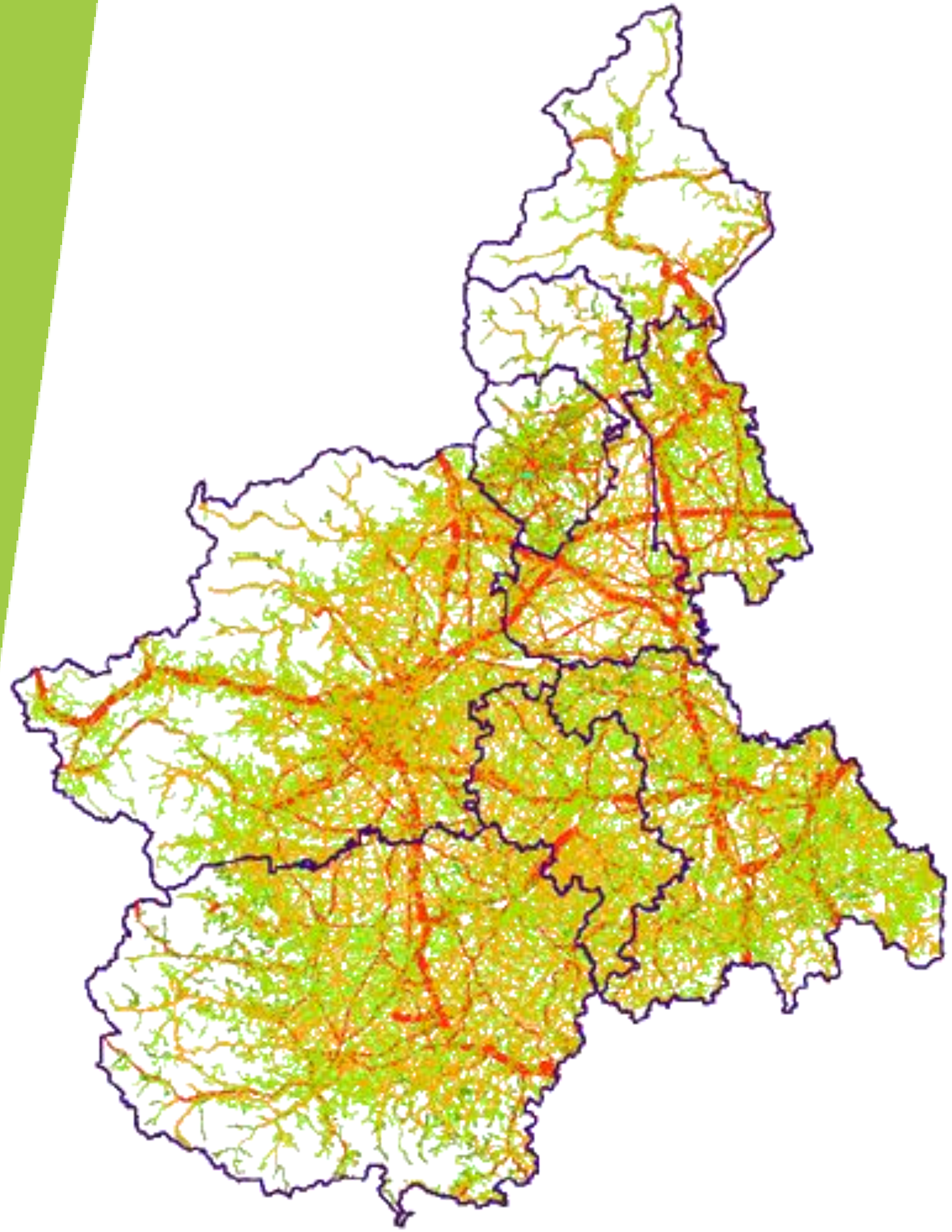
- Pyou Card
- University smartcards
- bike-sharing and car-sharing
- Regional museum card

1 smart-card, 1 million potential users

With decreasing costs and increasing power of technology, new options for EPS have emerged based on time and location. As mentioned previously about vehicle probes, the precise location of a vehicle may be determined automatically by GNSS (global positioning system), cell phones, or vehicle licence plate readers. The fees to be collected from a vehicle (and theoretically an individual) may be determined if the time and location of the vehicle or individual can be monitored accurately. Combined with weigh-in-motion (WIM) technologies, the collection of distance-related heavy vehicle fees, or some form of weight-distance charges, can be automated. Several ETC systems have seriously considered the GNSS-based location technology. The European Commission proposed in late 2003 the creation of an interoperable pan- European ETC system using GNSS (Galileo) and GSM telephony. The London congestion charging scheme, which has been implemented successfully, uses the vehicle licence plate reader approach. Much discussion has taken place about p-commerce (p for position) as well as m-commerce (m for mobile) suggesting new marketing opportunities for merchants advertising and selling to vehicle occupants travelling in their vicinity. Examples of location based consumer services include automatic tracking, road assistance, concierge services (e.g. information about nearby restaurants and service stations), weather and traffic information, personalised messaging, city guide, collision notification, etc.

Available datasets for mobility applications

Authoritative data - NGV Piemonte



UNIQUE road network for public administration

From 1:10000 to 1:5000/1:2000 scale (integration of data from local administration)

Compliant with **GDF** standard

<u>2 Level of Detail</u>

	GDF1 [1:2000]	GDF2 [1:5000]
Links	450’000	210’000
Nodes	380’000	170’000

<u>Availability:</u>

- shared database for Piedmont Region
- WMS for local administration

<u>Further development/missing features:</u>

- Attribute completion
- Directionality of the links
- Linear referencing for metric localisation and for POI
- Integration with TMC database

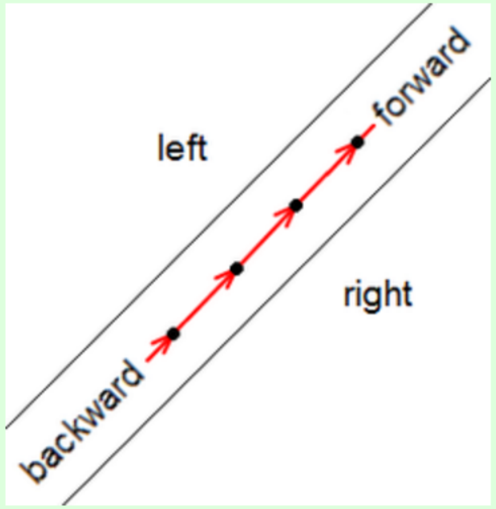
Open Data - OpenStreetMap

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=*`

Most of the roads is edited as **open way** with **highway** tag.

Use of specific tags to differentiate between the direction of travel or the side of the way:

- **Forward and Backward**
- **Left and Right (or Both)**

maxspeed:forward=*	maximum speed which only applies in forward direction
cycleway:left=*	a cycleway on the left side of the road
sidewalk=left	the side(s) of the road where sidewalks are present

Open Data – OpenStreetMap Limitations

Data of OSM are inherently **heterogeneous**:

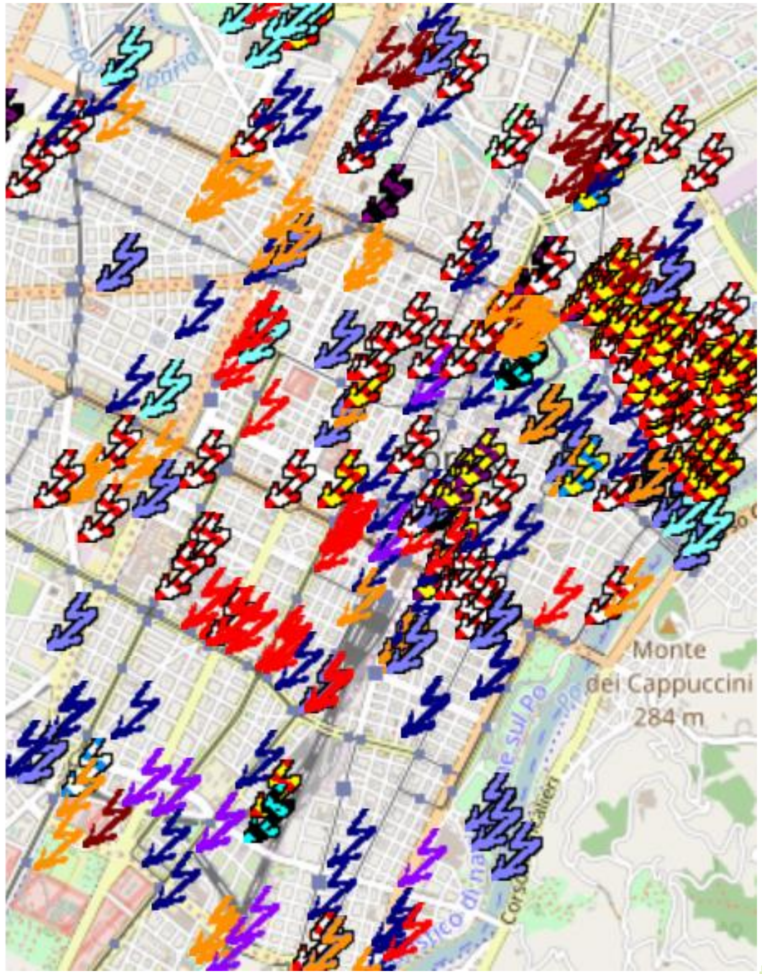
- Level of spatial completeness
- Degree of accuracy (dependent of existing data)
- Tag precision and richness

Not clear **road network concept** which would follow the basic topological concept (a line has to begin and end in a node).

