Evaluation of Cooperative Intelligent Transport Systems

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Overview

- Intelligent Transport Systems
- Thessaloniki smart city
- Field Operational Tests (FOTs)
- ITS testbeds in Europe
- The FESTA methodology
- Network performance evaluation
- Large databases management and analyses

Intelligent Transport Systems

- **Advanced Travelers Information Systems (ATIS)**
  - *VMS*
  - *Route and parking guidance*
  - *Public Transportation Information, etc.*
- **Advanced Driver Assistance Systems (ADAS)**
  - *Adaptive Cruise Control*
  - *Collision Warning/Assistance*
  - *ABS, etc.*
- **Advanced Traffic Management Systems (ATMS)**
  - *Actuated Control, Coordinated Control*
  - *Ramp metering, Lane management, Speed Control, etc.*
  - *Prioritarization, Route clearance, etc.*
- **Advanced Travel Demand Management (ATDM)**
  - *Congestion charge, eco-pricing, tolling system, mobility credits, etc.*

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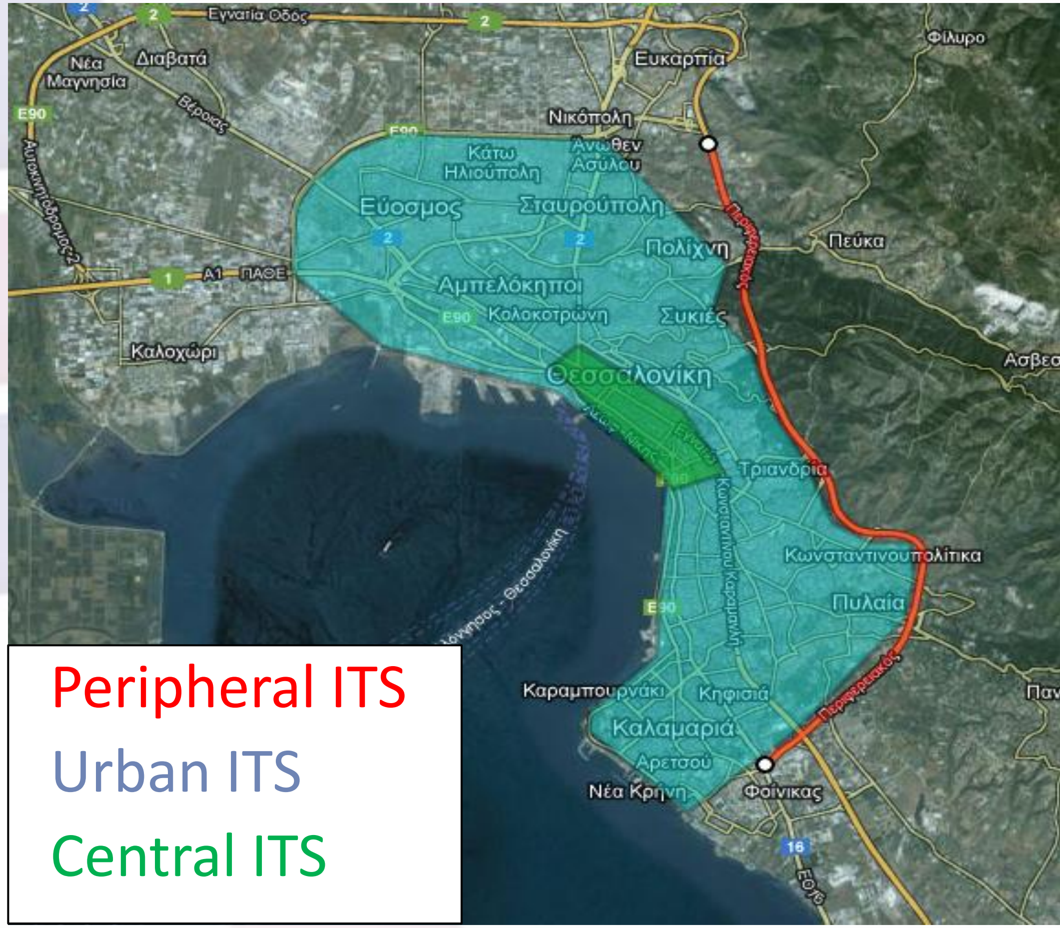
Intelligent Transport Systems

Smart Thessaloniki – ITS areas

- A traffic management System for the Inner Ring Road and the National roads emerging to the Ring Road and
- A Traffic management System for the urban road network



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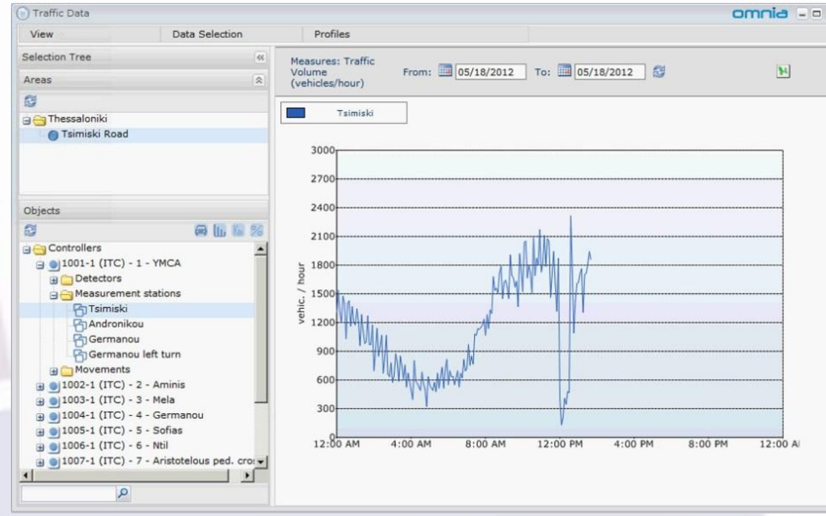
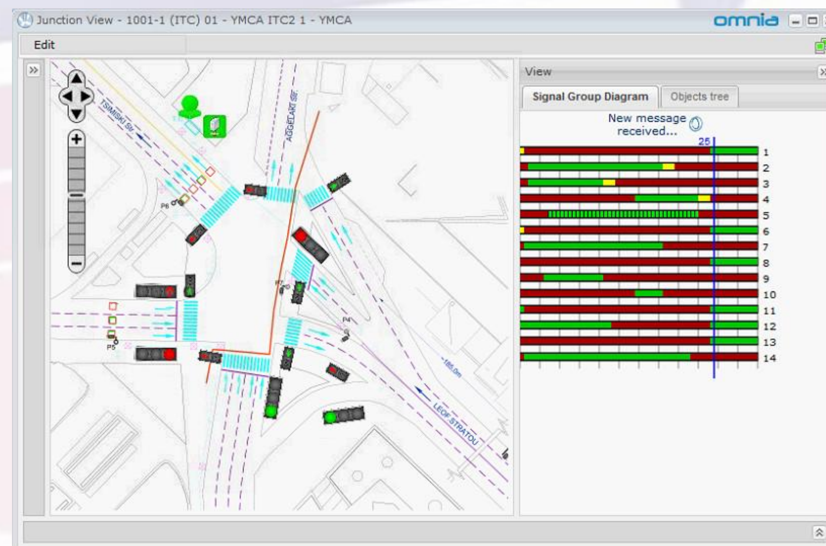
Intelligent Transport Systems
Smart Thessaloniki – Adaptive traffic lights





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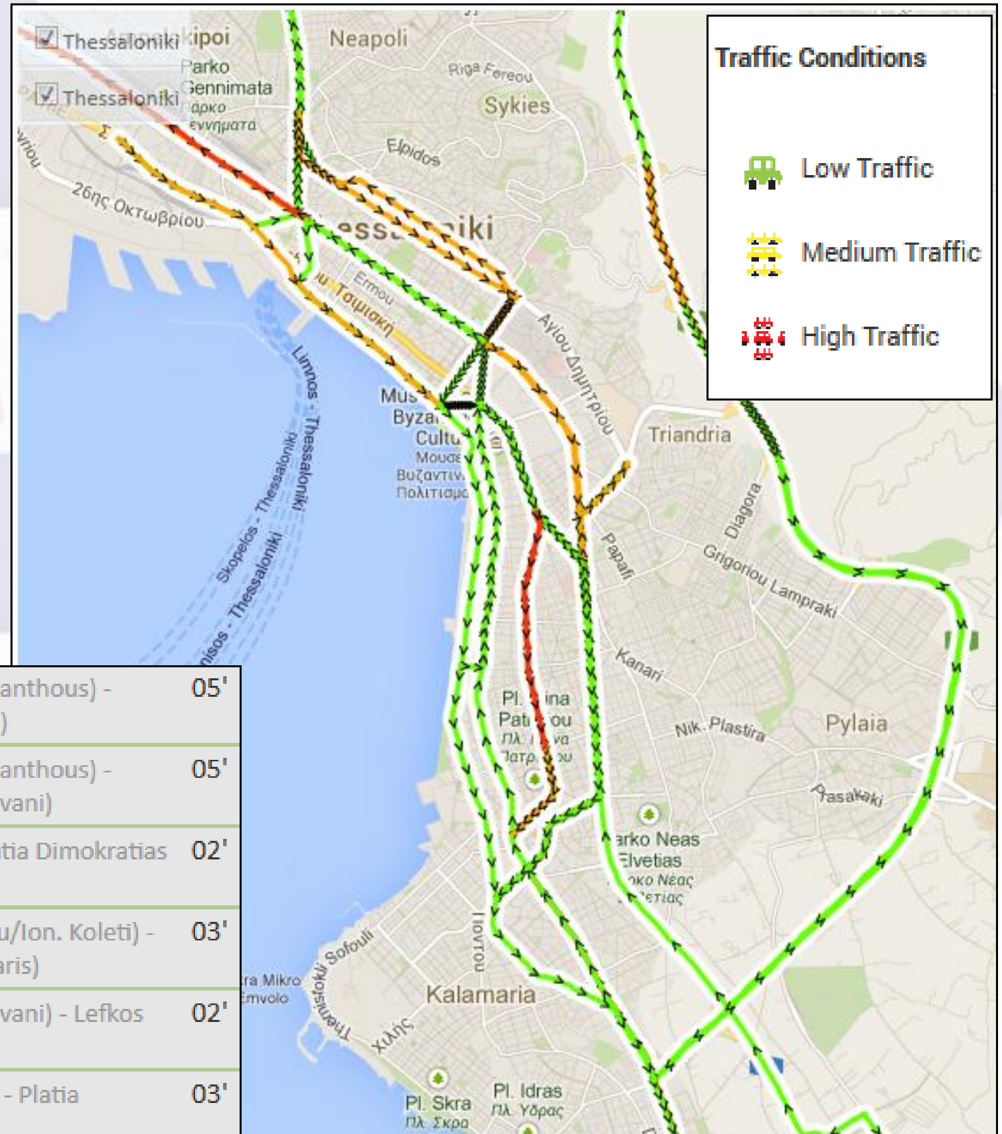
Intelligent Transport Systems

Smart Thessaloniki – Real time travel times

More than 40 BT sensors have been installed. These enable travel time estimation at real-time basis for major routes within the city.



