Geomantics for Mobility Management
A comprehensive database model for Mobility Management
Introduction
Research context

Mobility Management
Strategies and policies to reduce or redistribute travel demand in time and space

Wide range of tasks and data

Objective
Reduce the impact of transport (congestion, pollution, security)
Urban transport has a large impact on the socio economic growth and in general on the quality of life of citizens.

**SUSTAINABLE TRANSPORT**

- **Mobility management** is a key factor to provide integrated and real-time information
- **Data integration** as key strategy
  - Better managing to better inform

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

**SPATIAL INTEGRATION**

Concept promoted by the European Commission
Intelligent Transport Systems

Core technology for Mobility Management

Hardware and software applications for transport data management, devoted in particular with \textit{real-time} data

- AD HOC systems $\rightarrow$ one system one task
- Data and information produced are difficult to reuse
Mobility management companies

Wide variety of structures and tasks, inside and between countries:
• Private companies, public companies, public private partnerships
• Managing only private traffic, public transport or both, differences in information systems…
  • Overlays in duties and areas of responsibility

5T case study in Turin

Public private partnership, need of interaction with others mobility management companies, duties variety over time, general separation between ITS systems…

Traffic Operation Centre interfaces:
- VIDA & MOVIDA
- UTC platform
- FCD aggregator
- SCRIBA platform
- DATEX node
- ….
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

Testing and applications

Transport Standards review

ETL processing

Data analysis and catalogue

Physical data model

Conceptual data model

Logical data model

Spatial DB
Mobility data issues

The network data

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
Mobility data issues

The network data

Multiple sources of network data

OPEN DATA
OpenStreetMap
OpenTransportMap

COMMERCIAL AND CUSTOM DATA
Navstreets Streets dataset (Here/Navteq)
Custom Arcs and Path of 5T

OTM vs OSM

Navstreets Streets

OTM Advantages:
• easy query to select specific elements
• Topological correctness
Mobility data issues
The network data

Multiple sources of network data

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COMMERCIAL AND CUSTOM DATA
- Navstreets Streets dataset (Here/Navteq)
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Navstreets Streets vs OTM
Differences in LOGICAL REPRESENTATION
- Multiples or single centerline when there are more lanes

Differences in INTERSECTION representation
Multiple sources of network data

**OPEN DATA**
- OpenStreetMap
- OpenTransportMap

**COMMERCIAL AND CUSTOM DATA**
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**Navstreets Streets vs 5T arcs and paths**
Differences in LOGICAL REPRESENTATION, geometric accuracy and precision
Mobility data issues
Network data comparison

**OpenStreetMap – OpenTransportMap – Navstreets Streets**

Evaluate differences in:
- Spatial completeness
- Attribute completeness and accuracy
- Topology

Refined dataset in order to find a 1:1 correspondence between features:
- Selection in 5/10/30 m range
- Map matching between attributes

### Spatial completeness

<table>
<thead>
<tr>
<th></th>
<th>NAVSTREETS Street Data</th>
<th>OpenStreetMap</th>
<th>OpenTransportMap</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Piedmont - all</strong></td>
<td>Total Kms</td>
<td>58.924,85</td>
<td>101.324,40</td>
</tr>
<tr>
<td></td>
<td>Features count</td>
<td>462.875</td>
<td>306.465</td>
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<tr>
<td><strong>Piedmont - car traversable</strong></td>
<td>Total Kms</td>
<td>48.935,19</td>
<td>82.051,99</td>
</tr>
<tr>
<td></td>
<td>Nº of features</td>
<td>406.291</td>
<td>255.984</td>
</tr>
</tbody>
</table>
Mobility data issues
Network data comparison

OpenStreetMap – OpenTransportMap – Navstreets Streets

Evaluate differences in:
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Attribute completeness – functional class

<table>
<thead>
<tr>
<th>Feature</th>
<th>Data comparison for Functional Class - kms [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVSTREETS Street Data</td>
<td>![Graph showing data comparison]</td>
</tr>
<tr>
<td>OpenStreetMap 5m</td>
<td>![Bar graph showing data comparison]</td>
</tr>
<tr>
<td>OpenTransportMap 5m</td>
<td>![Bar graph showing data comparison]</td>
</tr>
</tbody>
</table>
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Attribute completeness – road name

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Features without name [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenTransportMap 5 m</td>
<td>0%</td>
</tr>
<tr>
<td>OpenStreetMap 5m</td>
<td>10%</td>
</tr>
<tr>
<td>NAVSTREETS Street Data</td>
<td>20%</td>
</tr>
</tbody>
</table>

0% 10% 20% 30% 40% 50% 60%
Mobility data issues
Network data comparison

OpenStreetMap – OpenTransportMap – Navstreets Streets

Evaluate differences in:
- Spatial completeness
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- Topology

Refined dataset in order to find a 1:1 correspondence between features:
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### Topology

<table>
<thead>
<tr>
<th></th>
<th>Feature Mean Length</th>
<th>N° of Features</th>
<th>Must Not Self-overlap</th>
<th>Must not Self-intersect</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVSTREETS Street Data</td>
<td>0.127</td>
<td>406.291</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OpenStreetMap</td>
<td>0.331</td>
<td>255.984</td>
<td>44</td>
<td>74</td>
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<tr>
<td>OpenTransportMap</td>
<td>0.183</td>
<td>609.952</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>OpenStreetMap - FeatureToLine</td>
<td>0.170</td>
<td>481.524</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
OpenStreetMap – OpenTransportMap – Navstreets Streets

Open data:
• Complete from a spatial point of view
• Presence of topology errors
  • Correction requires time and manual effort
• Problems in attribute completeness and reliability:
  • Wrong or missing hierarchy level
  • Missing road names, misspelling errors

Commercial data:
• High reliability even if at high cost

OpenTransportMap can be considered a valid source for some basic mobility management tasks.