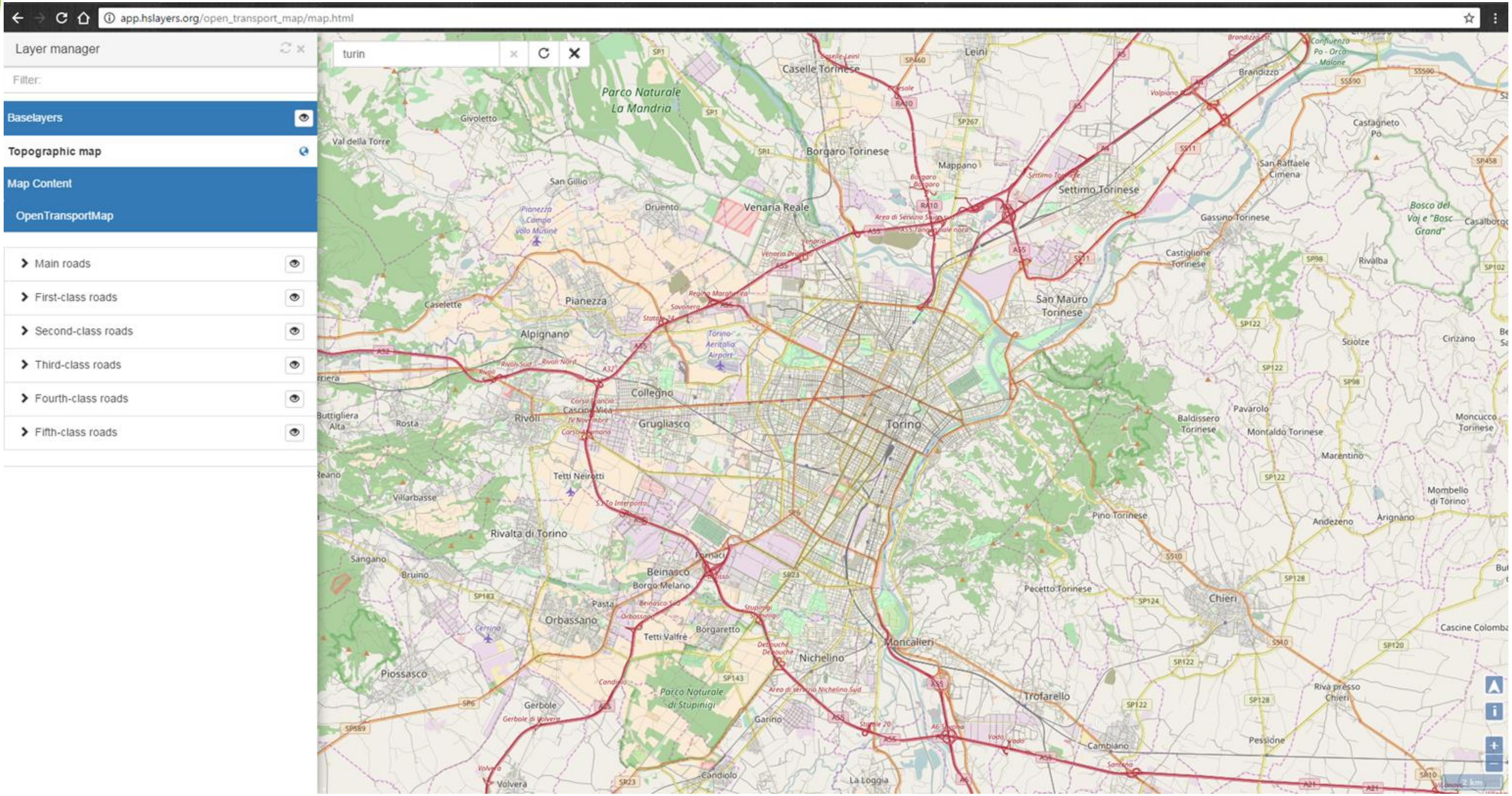
The OSM is not routable and not ready to use for analytical task.

http://keepright.ipax.at/report_map.php

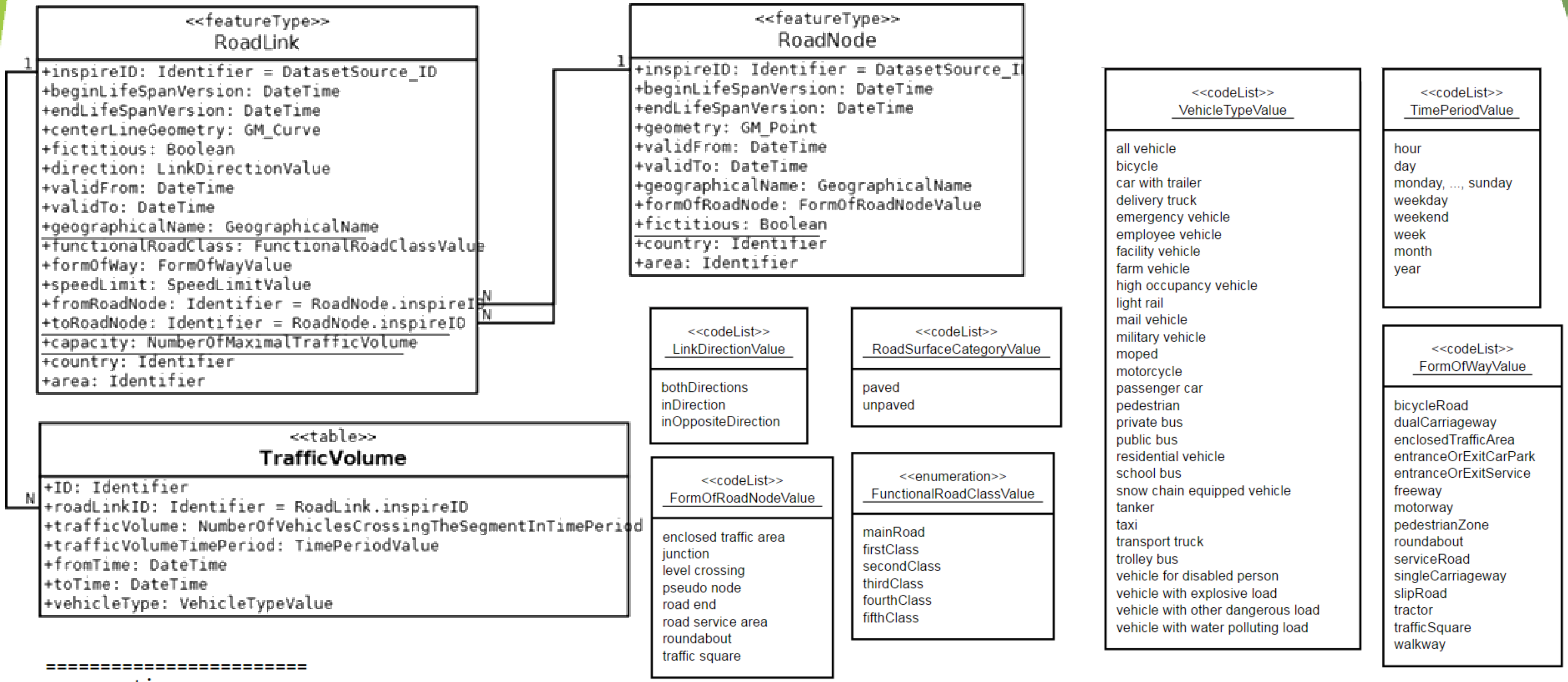
- non-closed areas
- dead-ended one-ways
- almost-junctions
- missing tags
- motorways without ref
- places of worship without religion
- point of interest without name
- ways without nodes
- floating islands
- railway crossings without tag
- wrongly used railway crossing tag
- fixme-tagged items
- relations without type
- intersections without junctions
- overlapping ways
- loopings
- misspelled tags



Open Data - OpenTransportMap
http://opentransportmap.info/)



Open Data - OpenTransportMap

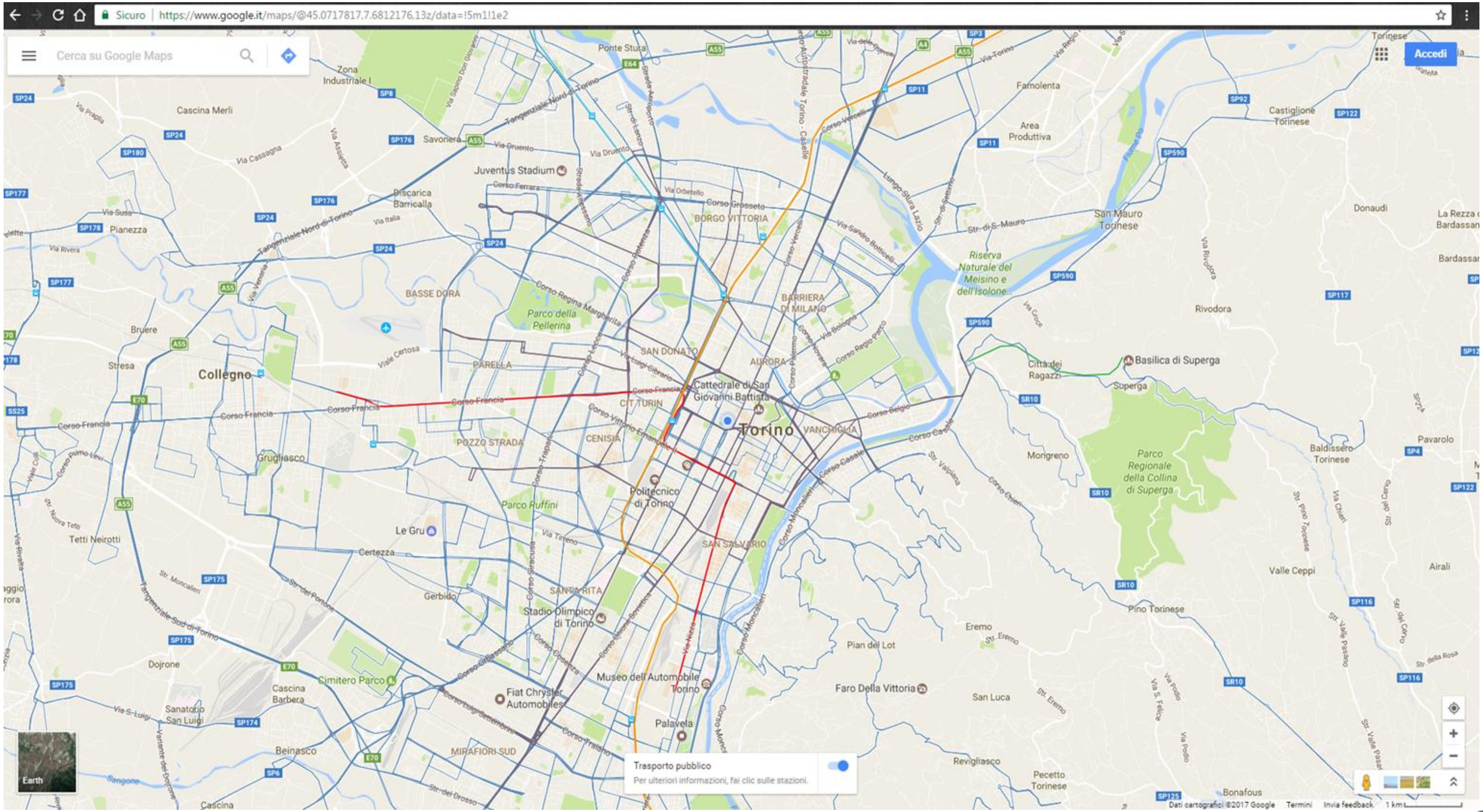



```
========================
«enumeration»
FunctionalRoadClassValue
========================
mainRoad
firstClass
secondClass
thirdClass
fourthClass
fifthClass
```

```
OSM.roads.type

motorway, motorway_link, trunk, trunk_link
primary, primary_link
secondary, secondary_link
tertiary, tertiary_link
residential, living_street, unclassified
<all other values>
```