	K. Karamanli (Psaron/Kleanthous) - Platia CHANTH (CHANTH)	05'
	K. Karamanli (Psaron/Kleanthous) - Platia Sintrivaniou (Sintrivani)	05'
	Lagada (Ag. Panton) - Platia Dimokratias (Vardaris)	02'
	D. Eisodos (E90 Stathmou/Ion. Koleti) - Platia Dimokratias (Vardaris)	03'
	Platia Sintrivaniou (Sintrivani) - Lefkos Pyrgos	02'
	V. Olgas (Arch. Mousiou) - Platia CHANTH (CHANTH)	03'

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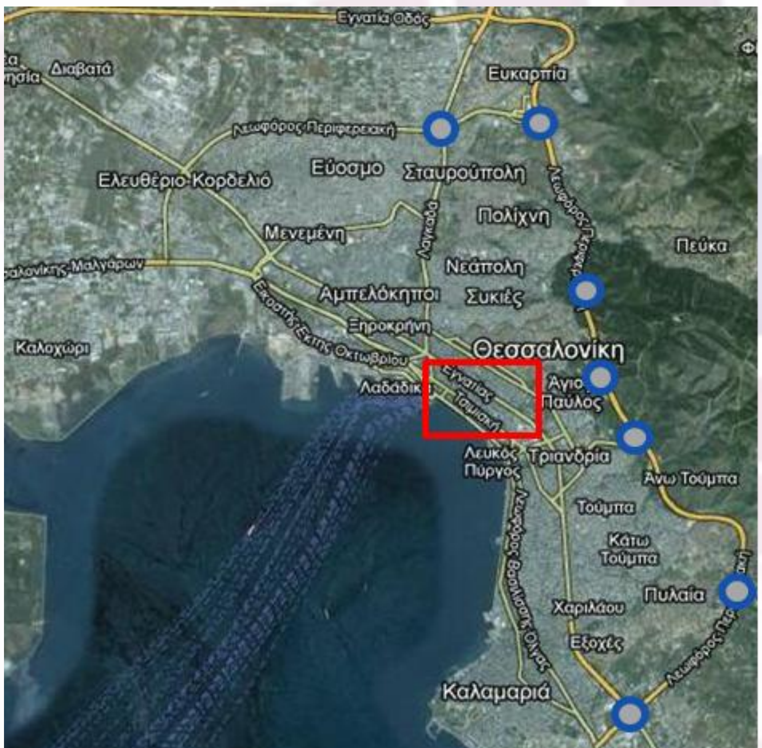
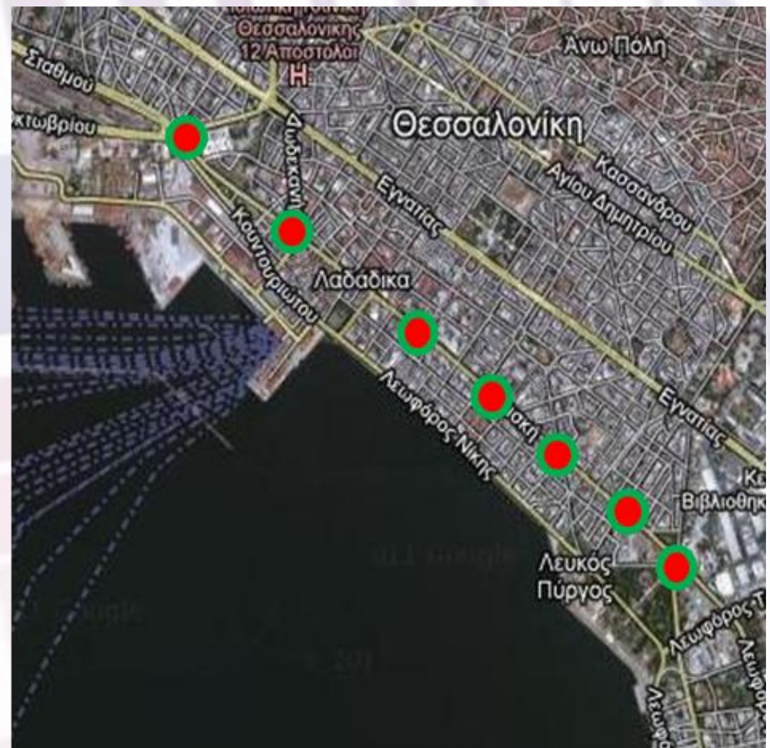
Intelligent Transport Systems
Smart Thessaloniki - Cooperative services

- Energy Efficient Intersection Control service along Tsimiski road
- Road Hazard Warning service along the Peripheral Ring Road of Thessaloniki.
- Routing and travel time information provision services along the main axes of the city.





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Intelligent Transport Systems
Smart Thessaloniki – HIT Mobility laboratory

- Network analysis and simulation tools
  - VISUM: Macroscopic model for traffic assignment
  - VISSIM: Microscopic model for traffic simulation
  - DYNUS-T: Mesoscopic model
  - AIMSUN: Macro, meso and microscopic model
- Analytical and development tools
  - GIS: Geographical Information System
  - MATLAB, AMPL, CPLEX: mathematical and optimization programming tools
  - SPSS: Statistical software
  - Microsoft visual studio: programming environment

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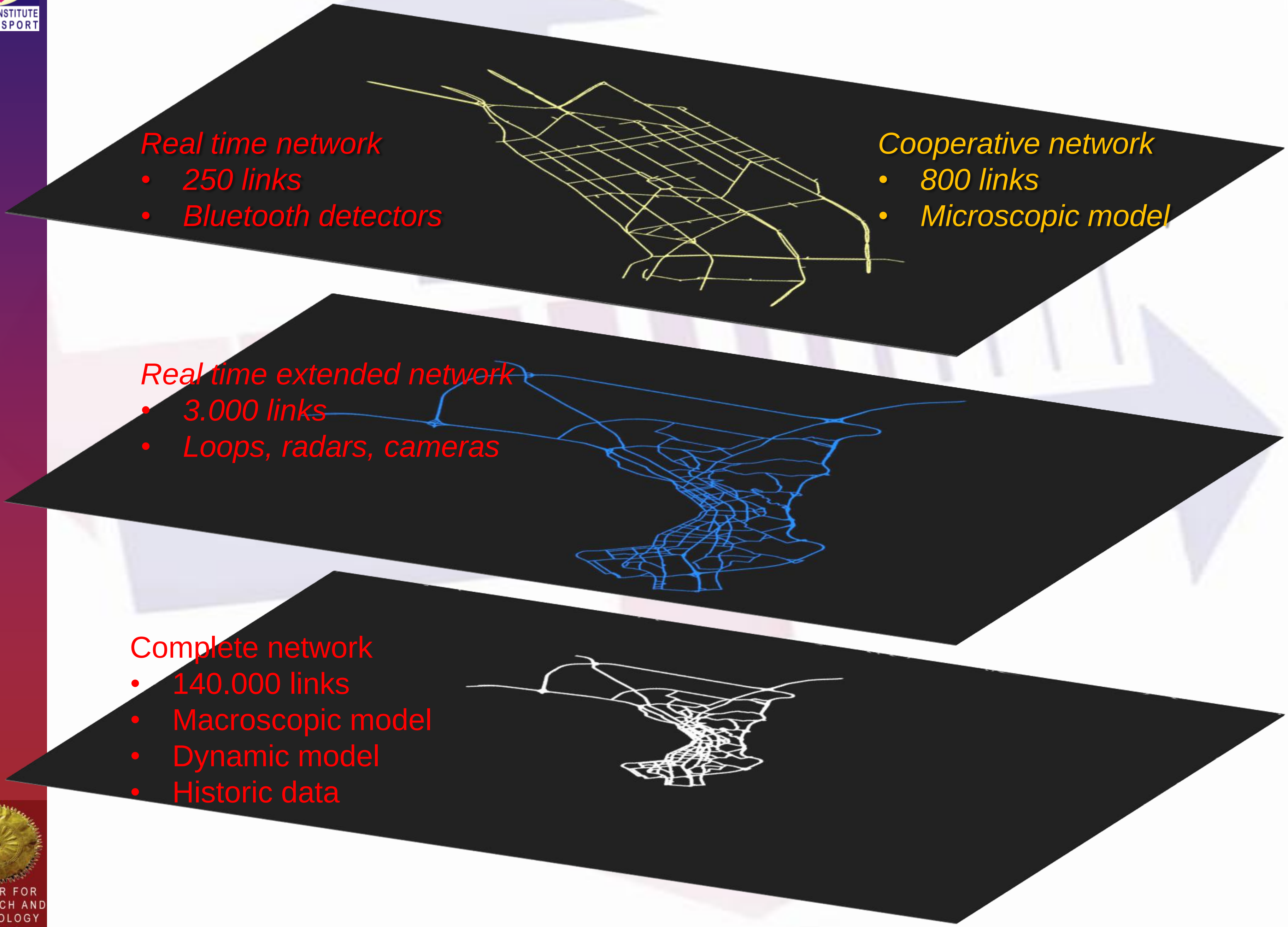

