OPTIMA
a simulation tool for real-time dynamic traffic prediction

Yuanyuan Wang
PTV China- PTV Group
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Shanghai China

Some Objectives…

- *"Predict future effects for the next 30 minutes and evaluate strategies within the next 5 minutes"* [1]

- *"From a reactive to a proactive approach to traffic management and infomobility"*

- *"Provide reliable, on-time, useful traveler information"*

[1] Transport for London vision for traffic management

Many questions…

- There is an incident
  - **Estimation**
    - It is producing congestion?
    - Does it affect my journey?
  - **Prediction**
    - How long will be the queue in 15 minutes?
    - How long will it take to go back to normal conditions?
    - How many vehicles will be blocked or significantly delayed?
    - How much late I will arrive at the office?
  - **Decision Support**
    - Should we close the road completely to accelerate clearance operation or should we leave one lane open to allow some traffic through?
    - Should I change route or just stay where I am or maybe stop for a coffee because there no way I will get to the office this morning?

From data to information: How to bridge the gap?

- ITS Significant technological developments in ITS
  - On the input side: automatic and time-continuous monitoring systems
  - On the output side: custom and real-time information based on wireless communication
- Today few methodological improvements to elaborate traffic data and provide mobility information
- We need transport simulation models conceived for infomobility and traffic management
- Providing accurate and realistic estimation of link travel times queues and flows, as well as their possible evolution for given scenarios
- What kind of models?

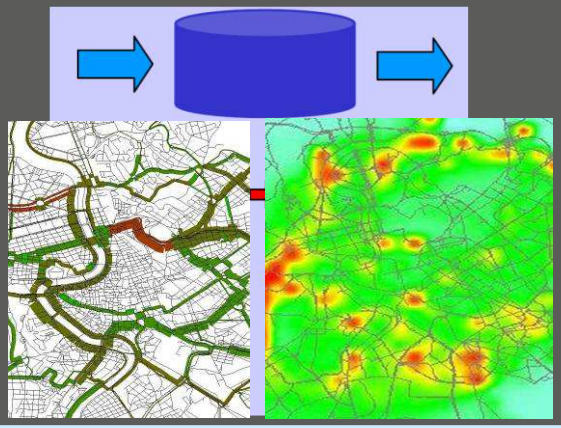
INPUT	ELABORATION	OUTPUT
		

Comparing approaches for traffic forecast

Objective → / Method ↓	Traffic Estimation *"What is going on?"*	Traffic Forecast *"What is going to happen?"*	Scenario Evaluation & Decision Support *"What would happen if?" "What should we do?"*
Observed data — EASY	Maybe with extensive measures	No	No
Statistical approach — ROBUST	YES	"usual" conditions only	No
Simulation Approach — EFFECTIVE	YES	YES	YES

Our answer: OPTIMA

- Suite of real-time dynamic simulation models and tools
- For traffic and congestion estimation and forecast

INPUT	**OPTIMA**	OUTPUT
		
▪ Veicoli sonda (bus, taxi, ncc, veicoli commerciali) ▪ Spire elettromagnetiche ▪ Telecamere con OCR ▪ Polizia municipale	▪ Modello del sistema di trasporto ▪ Simulazione ed Elaborazione Real-Time ◆ stima e previsione del traffico ◆ calcolo itinerari ottimali	▪ Stato del sistema di trasporto attuale o previsto (traffico, tempi di percorrenza, …) ▪ Strategie di intervento (Decision Support System)