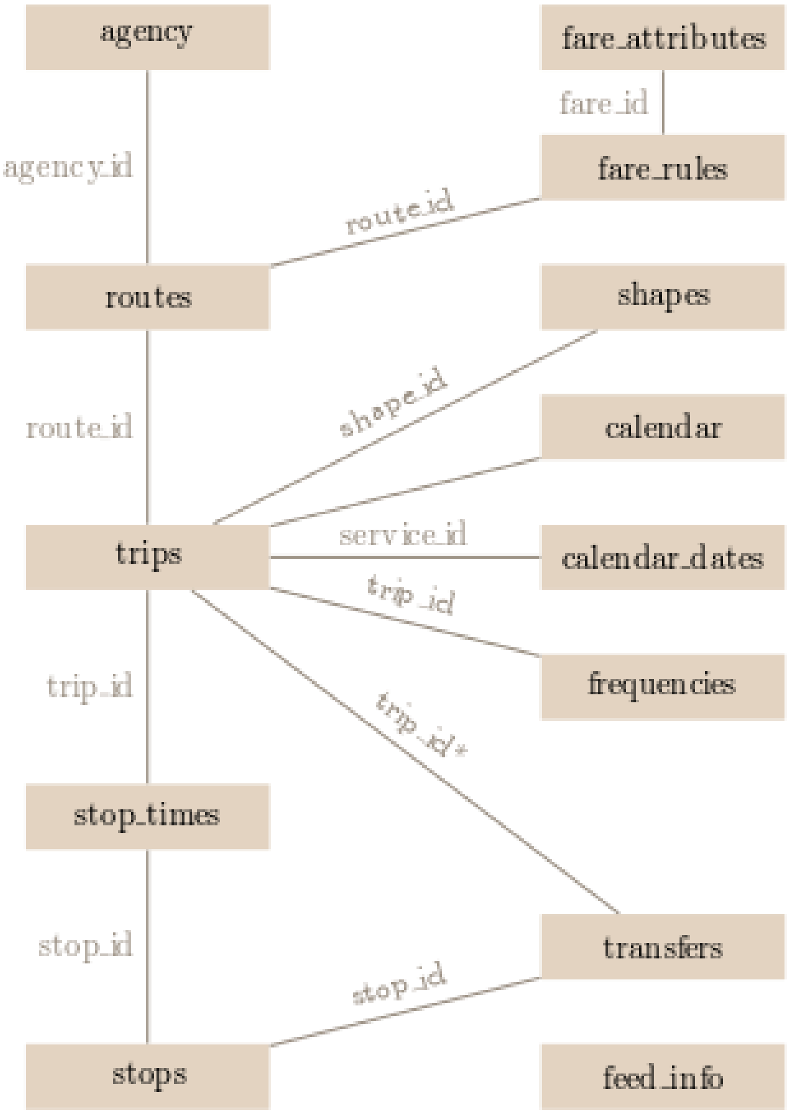
Open Data - General Transit Feed Specification



PRIN PROJECT: *URBAN GEOmatics for Bulk Information Generation, Data Assessment and Technology Awareness*

Open Data - GTFS - http://opendata.5t.torino.it/gtfs/

Table	Description	Fields
agency	Provides information about the transit agency as such, including name, website and contact information.	agency_name agency_url agency_timezone
routes	Identifies distinct routes. This is to be distinguished from distinct routings, several of which may belong to a single route.	route_id (primary key) route_short_name route_long_name route_type
trips	Trips for each route. A trip is a sequence of two or more stops that occurs at specific time.	trip_id (primary key) route_id (foreign key) service_id (foreign key)
stop_times	Times that a vehicle arrives at and departs from individual stops for each trip.	stop_id (primary key) trip_id (foreign key) arrival_time departure_time stop_sequence
stops	Defines the geographic locations of each and every actual stop or station in the transit system as well as, and optionally, some of the amenities associated with those stops.	stop_id (primary key) stop_name stop_lon stop_lat
calendar	Defines service patterns that operate recurrently such as, for example, every weekday. Service patterns that don't repeat such as for a one-time special event will be defined in the calendar_dates table.	service_id (primary key) monday tuesday wednesday thursday friday saturday sunday start_date end_date



Open Data - Traffic Message Channel

Traffic Message Channel (TMC) is a technology for delivering traffic and travel information to motor vehicle drivers.

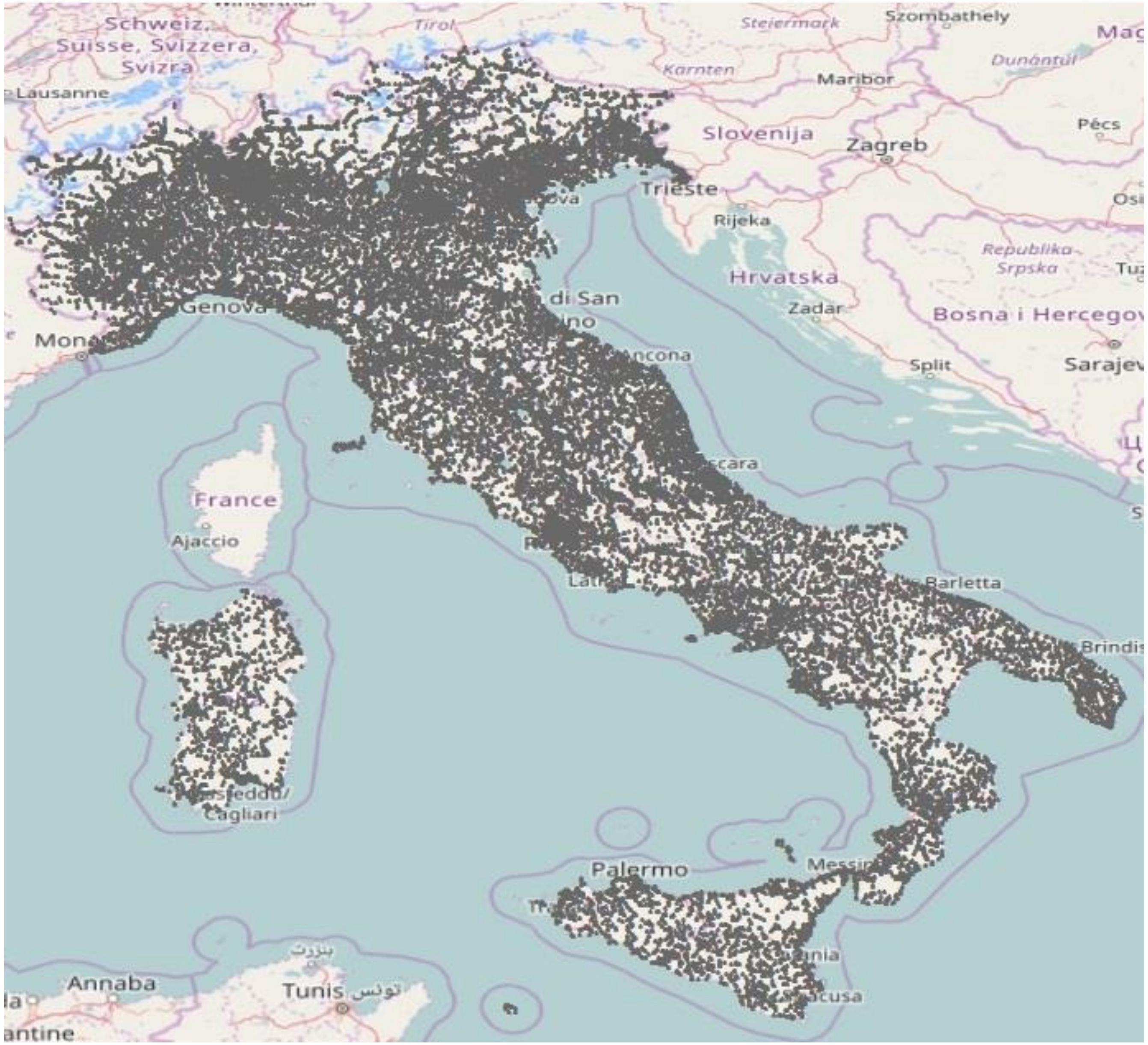
Normalised database that associates a unique numeric code to each point road, thus transmitting only the numerical code [LocationCode] all Traffic Information/Control Center can understand exactly in **which locations** and on **which way** the event is located.

The database TMC are one for each state of the European Union and were made following the standards CEN.

Points are materialized in WGS84 coordinates but they represents a logical position so the geographic accuracy is low.