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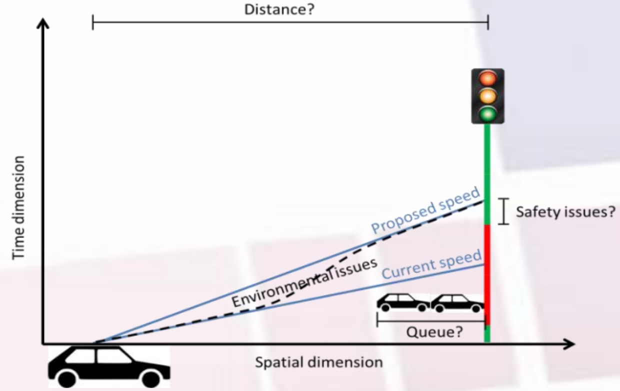
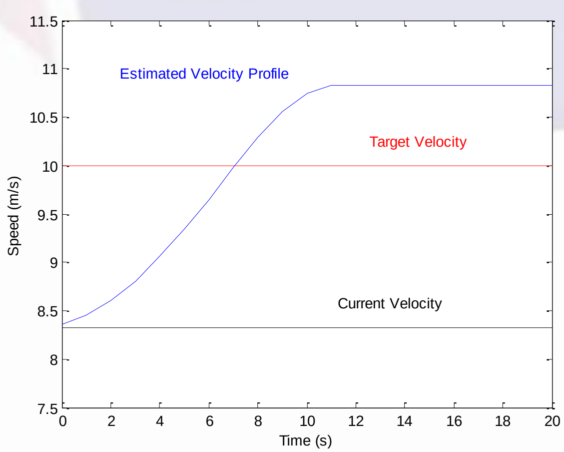
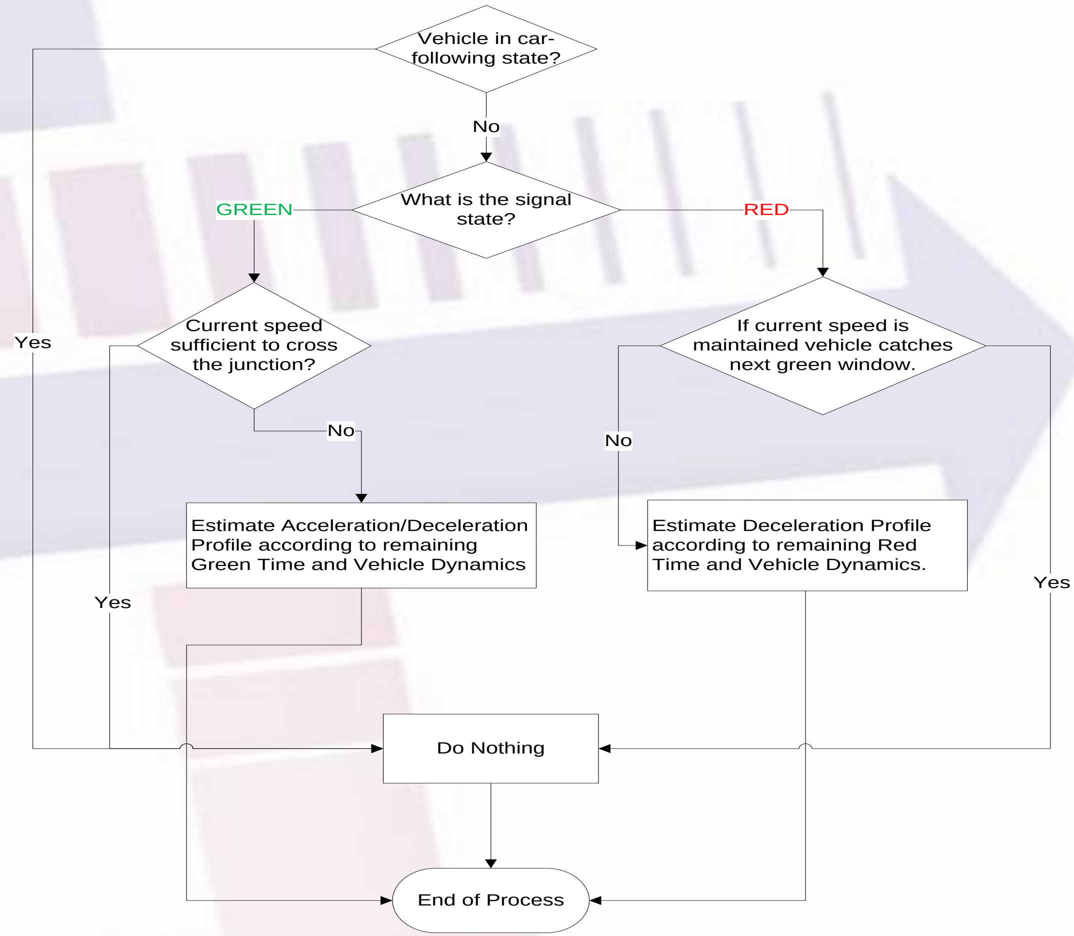
Intelligent Transport Systems
Smart Thessaloniki - Speed advice logic







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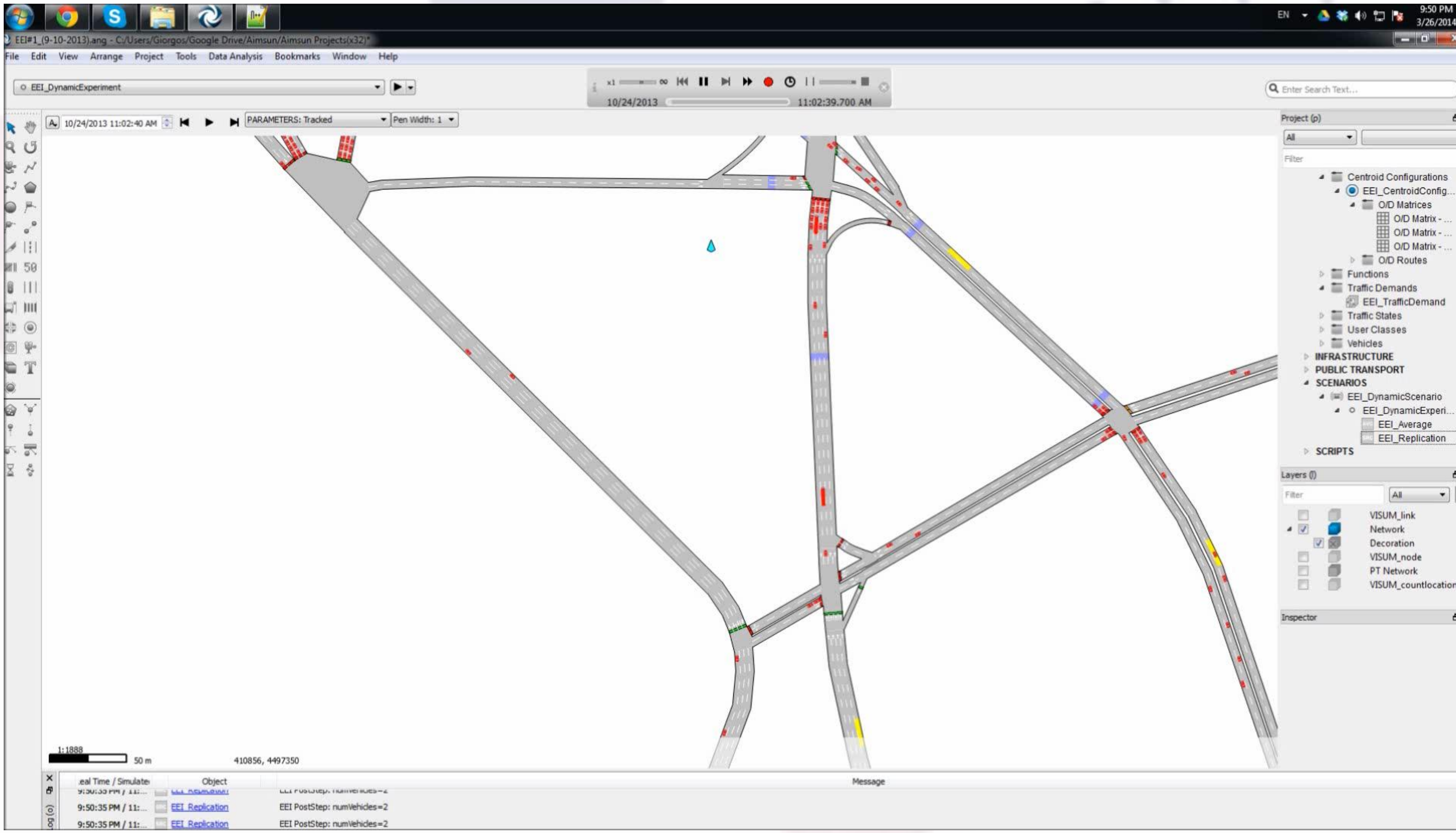
Intelligent Transport Systems
Smart Thessaloniki - Simulation model

- Microscopic Simulation Tool used: AIMSUN
- AIMSUN Application Programming Interface (API) under development in C++ to replicate the operation/logic of the Speed Advisory Algorithm



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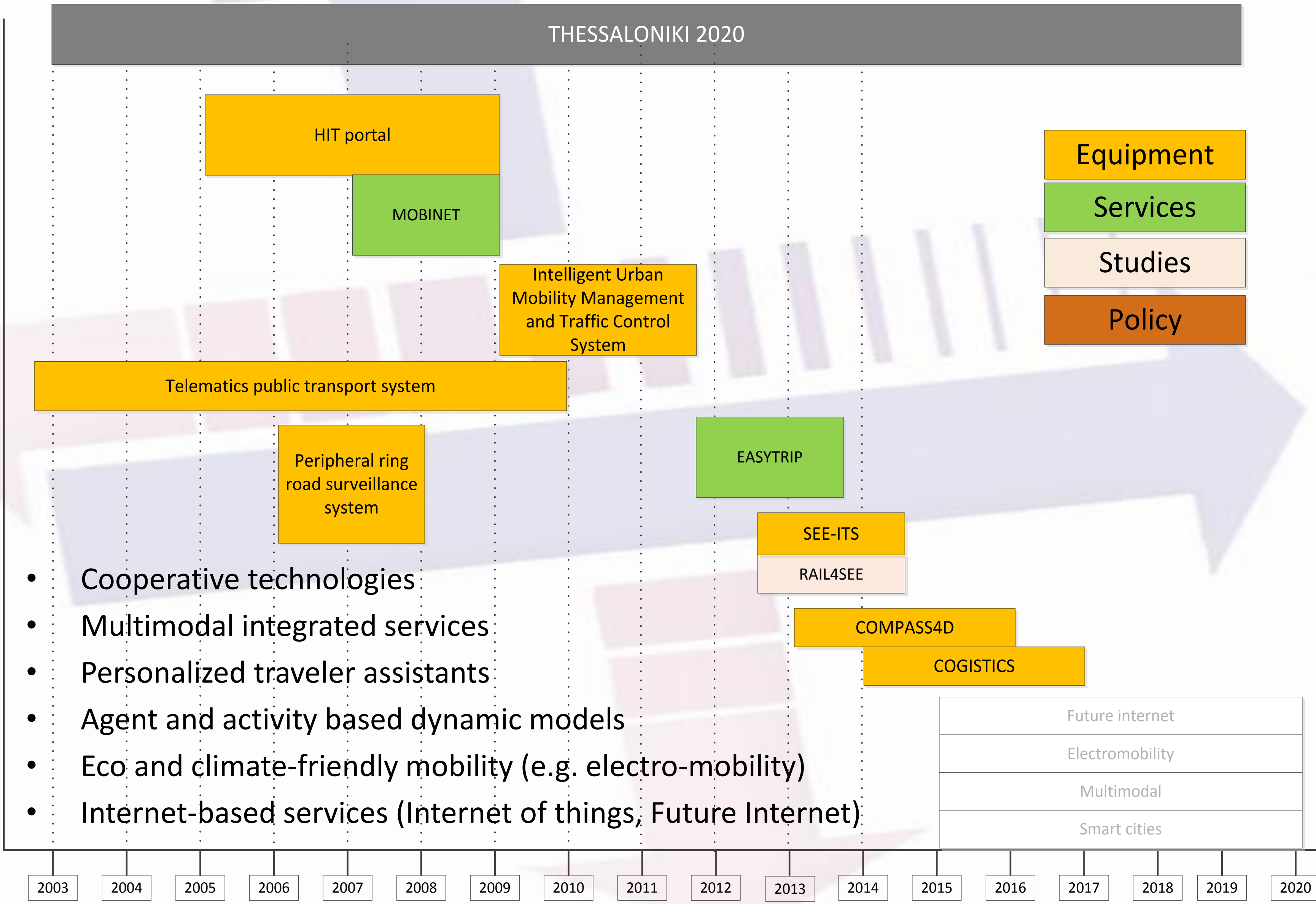
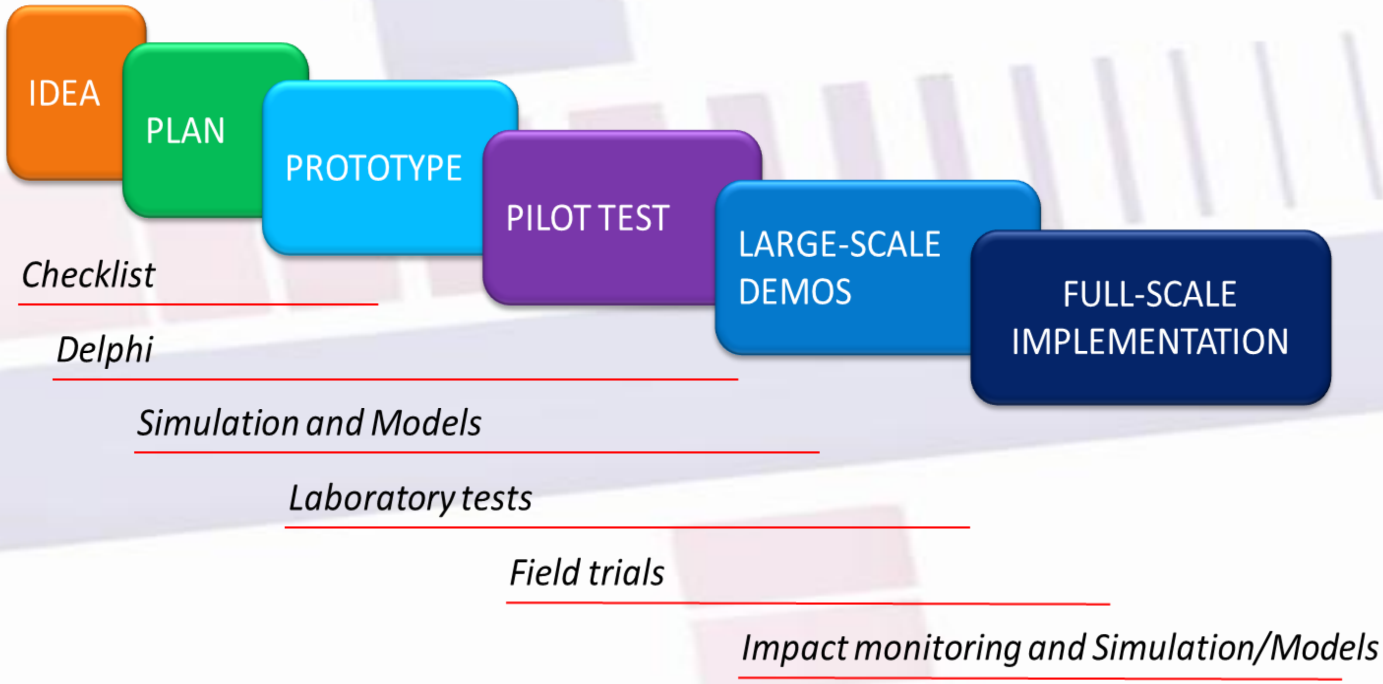
Smart Thessaloniki future timeline and vision