Modelling approach for traffic forecast

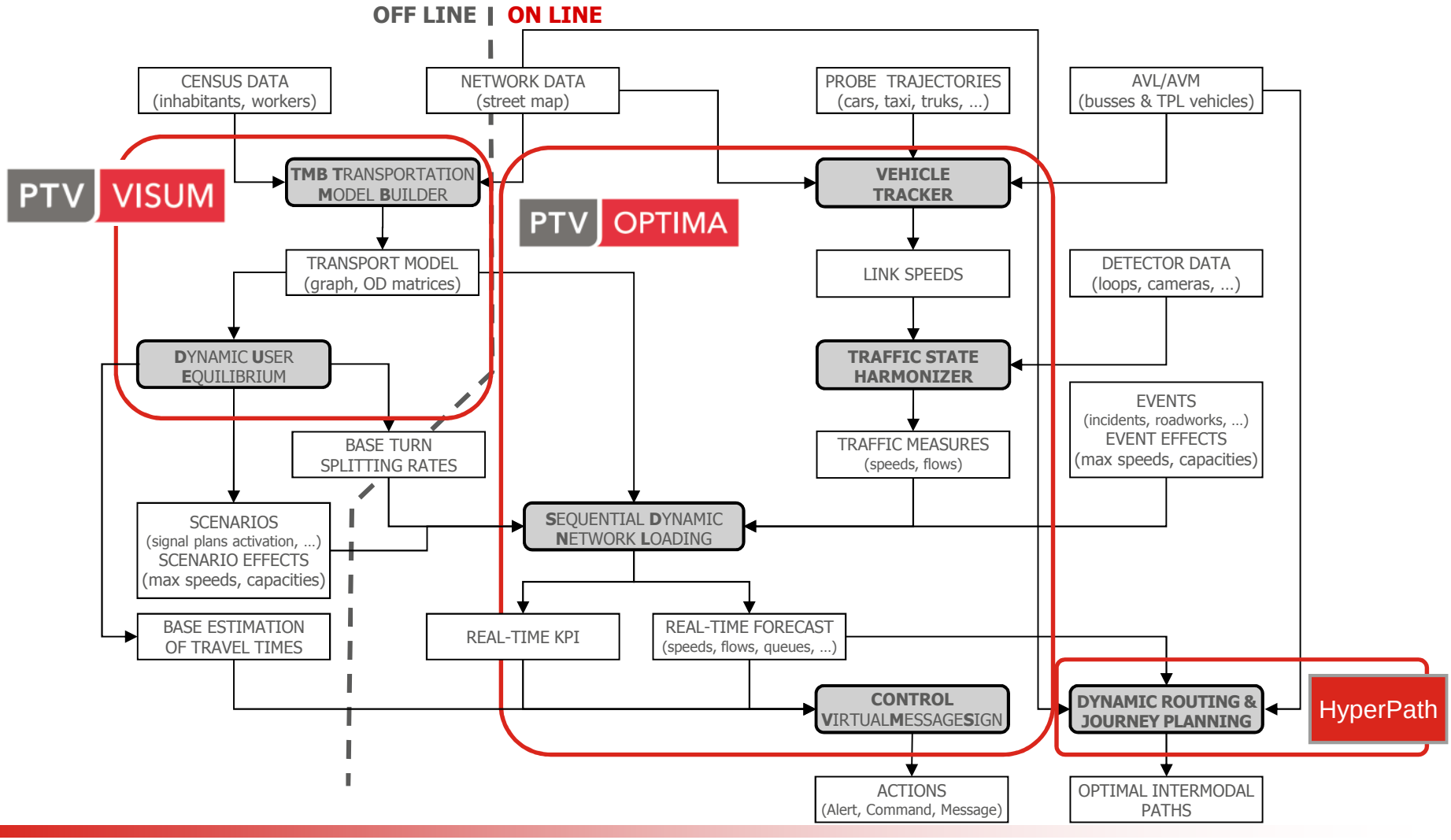
- Simulating explicitly the interaction between travel demand and road networks through dynamic traffic assignment
  - able to reproduce explicitly the formation, propagation, and dispersion of vehicle queues on the road network during the day, including spillback
- Detector counts, Floating car data and Events retrieved in real time are then used to alter in rolling horizon the base simulation of the current day type
  - corrections are applied locally to densities and capacities and are propagated on the network by the model
- Taking into account the network structure and the path flows allows also for
  - data completion and traffic estimation on links that are not monitored
  - forecast the consequences of unexpected events on the congestion
  - assess and compare alternative scenarios