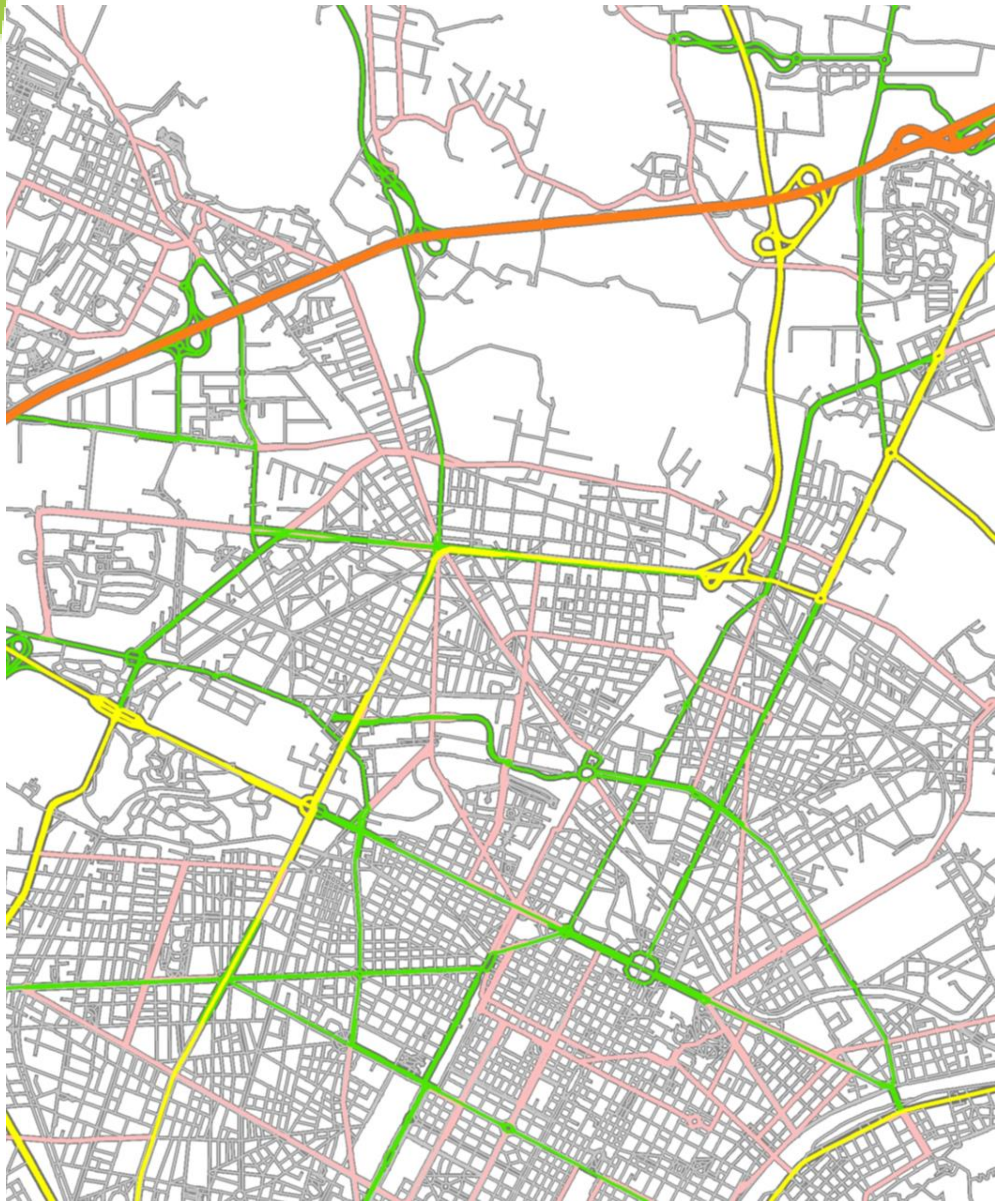
Italian dataset distributed by CCISS available at:
http://www.cciss.it/portale/cciss.portal?_nfpb=true&_windowLabel=quicklinks_1&quicklinks_1_actionOverride=%2Fportlets%2Fquicklinks%2FgoRdsTmc

Open Data - TMC



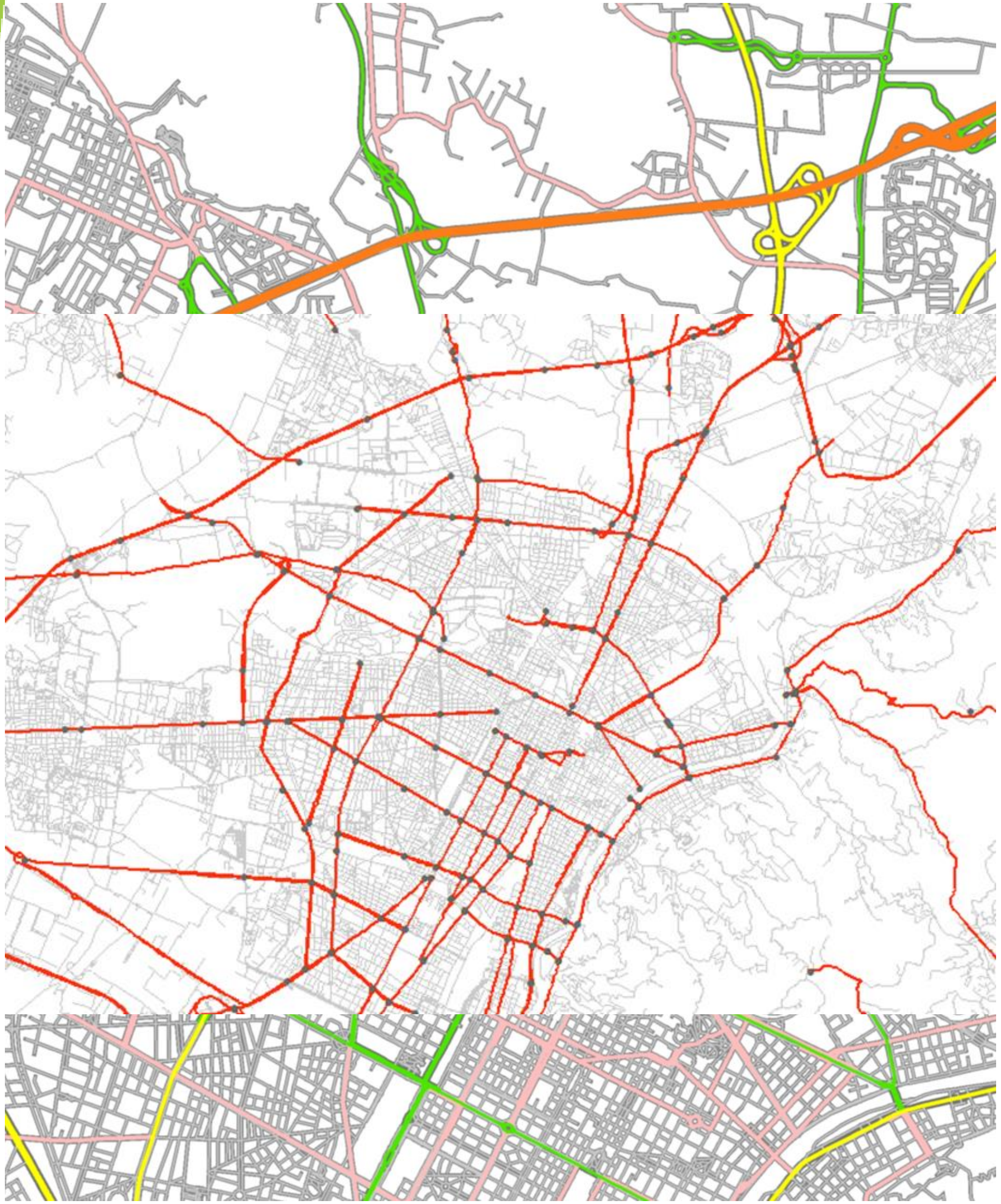
ADMINISTRATIVEAREA
CLASSES
COUNTRIES
ERNO_BELONGS_TO_CO
EUROROADNO
INTERSECTIONS
LANGUAGES
LOCATIONSCODES
LOCATIONDATASETS
NAMES
NAMESTRANSLATIONS
OTHERAREAS
POFFSETS
POINTS
ROADS
SEG_HAS_ERNO
SEGMENTS
SOFFSETS
SUBTYPES
SUBTYPESTRANSLATION
TYPES
ROAD_NETWORK_LEVEL_TYPES
README

Commercial datasets - Navteq/Here



- New updates each year
- Spatial completeness over required area
- Attributes at lane-level precision, switched for direction
- Designed for mapping, cartographic representation and routing applications [navigable links]
- Advanced geocoding (multiple street names, references to address numbers and location codes)
- Accuracy vary from +/- 5 metres for absolute position and +/- 1 metre for relative position (in case of enhanced geometry)
- Precision is 11 cm.
- Consistent set of digitalization rules
- Topological correctness (connectivity assured)
- Set of additional thematic layers (administrative divisions, land use, hydrography, point of interest)
- TMC reference [traffic.dbf]