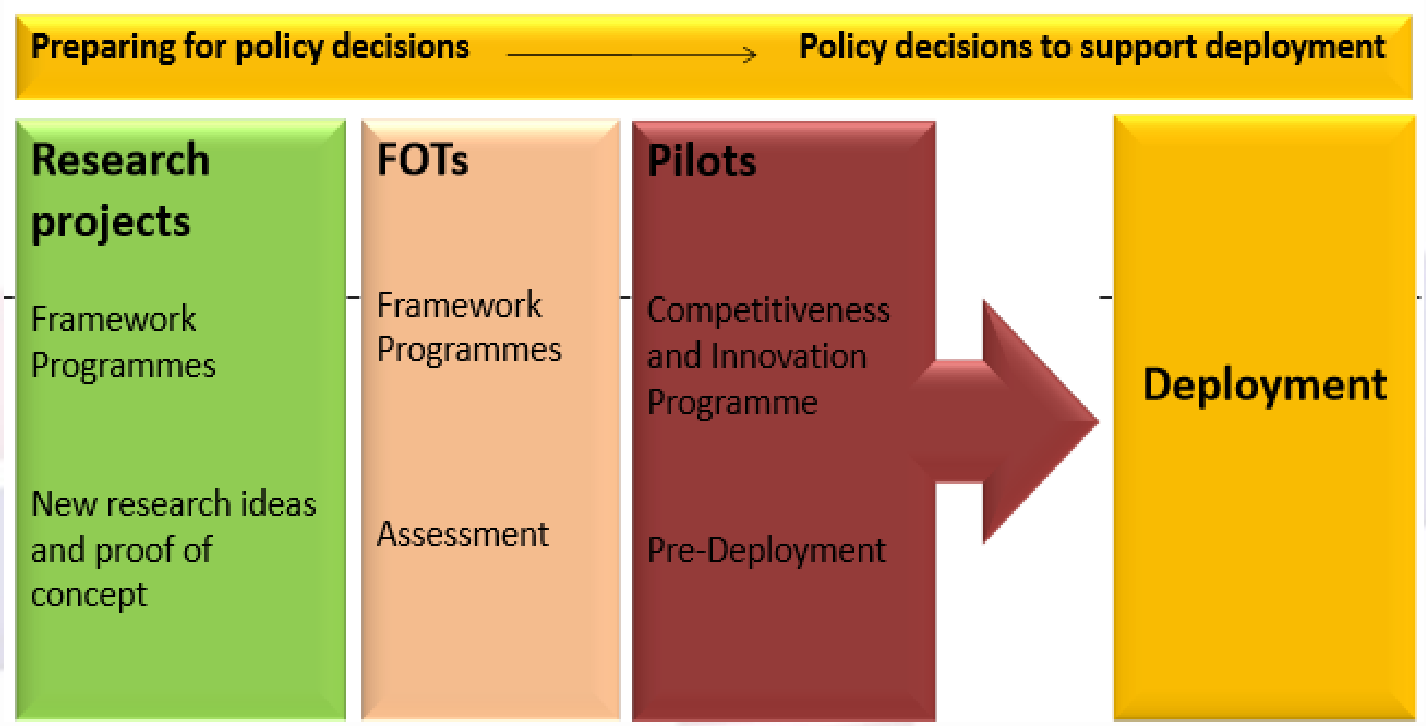
- Cooperative technologies
- Multimodal integrated services
- Personalized traveler assistants
- Agent and activity based dynamic models
- Eco and climate-friendly mobility (e.g. electro-mobility)
- Internet-based services (Internet of things, Future Internet)

Field Operational Tests



Source: EEG TEMPO Euro-Regional Evaluation Guidelines, 2005

From research to deployment



Source: “EU-JAPAN COOPERATION WORKSHOP ON ITS” by Vincent Blevarque

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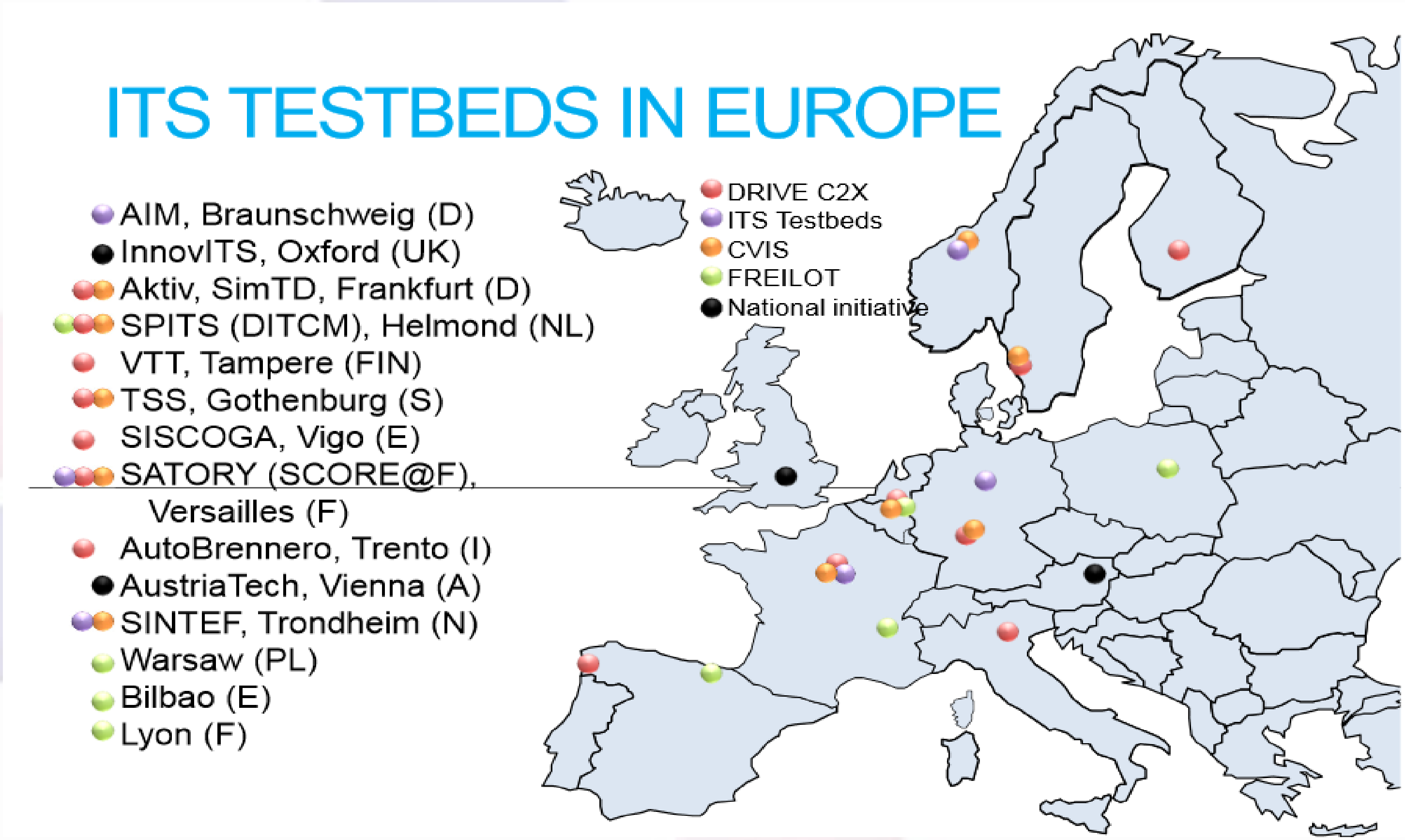
ITS testbeds in Europe