Commercial dataset represent the most appropriate solution for advanced mobility management tasks.
Mobility data issues
Ancillary elements of transport network

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 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

![Yearly data volume in 5T](image)
Mobility data issues
Traffic measures and events

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 Standards
Description and comparison

Private Transport Network
- Strong geometric and topological definition
- Dictionaries of elements
- Lacks of ancillary elements definition

FGDC – Transportation Data Model
- Strong geometric and topological definition
- Dictionaries of elements
- Lacks of ancillary elements definition

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

Public Transport

GTFS – General Transit Feed Specification
- Poor geometric and topological definition
- Complex category dictionary
- Deep temporal definition

Traffic Events and Measures

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

S.I.M.O.N.E.
- Variable geometric and topological definition
- Inconsistencies between dictionaries
- Several temporal aspects

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

TRANSMODEL (IFOTP)
- Variable geometric and topological definition
- Inconsistencies between dictionaries
- Several temporal aspects

TRANSMODEL (NETEX)
- Poor geometric and topological definition
- Complex category dictionary
- Deep temporal definition

TRANSMODEL (SIRI)
- Variable geometric and topological definition
- Inconsistencies between dictionaries
- Several temporal aspects

INSPIRE O&M Standard Implementation (ISO 19156:2011)
- Strong geometric and topological definition
- Dictionaries of elements
- Lacks of ancillary elements definition

TMC – Traffic Message Channel
- Variable geometric and topological definition
- Inconsistencies between dictionaries
- Several temporal aspects

TRANSMODEL (IFOTP)
- Strong geometric and topological definition
- Dictionaries of elements
- Lacks of ancillary elements definition

TRANSMODEL (NETEX)
- Poor geometric and topological definition
- Complex category dictionary
- Deep temporal definition

TRANSMODEL (SIRI)
- Variable geometric and topological definition
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- Several temporal aspects

GTFS – General Transit Feed Specification
- Poor geometric and topological definition
- Complex category dictionary
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CityGML
Data modelling
The conceptual data model
Data modelling

The conceptual data model

Main elements
Data pre-processing and ETL

Road Network

Direction of flow pre-processing

Navstreets Streets 2016

Conflation processing

LinkSVR →

5TArcs

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
Visualisation and queries of fixed ancillary traffic elements
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)
**Applications**

**Traffic events visualisation – a case study**

**TMC traffic events for Emergency Mapping**

**CASE STUDY – Piedmont floods November 2016**

**Goal:** Integrate TMC info in routinary emergency mapping services

**Workflow:**

- 3 different sources (WordPress page, ISTA/mistic, ISTD/tcm_sistema);
- Filtering on temporal window [22/11/2016 – 02/12/2016];
- Filtering on event category;
- Materialisation of ISTA/mistic events from TMC reference to Navstreets Streets network + Parsing of WP pages versions & materialization on Navstreets Streets;
- Confrontation between EMS damage detection and traffic events with and without a time window (Scenarios);
- Evaluation of traffic events utility in both scenarios.
Applications

Traffic events visualisation – a case study

→ Enhancement of reference data

→ Damages outside TMC

→ New road blocks
Applications
Traffic events visualisation – a case study

TMC traffic events for Emergency Mapping

Considerations on the case study - Piedmont floods November 2016

• TMC events pertaining to several km of roads: not best condition to identify spot damages. Very limited number of point events
• TMC only operational on “major” network → extend it to small rural/mountain roads (openLR?, WGS84 coordinates?)
• several TMC events pertaining the same road, not only in different mechanisms (WP, ISTD, Mistic) but also within the same mechanism → duplicated “alerts”
• DATEX II solves several issues:
  • Event categories improvement
  • Possibility to provide point coordinates and openLR referencing
• TMC for pre-alerting-imagery triggering?
• Integration TMC-OSM: the German case, impact on crowdsourcing, etc.
Comprehensive spatial data model

- A concrete proposal of dictionary and relationships for ancillary traffic data (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

Prin further developments

Data models will be operational deployed for different goals related to operational services:

1. Extensive harvesting (and possible survey) of all the Piedmont Region bus stops with the aim to build-up a comprehensive geodatabase needed for public transportation service clearing;

2. Definition of all Piedmont Region public transportation routes (linked to bus stops) for regional routing and infomobility services deployment;

3. Extensive harvesting (and possible survey) of all Piedmont Region cycling routes for the full management of sustainable mobility and infomobility delivering;

4. Implementation of an operational data model based on radio base analytics both in static and dynamic modes to define and update already available origin-destination matrix
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
Conclusions

Further developments

Prin further developments

Data models will be operational deployed for different goals related to operational services:

1. Massive harvesting and possible survey to implement a Piedmont Region bus stops GeoDB needed for public transportation service clearing and for infomobility dispatch;

2. Setting-up of a Piedmont Region bus routes GeoDB (to be linked with the bus stops one) for public transportation regional routing;

3. Massive harvesting and possible survey to implement a Piedmont Region cycling routes GeoDB for sustainable mobility and infomobility purposes;
Conclusions

Further developments

Prin further developments

4. Implementation of an operational data model based on radio base analytics both in static and dynamic modes to define and update already available origin-destination matrix;

5. Setting-up of an homogeneous National road graph (at a different map scale) in collaboration with MIT to be used for traffic monitoring, assets inventory, meteo application, etc. (accordingly to the recent “Smart road” act);

6. Definition of navigable road graphs (both 2D and 3D) for connected cars and autonomous driving applications.