Commercial datasets - Navteq/Here



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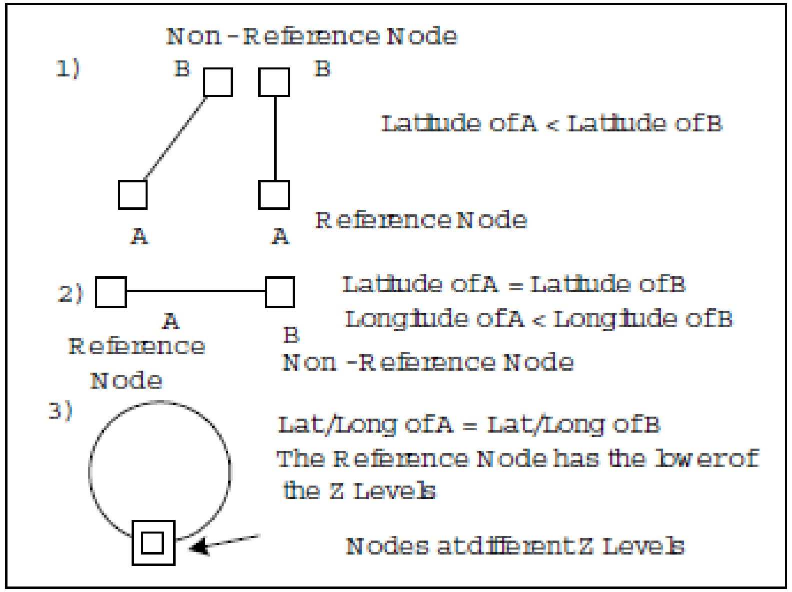
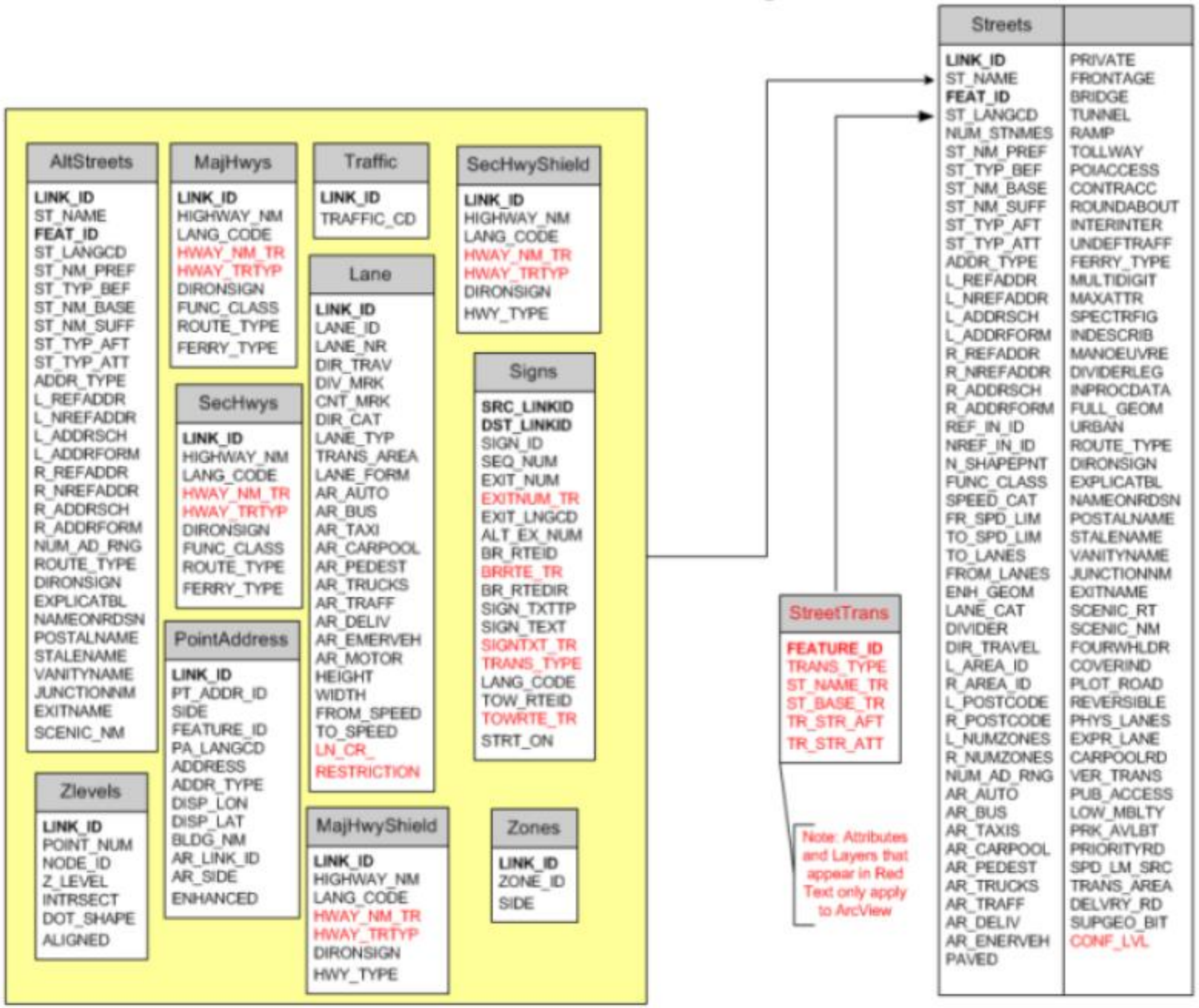
Commercial datasets - Navteq/Here

Link is the minimum mapping element. Link are grouped by FEATURE ID that represent a streets (same name).
Each link is defined by a REFERENCE and NON REFERENCE node.
The attribute «Direction of travel» identifies legal travel directions for a navigable link [BOTH, FROM, TO]



Nodes are materialized by the Zlevel.shp that contains digitalization nodes and intersection nodes. The attribute Zlevel represents a relative vertical position of nodes in relation to “0” when features do not meet at-grade.
Persistence of ID for Link and Nodes, to assure a correct versioning between updates.

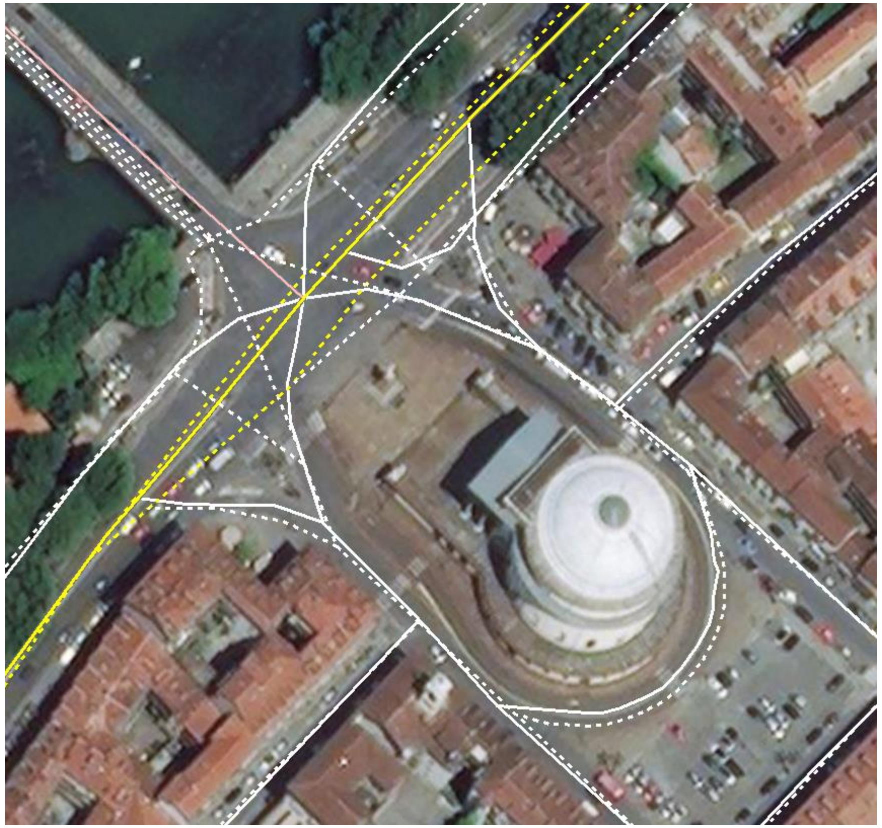
Commercial datasets - Navteq/Here



Integration between sources

NAVTEQ/Here – OpenTransportMap
Differences in LOGICAL REPRESENTATION

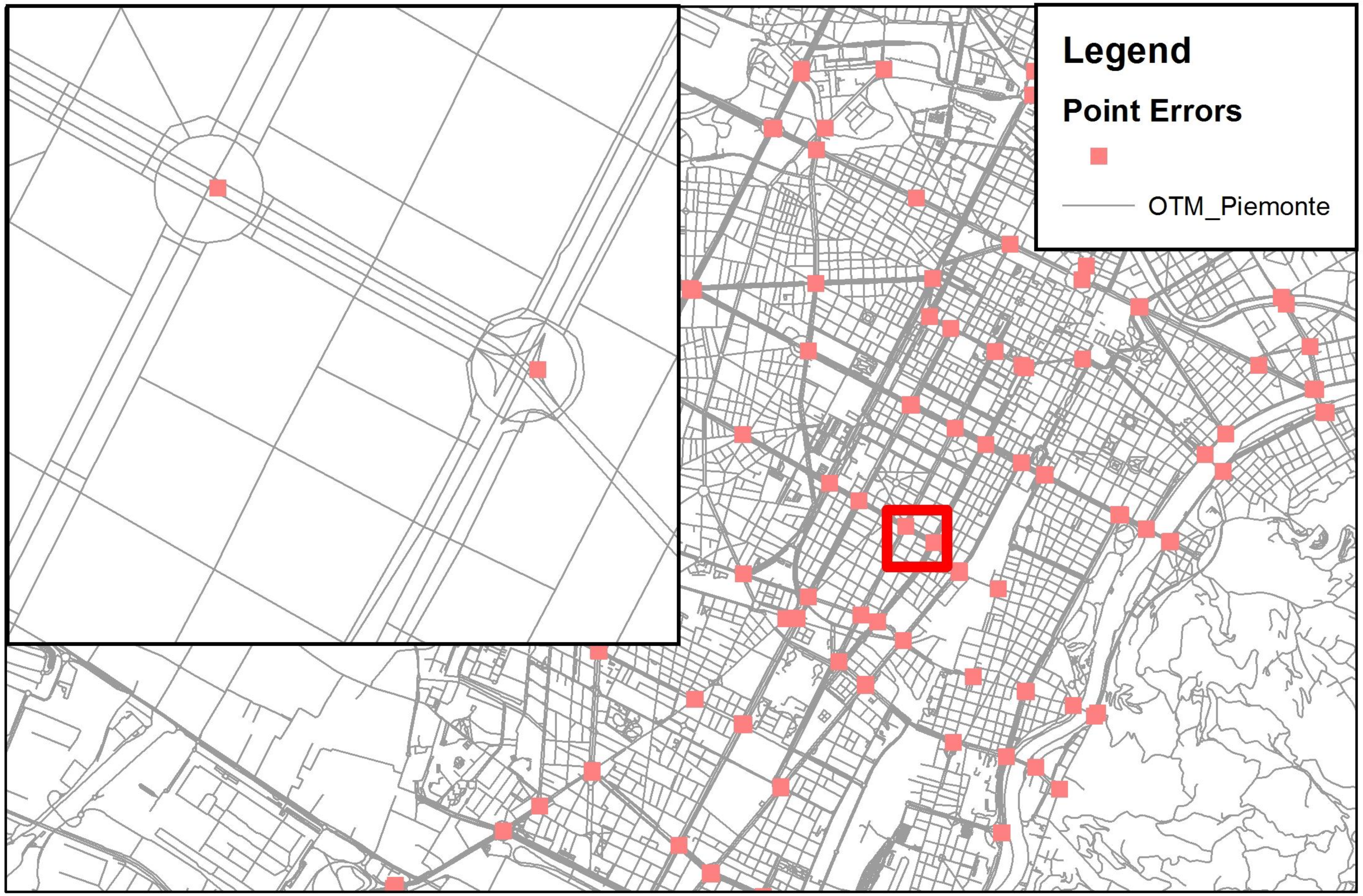
Multiples or single certerline
when there are more lanes →