Source: “EU-JAPAN COOPERATION WORKSHOP ON ITS” by Vincent Blevarque

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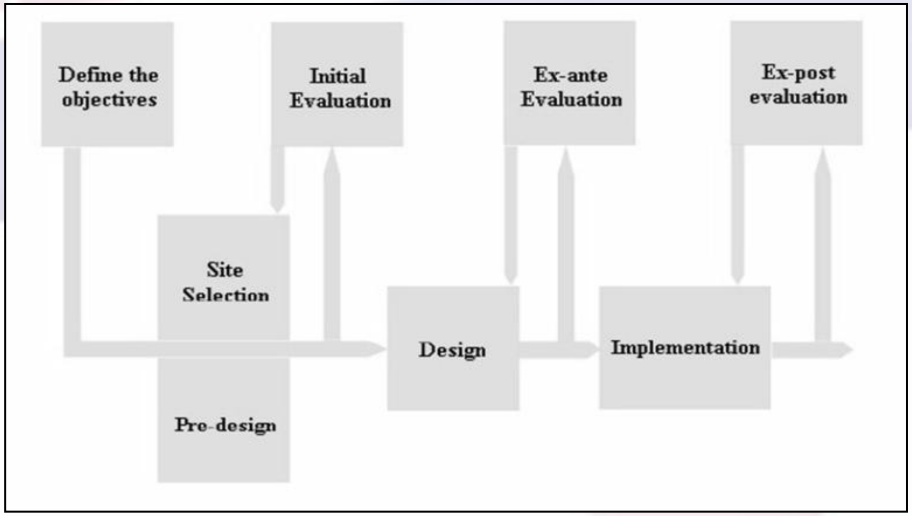
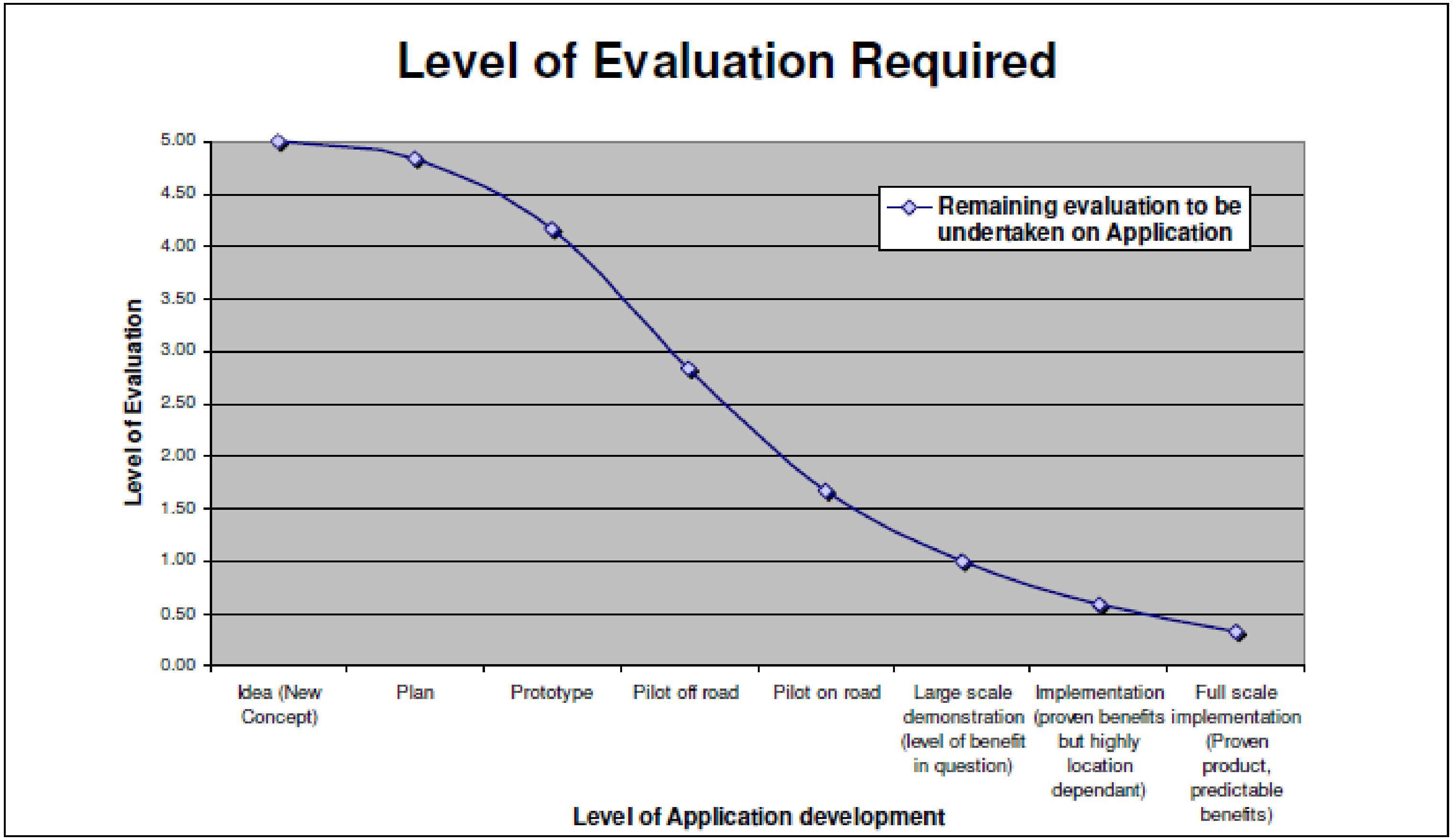
Evaluation of FOTs

- **Why Evaluate ITS?**
  - Understand the impacts
  - Quantify the benefits
  - Help make future investment decisions
  - Optimize existing system operation and design



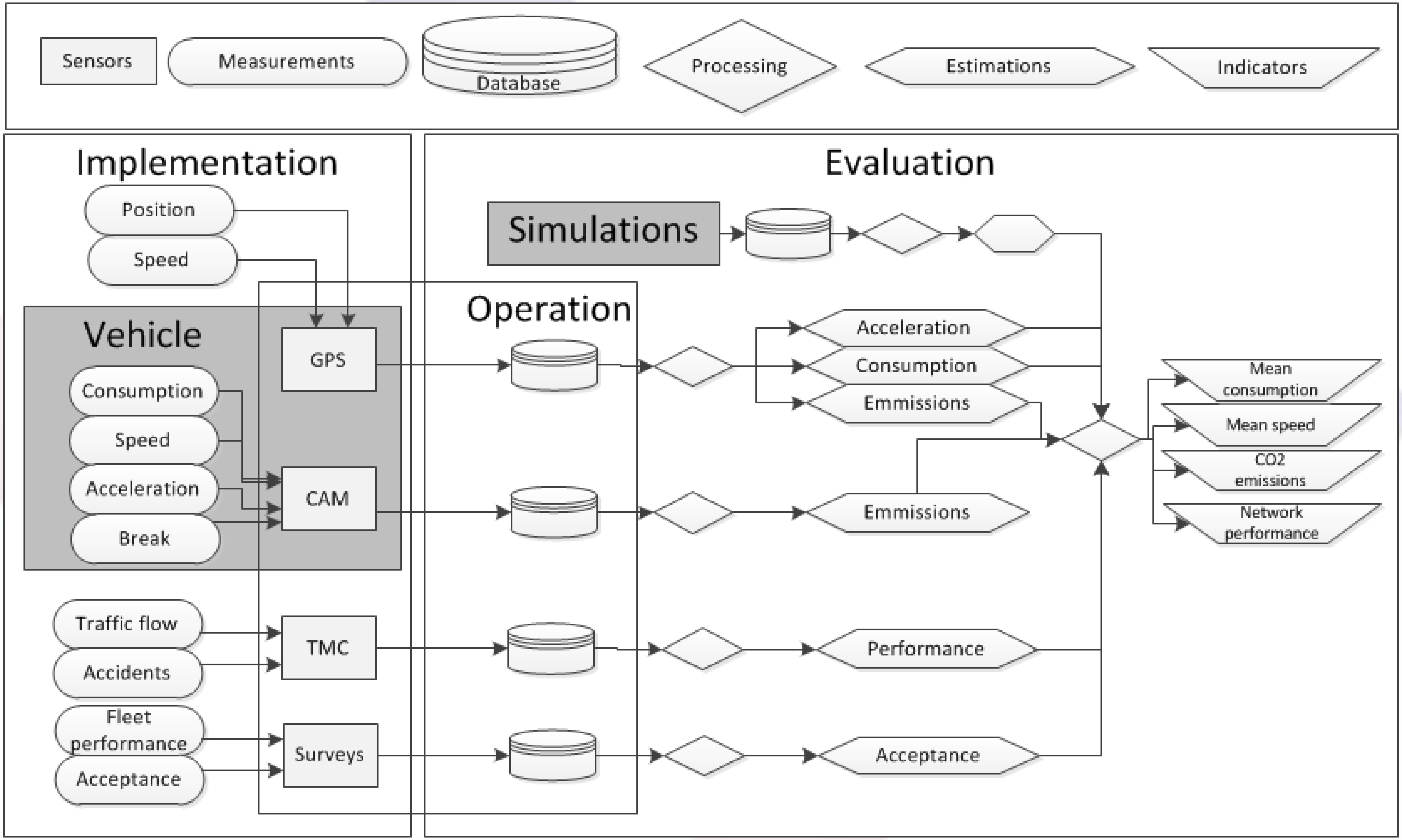
Source: MAESTRO guidelines (2002)

Evaluation of FOTs



Source: EasyWay Euro-Regional Project Evaluation Guidelines, 2005

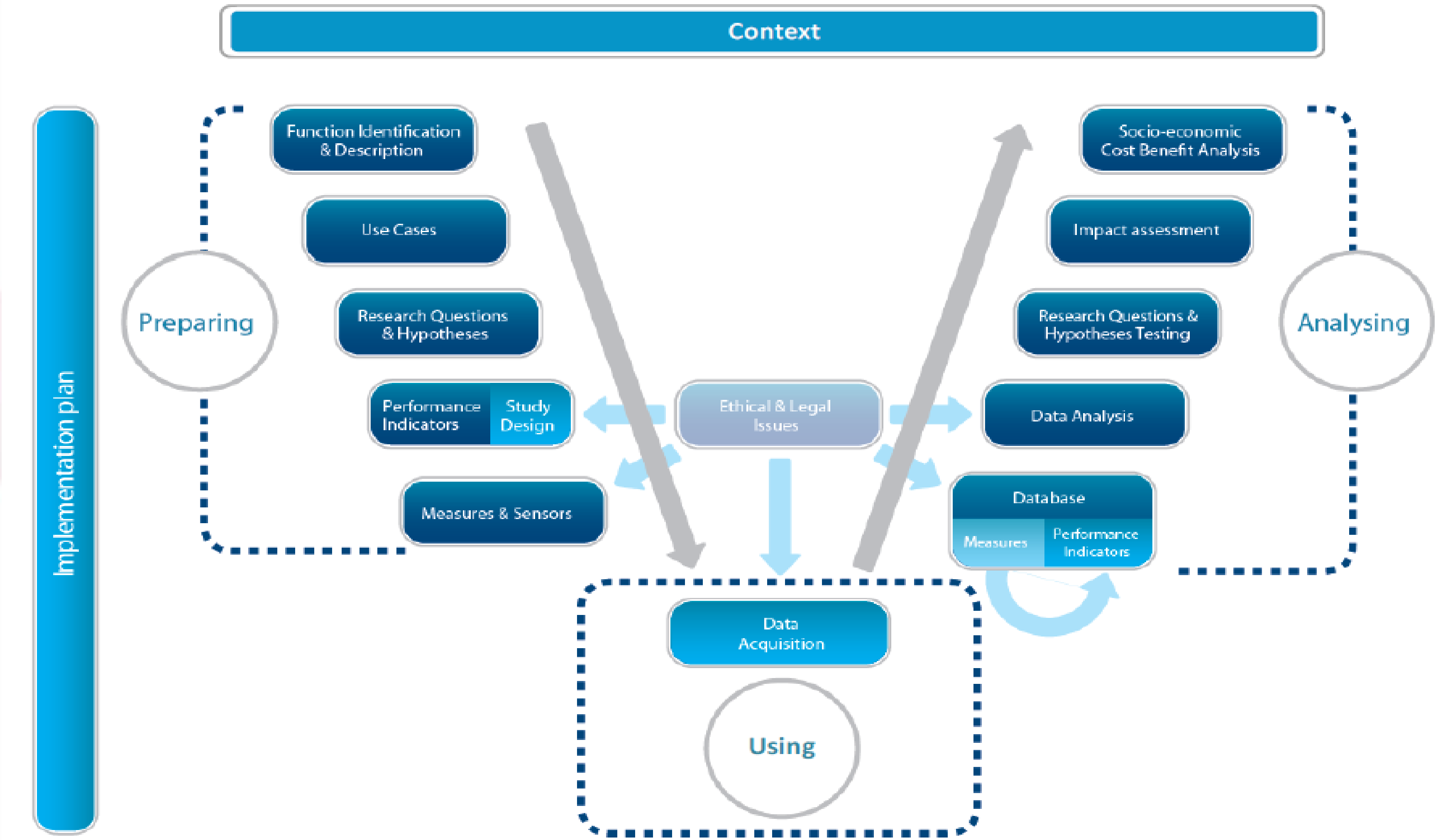
Evaluation of FOTs



The FESTA methodology

- The FESTA project was funded by one of the first FP7 calls within the Challenge 6: ICT for Mobility, Environment Sustainability and Energy of the Information and Communication Technologies Priority.
- The project aimed at the supporting of the FOTs with the provision of the **FESTA Handbook of good practices**, covering aspects such as the time-line and the administration of a FOT or the **integration of the acquired data** and **estimation of socio-economic benefits.**
- The methodology proposed in 2008 has been updated during 2011.

The FESTA methodology



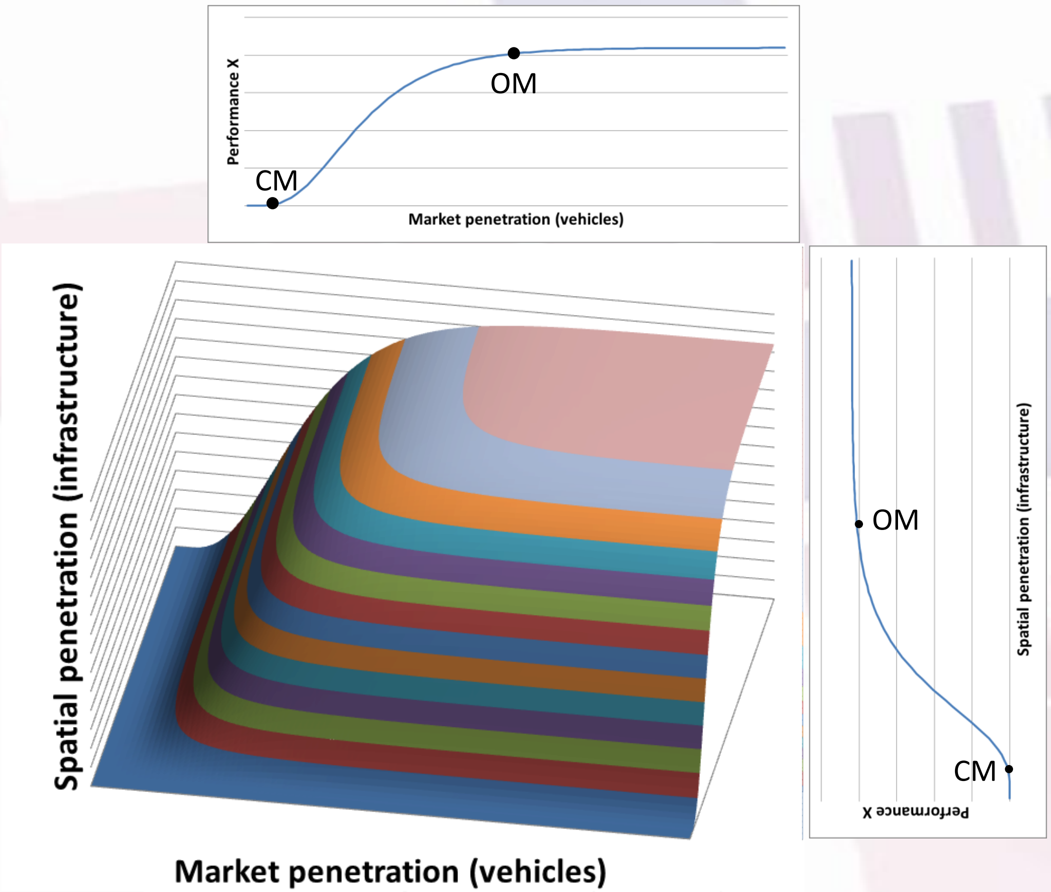
Network performance evaluation

- **Techno-economic assessment** based on the data envelopment analysis (Farrel, 1957).
- **Analytical methodology** based on continuous approximations and geometrical probabilities (Daganzo, 2010).
- **Empirical methodology** based on desktop research of the impacts of each service under various traffic conditions and network types (free flow vs congestion, urban vs interurban road) and the collection of statistical data related to the weight of each one of the abovementioned conditions.

Network performance evaluation

Techno-economic assessment

- Large-scale network simulation methodology



- CM (Critical mass): the minimum number of equipped vehicles that will have a significant impact on the network performance
- OM (Optimal mass): the minimum number of equipped vehicles that will have the maximum impact on the network performance

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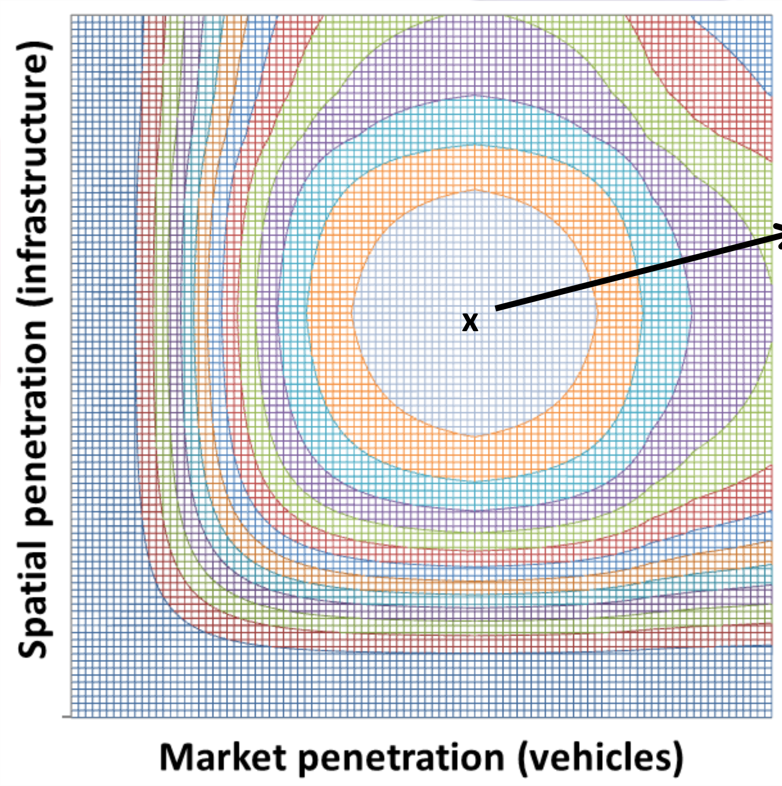
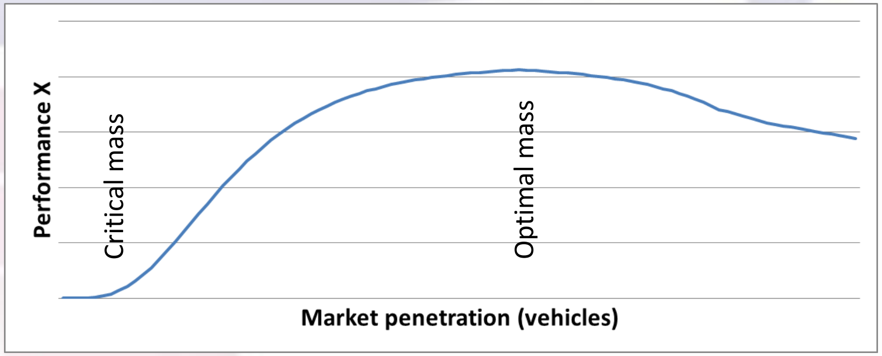
Network performance evaluation
Techno-economic assessment

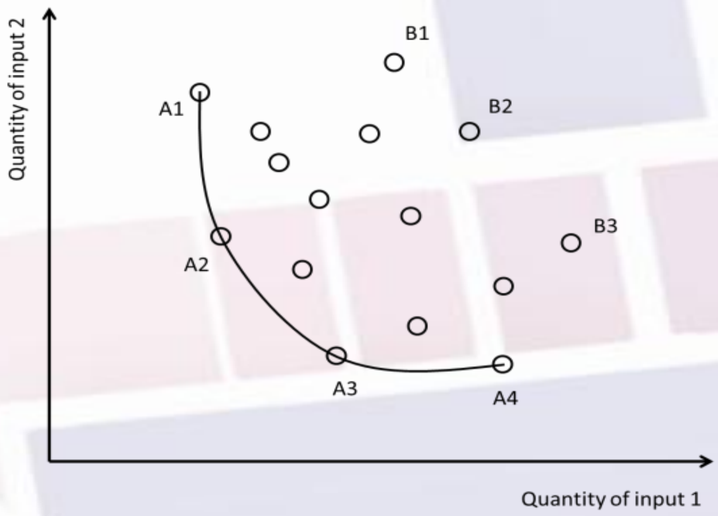
- Large-scale network simulation methodology