← Differences in INTERSECTION representation

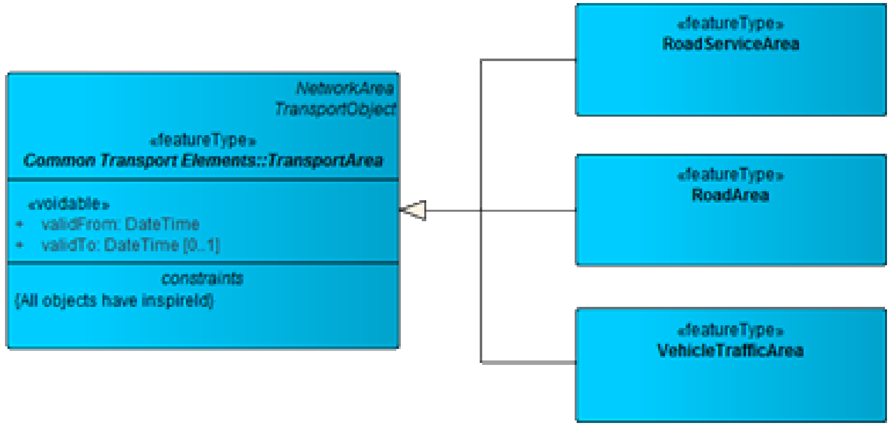
Integration between sources

TMC points on OpenTransportMap



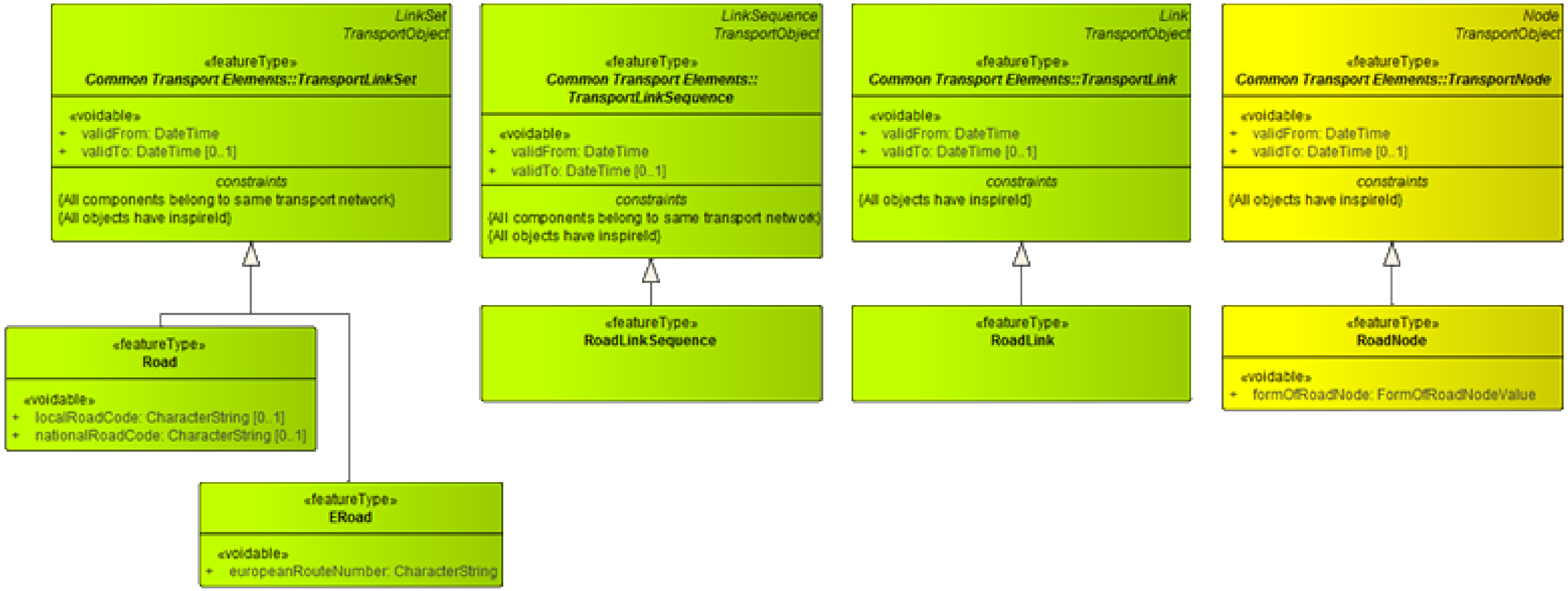
Standards for mobility applications

STANDARD - INSPIRE Road Networks

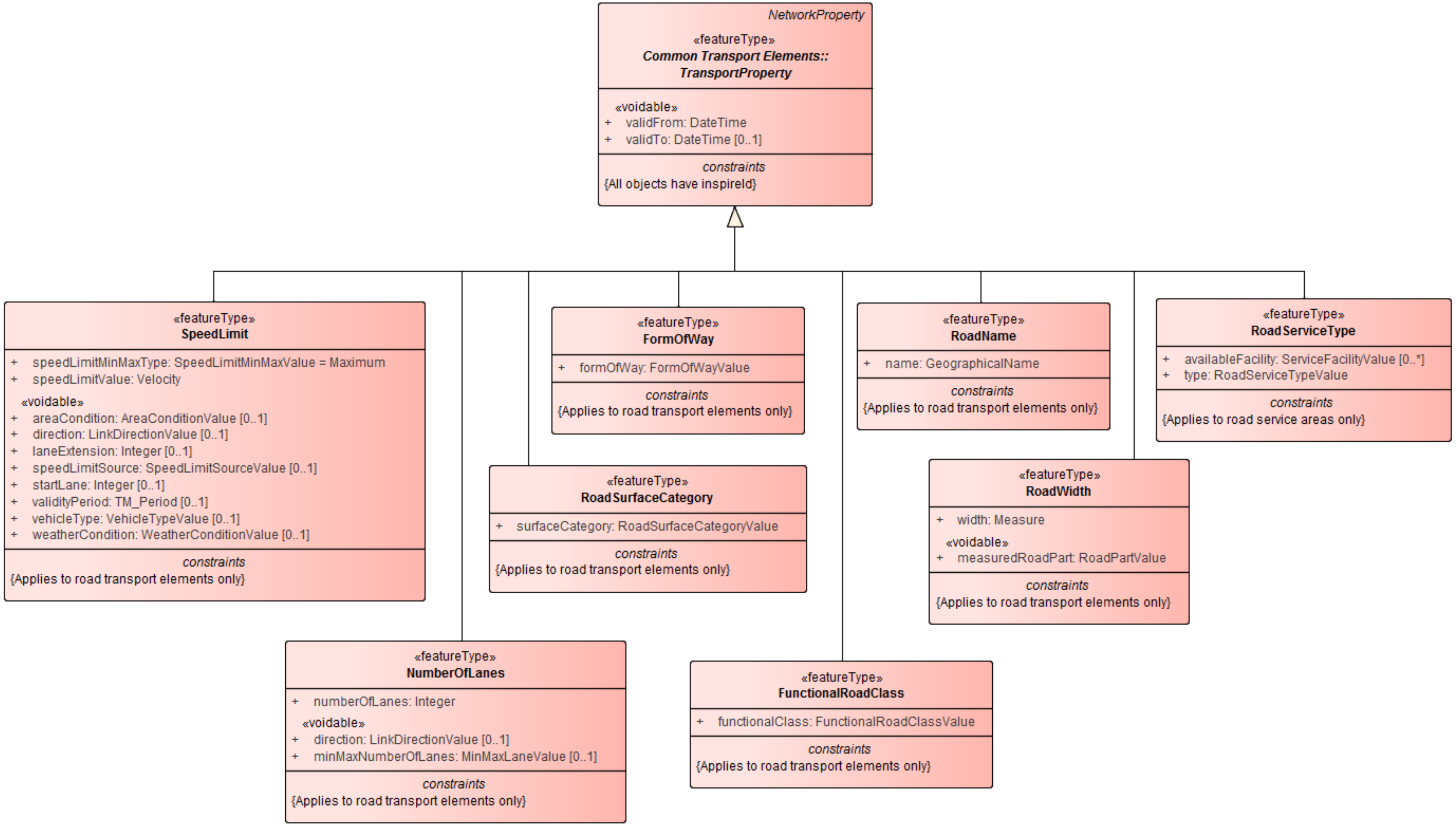


INSPIRE - INfrastructure for Spatial Information in Europe
is a European Directive, which came into force on 15 May 2007 establishing an Infrastructure for Spatial Data at European level.