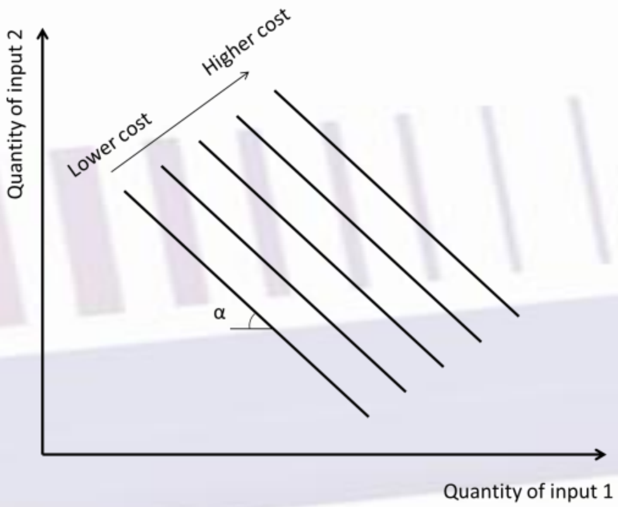


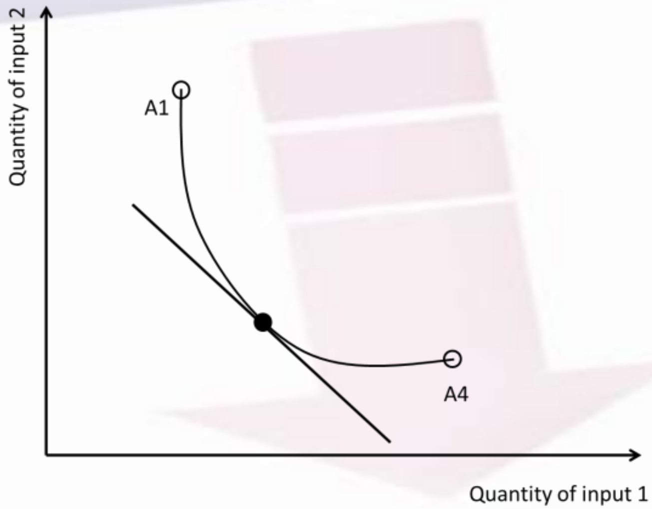
Optimal combination of equipped vehicles and infrastructure



Network performance evaluation
Techno-economic assessment







Network performance evaluation
Analytical methodology

- **Analytical formulations** for the calculation of the network performance based on basic and **generic parameters of the network geometry and demand**.
- The analytical formulations can be used for **any type of city** for assessing the performance of the cooperative services in the whole network or a part of it.
- The **characteristic parameters** of a network are the following:
  - Area of the city (A)
  - Demand for trips per unit of area and time (Λ)
  - Length of the primary road network (L)
  - Spacing between intersections (s)
  - Number of lanes (k)
  - Percentage of intersection with traffic lights (v)
  - Type of traffic lights control (fixed, actuated and adaptive)
  - Green wave factor (θ)

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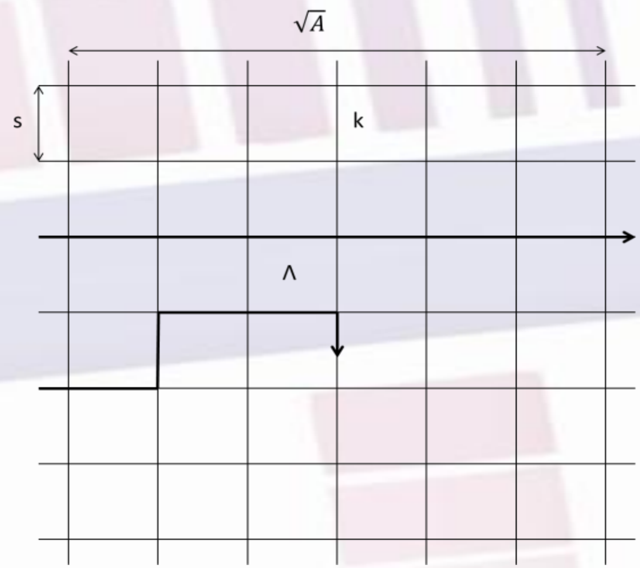
Network performance evaluation
Analytical methodology

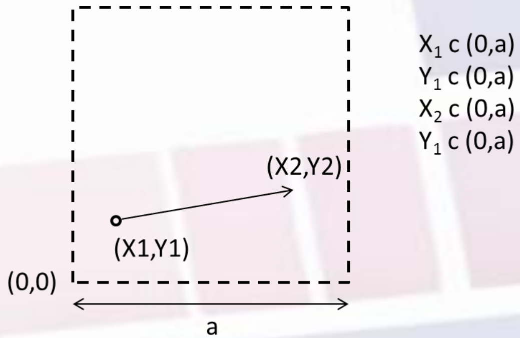
- The **theoretical city network** is composed by an orthogonal grid of streets, in order to simplify the analytical expressions, but the results can be accepted as valid also for other network geometries, since the variations will not be significant.



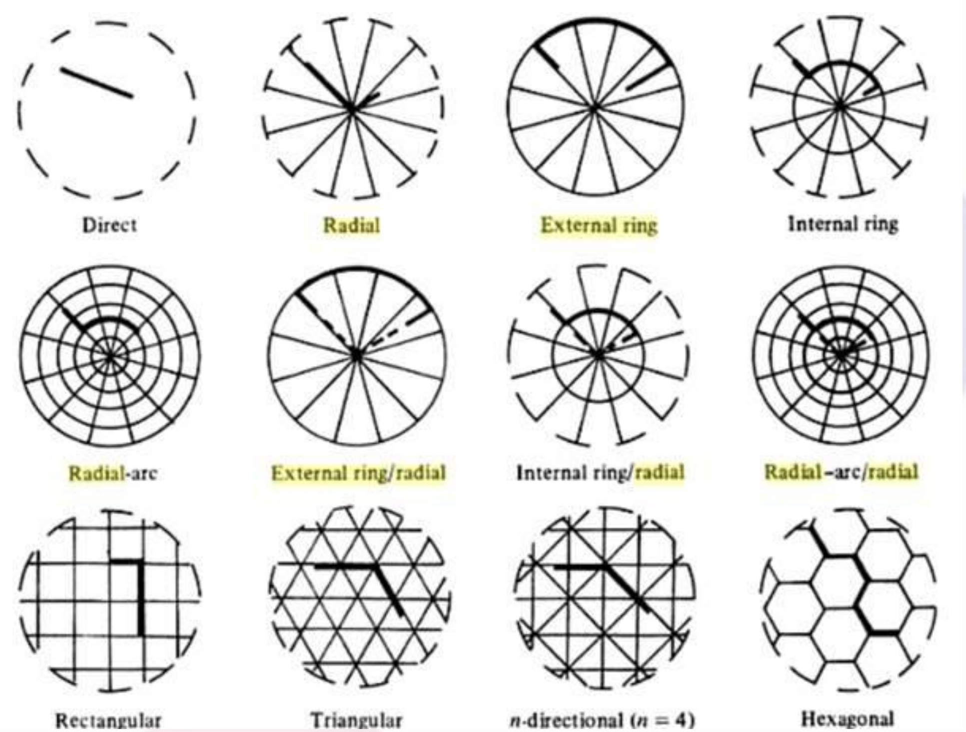
- **Various scenarios** for different **penetration rates** at both infrastructure (μ) and fleet (δ) side will be evaluated, in order to analyze benefits and costs of the implementation of cooperative services.

Network performance evaluation
Analytical methodology

- Estimation of the **average trip distance**



$$d = r \cdot 0.5 \cdot \sqrt{A}$$



Network	Network parameter		
	Smeed	Holroyd	r
Direct distance		0.905	1.00
Radial		1.333	1.47
External ring		2.237	2.47
Internal ring		1.445	1.59
Radial arc		1.104	1.21
Rectangular	0.78 – 0.97	1.153	1.27
Triangular		0.998	1.1
Hexagonal		1.153	1.27
Irregular	0.80 – 1.06		

Network performance evaluation
Analytical methodology

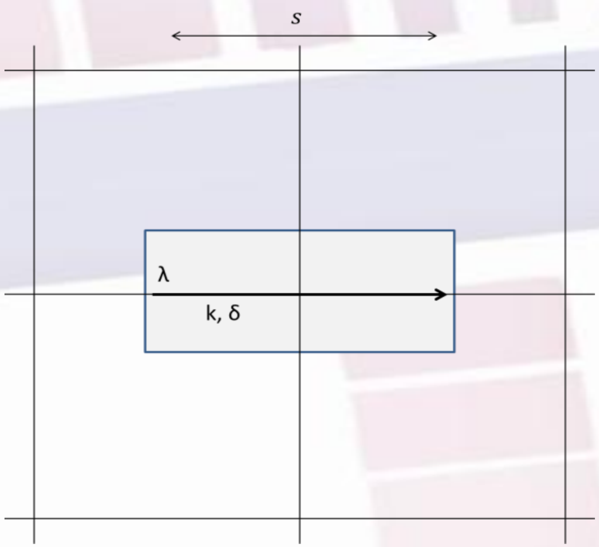
- Estimation of the **demand per road section**

The total vehicle-kilometers in the city can be obtained by multiplying the total demand (λA) and the average trip distance (d). The total vehicle-kilometers per unit of distance are obtained by dividing with the road network length (L).

$$\lambda = \frac{\Lambda \cdot A \cdot d}{L}$$

Network performance evaluation
Analytical methodology

- **Simulation tools** can be used for estimating these benefits for various **simplified scenarios**, composed by one street and one traffic light.
- The scenarios can account for different **demand levels** (λ), **number of lanes** (k) and **penetration rates at the vehicles side** (δ).



- The **output of the simulations** is the benefit (B) of the provision of the services for the whole fleet at the proximities of the traffic light (eg approx. 200 meters).

Network performance evaluation
Analytical methodology

- Estimation of the fuel consumption reduction at network level

It is important to highlight at this point that for distances between intersections below a minimum value no benefits exist since the service cannot operate appropriately (empirical finding).

$$Benefit\ at\ network\ level = \frac{400 \cdot B}{2s} \cdot \theta \cdot \nu \cdot \mu$$

- Percentage of intersection with traffic lights (ν)
- Spacing between intersections (s)
- Penetration rate at infrastructure side (μ)
- Green wave factor (θ)

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Network performance evaluation
Empirical methodology

- **Statistical extrapolation** of the **measured results** at intersection, section and route level to a larger geographical scale (the entire network).
- This methodology does not require simulation analysis, but it requires a **desktop research** of statistical data at city or country level related to the tested scenarios.
- The main disadvantage is that secondary or indirect effects cannot be easily taken into account.
- The **data** that should be collected is the following:
  - Number of vehicles of the same type in the city/region/country
  - Number of vehicle-kilometers per vehicle in the same specific conditions as in the pilot
  - Total emissions per vehicle type and type of road in the same specific conditions as in the pilot

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Network performance evaluation

Empirical methodology

Scaling up

Distribution (%)		Road group 2					
		Rg2.1	…	Rg2.j	…	Rg2.m-1	Rg2.m
Vehicle group 1	Vg1.1						
	…						
	Vg1.i			Dp_{ij}			
	…						
	Vg1.n-1						
	Vg1.n						

Measured (during project)

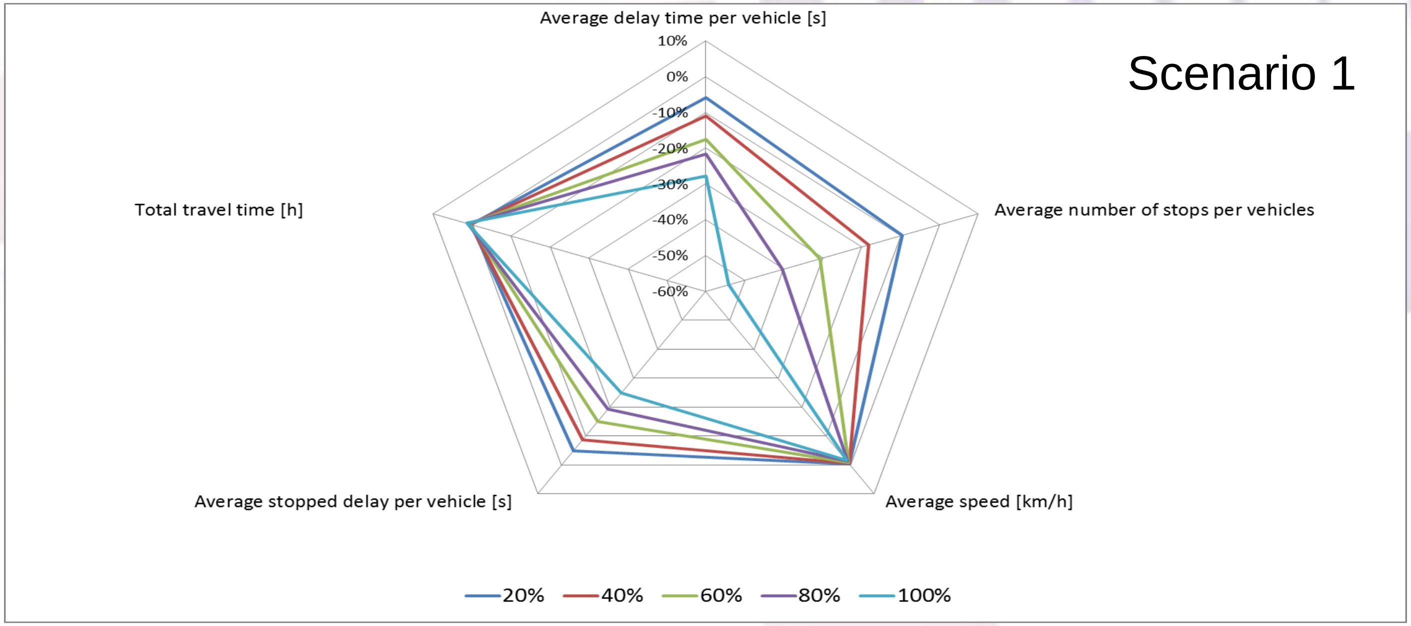
Fuel consumption reduction or emissions reduction		Road group 2					
		Rg2.1	…	Rg2.j	…	Rg2.m-1	Rg2.m
Vehicle group 1	Vg1.1						
	…						
	Vg1.i			Rp_{ij}			
	…						
	Vg1.n-1						
	Vg1.n						

$$Reduction\ percentage\ at\ network\ level = \sum_{n}^{i=1} \sum_{m}^{j=1} Rp_{ij} * Dp_{ij}$$

Network performance evaluation
Example: EEIS in Thessaloniki

Four scenarios have been simulated by incrementing the flow on the principal road:

- Scenario 1: Low flow conditions 1.000 veh/h (V/C~0.33)



- Scenario 2: Medium flow conditions 2.000 veh/h (V/C~0.66)
- Scenario 3: Congested flow conditions 3.000 veh/h (V/C~1)
- Scenario 4: Over-congested flow conditions 3.500 veh/h (V/C>1)

Network performance evaluation
Use case: EEIS in Thessaloniki

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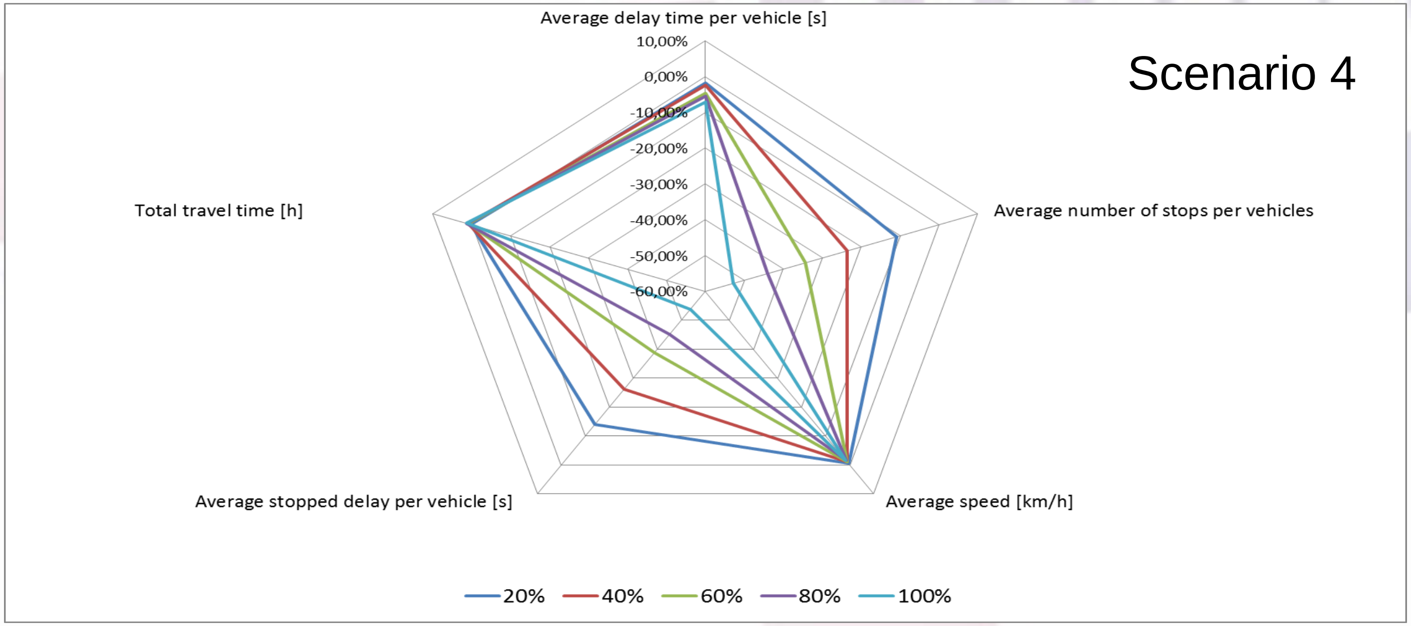

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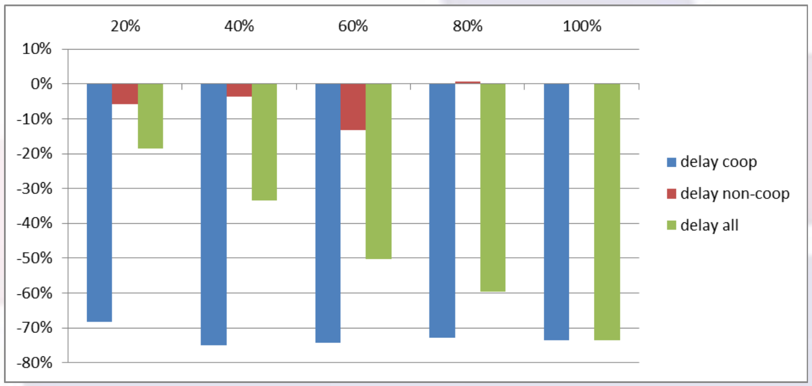
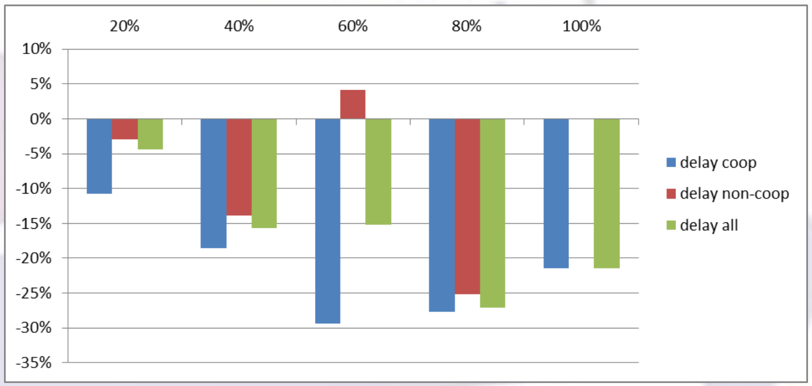
Network performance evaluation
Use case: EEIS in Thessaloniki

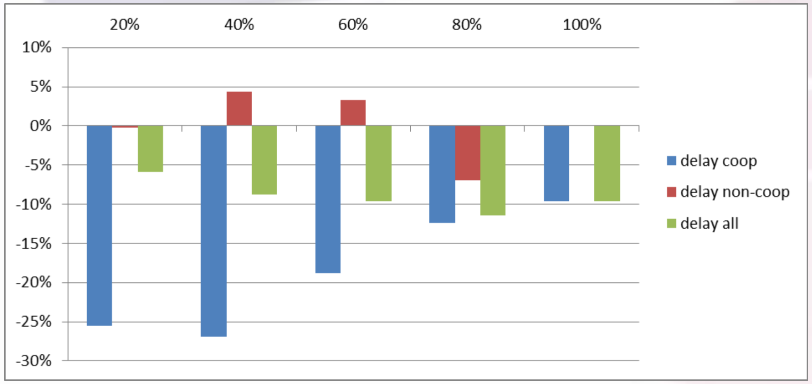
Results at vehicle level



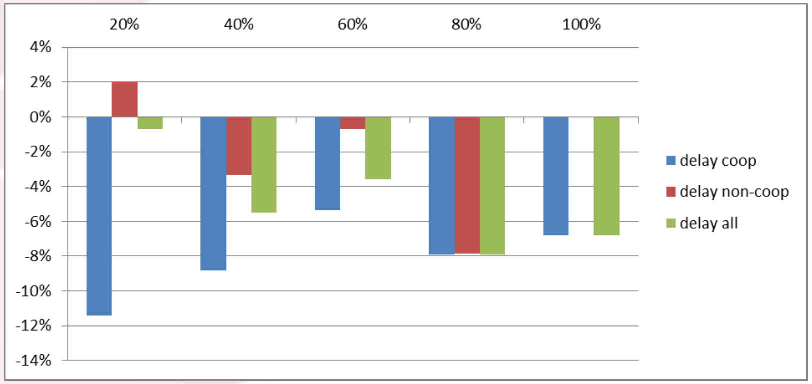
Senario 1



Senario 2



Senario 3



Senario 4

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Importance of datasets

- Data sources
- Data monitoring
- Data privacy
- Data analyses
- BIG DATA

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