Themes - ANNEX I - Transport Networks



STANDARD - INSPIRE Road Networks



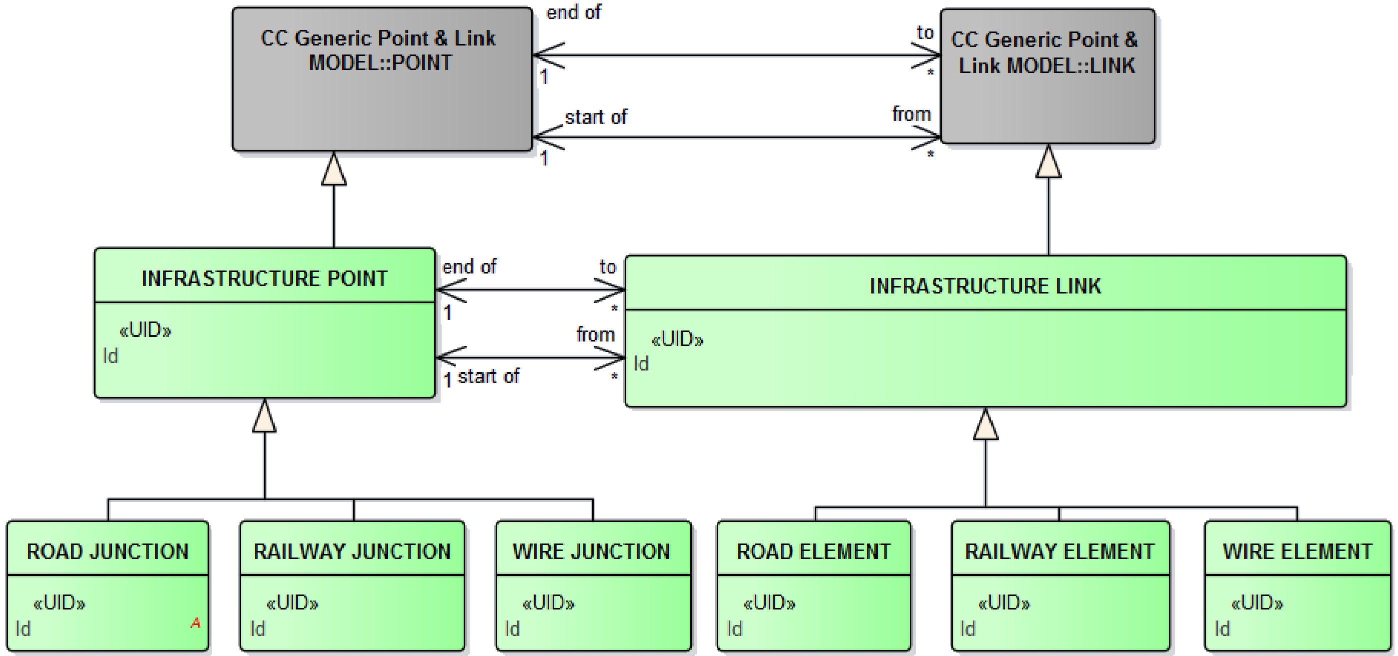
STANDARD - TRANSMODEL Public Transport Reference Data Model

- Transmodel v6 -September 2015
  - Part 1 - Common Concepts (CC)
    - Methodology
    - CC Versions & Validity MODEL
    - CC Responsibility MODEL
    - CC Explicit Frames MODEL
    - CC Generic Framework MODEL
    - CC Reusable Components MODEL
  - Part 2 - Public Transport Network Topology (NT)
    - ND Network Description MODEL
    - FO Fixed Object MODEL
    - TP Tactical Planning Components MODEL
    - NT Explicit Frames MODEL
  - Part 3 - Timing Information & Vehicle Scheduling (TI)
    - TI JourneyAndJourneyTimes MODEL
    - TI Journey Accounting MODEL
    - TI Dated Journey MODEL
    - TI Passing Times MODEL
    - TI Vehicle Service MODEL
    - TI Vehicle Journey Assignment MODEL
    - TI Explicit Frames MODEL
  - Part 4 - Operations Monitoring & Control (OM)
  - Part 5 - Fare Management (FM)
    - Fare Frame MODEL
  - Part 6 - Passenger Information (PI)
  - Part 7 - Driver Management (DM)
    - Diver Schedule FRAME
  - Part 8 - Management Information & Statistics (MI)

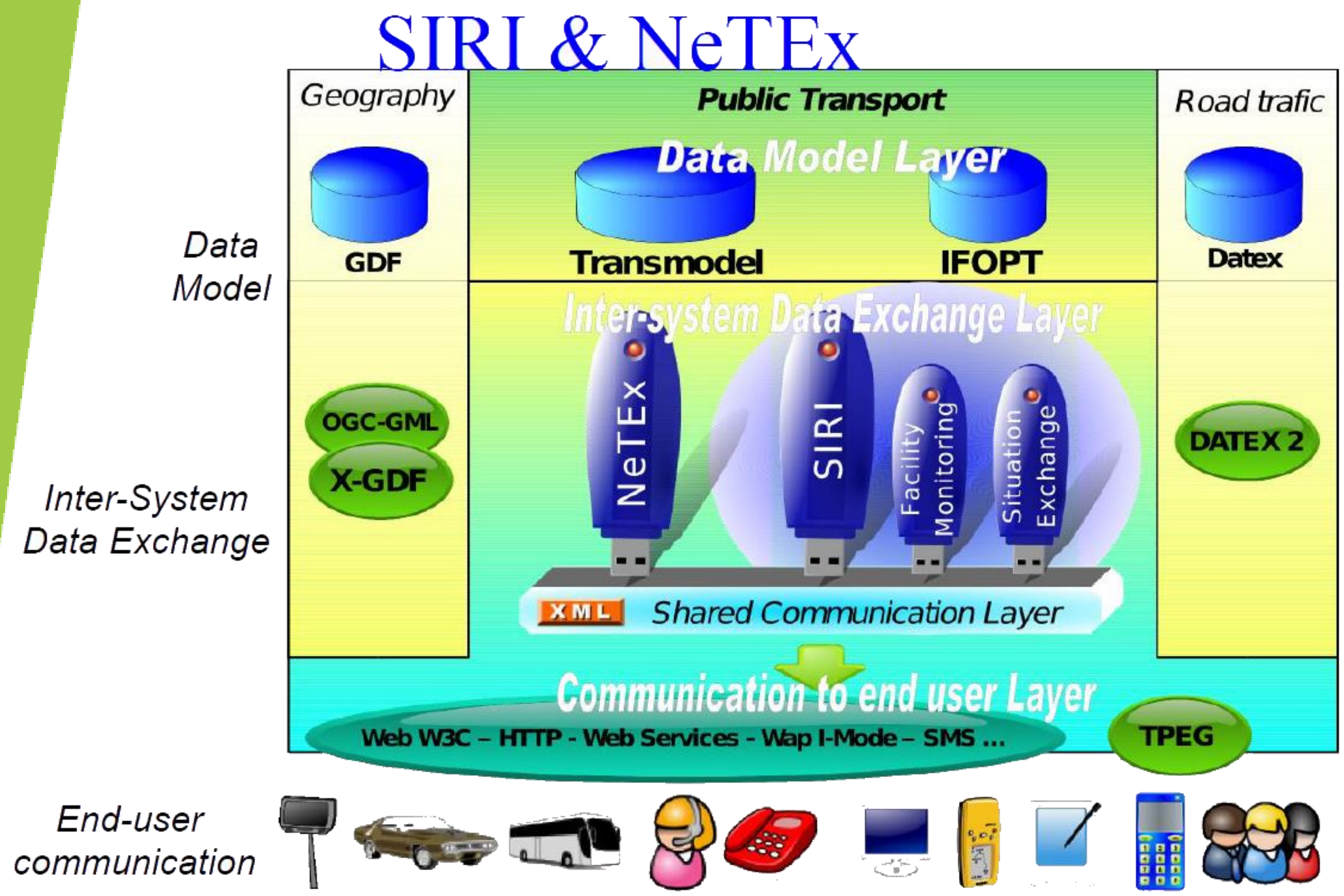
Describe a number of features of **public transport information** and **service management**.

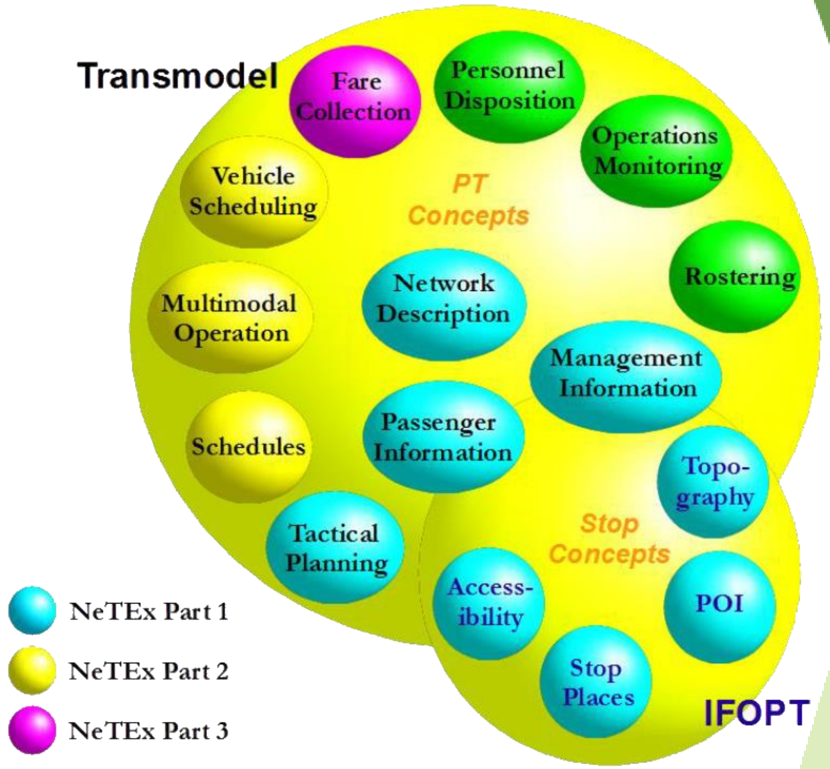
Facilitates the interoperability between information processing systems of the transport operators and agencies.

Transmodel is a large and complex model, and can be implemented for a particular aspect.



STANDARD - NeTEx - Network Timetable Exchange

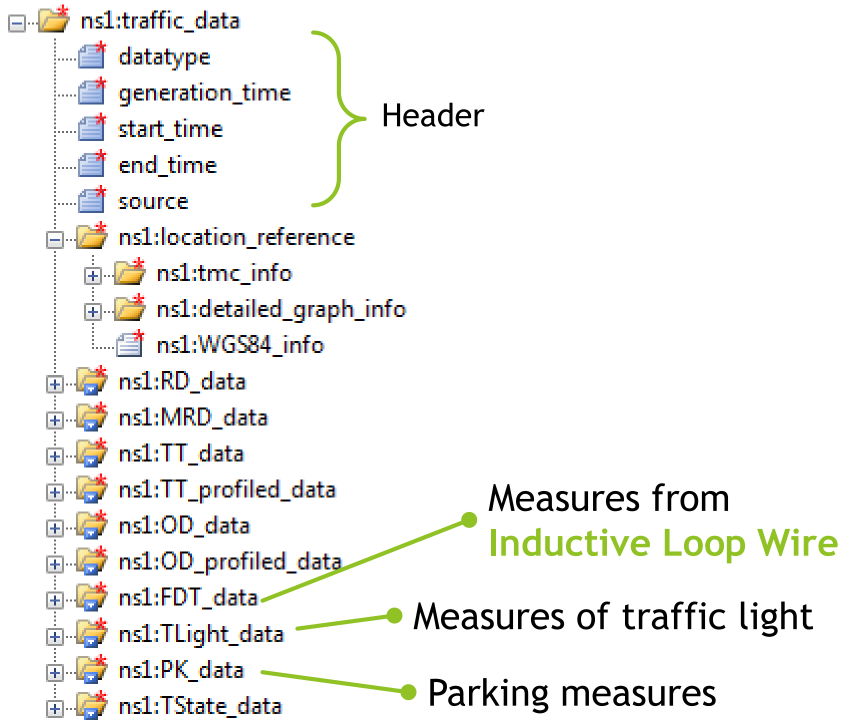


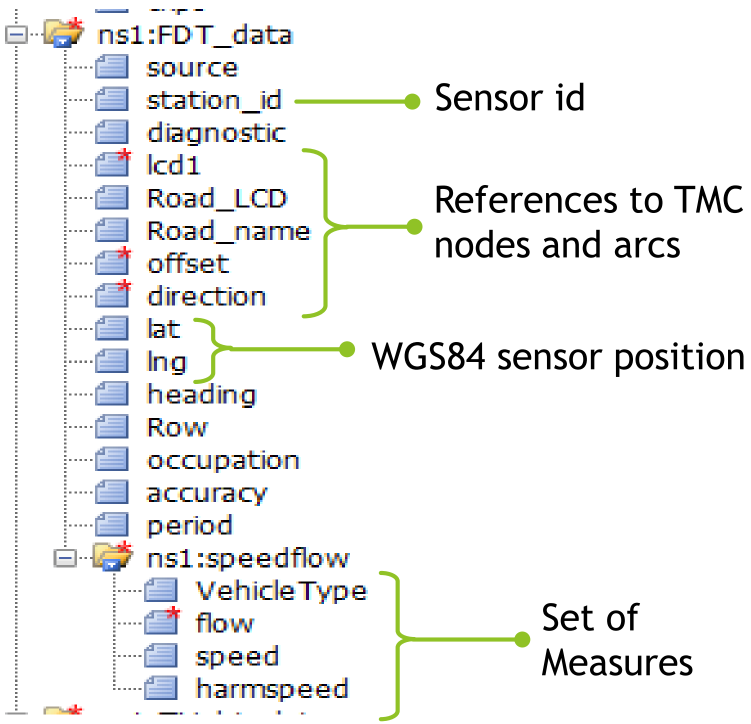


STANDARD - DATEX I/II
and S.i.mo.ne (traffic events and status)

S.I.MO.NE is the Italian standard de-facto communication protocol, supporting interoperability among different actors operating in the Traffic Management field.

It represent an implementation of DATEX standard for exchanging traffic information events (FloatingCarData, traffic events, ZTL information, traffic flows, parking information, traffic light phases, traffic state).





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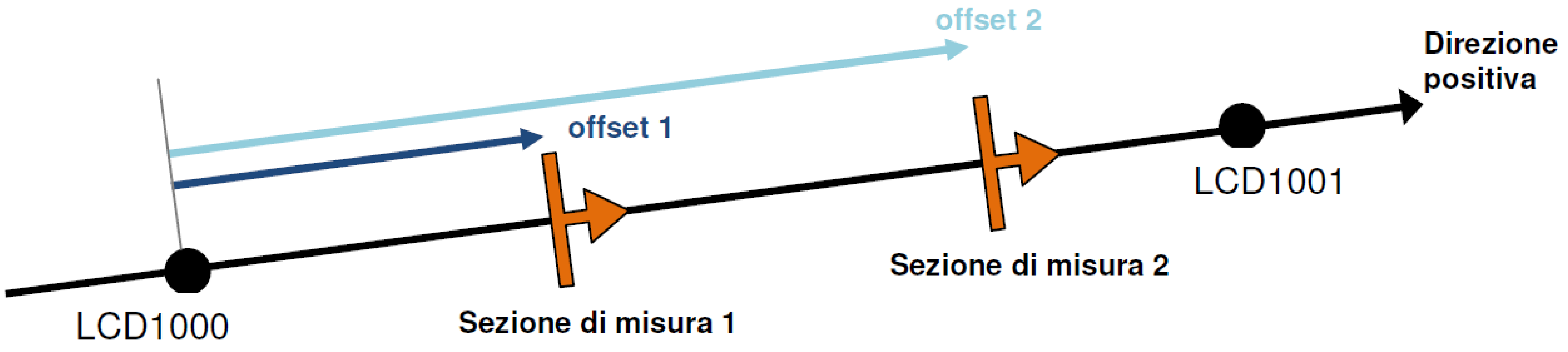


Data modelling - proposals

LINE FEATURE CLASS

- Set of connected and navigable LINKS [roads, cycle ways, railways, pedestrian path, public transit path]
- Aggregation of LINK in relevant PATH [reference arcs]
- PATH **subtyping** following INSPIRE code list → establishing connectivity rules
- Application of M measure over PATH [linear referencing]

POINT FEATURE CLASS

- Intersections and elements of INTERCONNECTION [parking, bus stop, railway station, bike sharing station]
- **Subtyping** following INSPIRE code list → establishing connectivity rules

OBJECT TABLE

- Links attributes harmonised with INSPIRE code list
- Traffic management elements: Sensor loop, traffic light, count stations, variable message panels, cameras… (harmonised through DATEX dictionary)
- Traffic state measures, traffic events…
- Referenced to PATH or to others traffic management elements through linear referencing

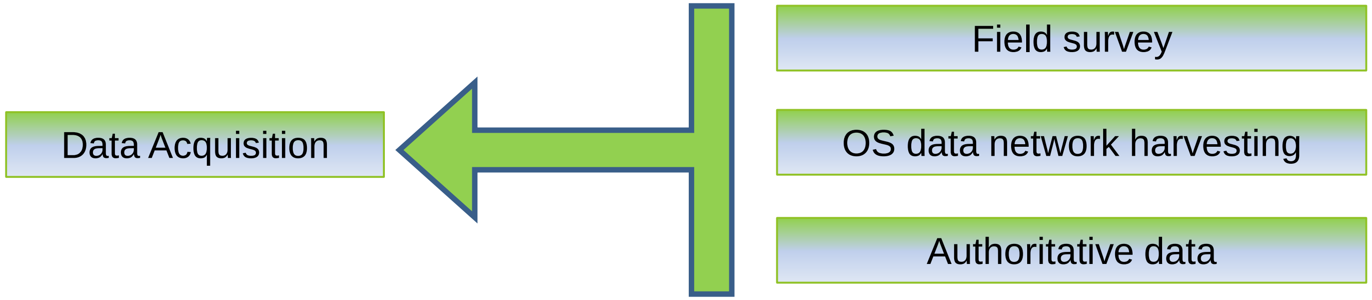
Network dataset
to assure connectivity
Topology Layer
to assure topological correctness

Relationship classes
Linking tables to features and features to features

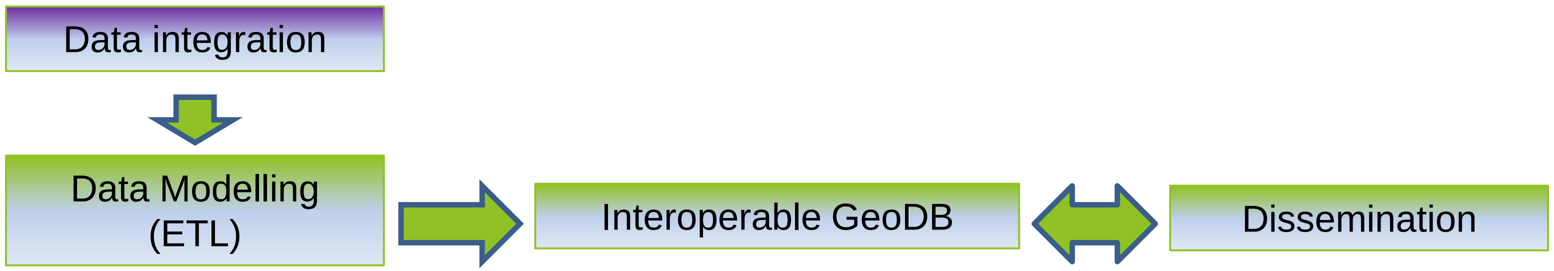
Point and linear events
Displayed on the fly thanks to linear referencing

Wrapping-up: actual situation and further future developments

(list to be discussed and possibly integrated)



1. Implementation of road network data integrating authoritative, OS and directly surveyed sources
2. Extraction of road attributes and impedences
3. Integration of social media and dedicated apps data and information extraction (geointelligence)
4. Incorporation (for large areas) of FVD
5. Infrastructure and On Board Unit (OBU) integration



1. **Implementation of road network data model including road attributes and impedences**
2. **Implementation of a general GeoDB**
3. **Implementation of all-purposes WebGIS portals**

Data Processing → SOP ↔ Testing

1. Implementation of GNSS data procedures able to determine submetric positioning from standard devices and permanent stations post-processing
2. Deep learning algorithms for plate, vehicle and human recognition
3. Geointelligence procedures devoted to information extraction
4. Automatization of FVD and mobile phone data processing
5. Definition of SOP for infrastructure OBU interactions

Application domain ⟷ User feedbacks and validation ⟷ Fine tuning

1. Definition of a of Geomatics-ITS state-of-the-art check list
2. Gap analysis for a geomatics full implementation in ITS
3. **Suggested procedures validation from a service provider perspective**
4. Technology and procedures scouting

Thanks for your attention!

Contacts

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emere.arco@siti.polito.it

piero.boccardo@polito.it