OPTIMA: Approach

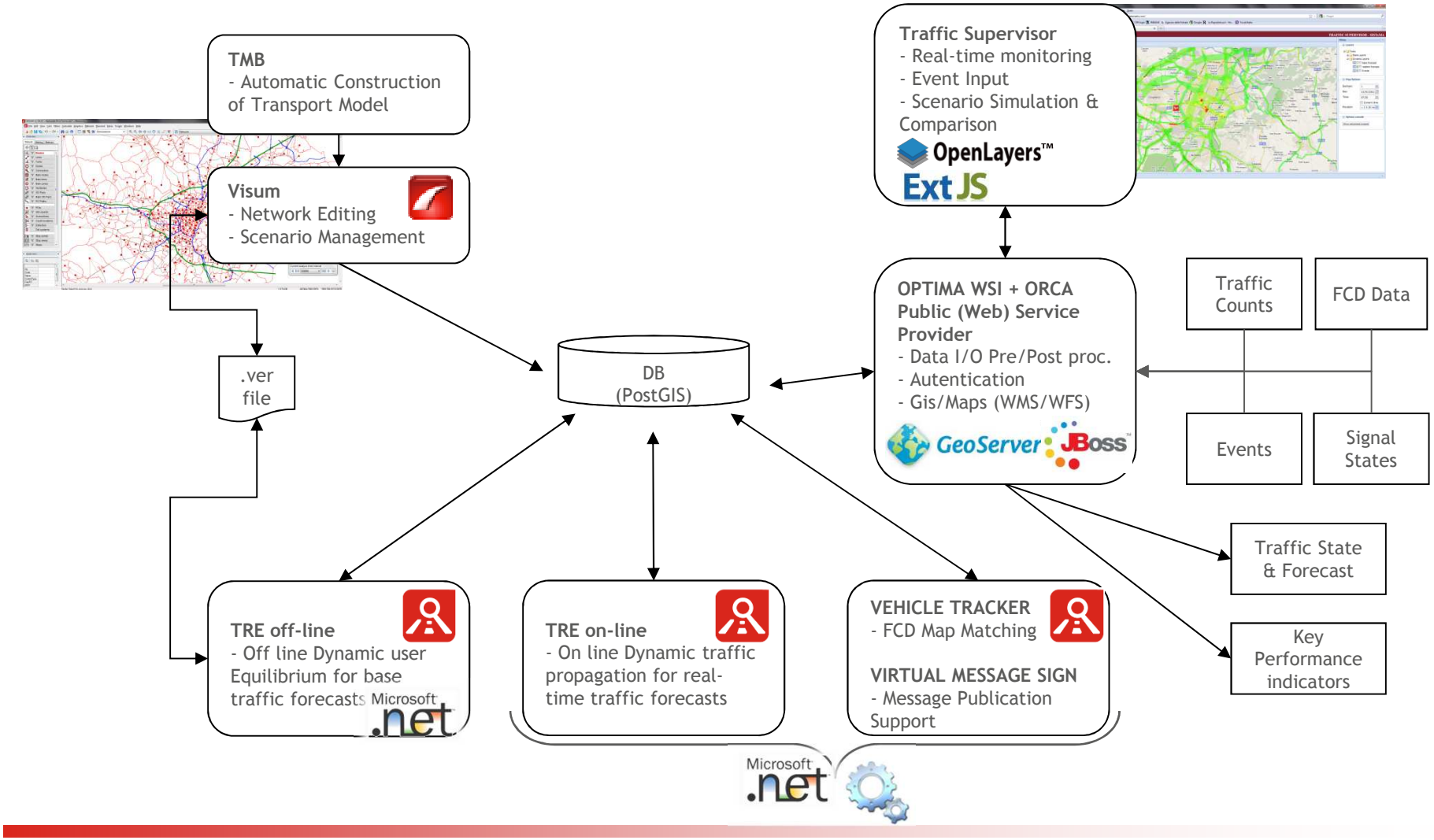
- A priori estimation of traffic patters for each day type
  - Travel time and turn probability temporal profiles
- By means of a within-day macroscopic Dynamic Assignment at equilibrium
  - Yielding route choices of users traveling on a congested networks at different times

- Short term real-time estimation of the actual traffic and travel time evolutions
- By means of a sequential (i.e. rolling horizon) macroscopic Dynamic Network Loading model
  - Yielding network flow propagations on a congested network for given OD flow and turn probability temporal profiles
- Calibrate in real-time based on measures continuously collected on the network
  - Traffic counts, FCD Data, Events

Logical & Functional Model



Architecture



Focus on: OPTIMA inputs

- **Traffic States**: all observed traffic measurements (speeds, flows, occupancies) on the read network
- **Events**: all planned (e.g. road works) or unpredictable (e.g. accidents, incidents) events on the road network
- **Trajectories**: all observed vehicle trajectory points, collected from Probe Vehicles, ANPR, CCTV or Mobile phone data, that have only spatial reference
- **Signal Control Plans/ Strategies**: all signal plans and existing bespoke response strategies that can be activated in the field
- **Signal Control Status**: current status of each signal control group (current green and cycle times, phases etc.)

Inputs Overview and Usage

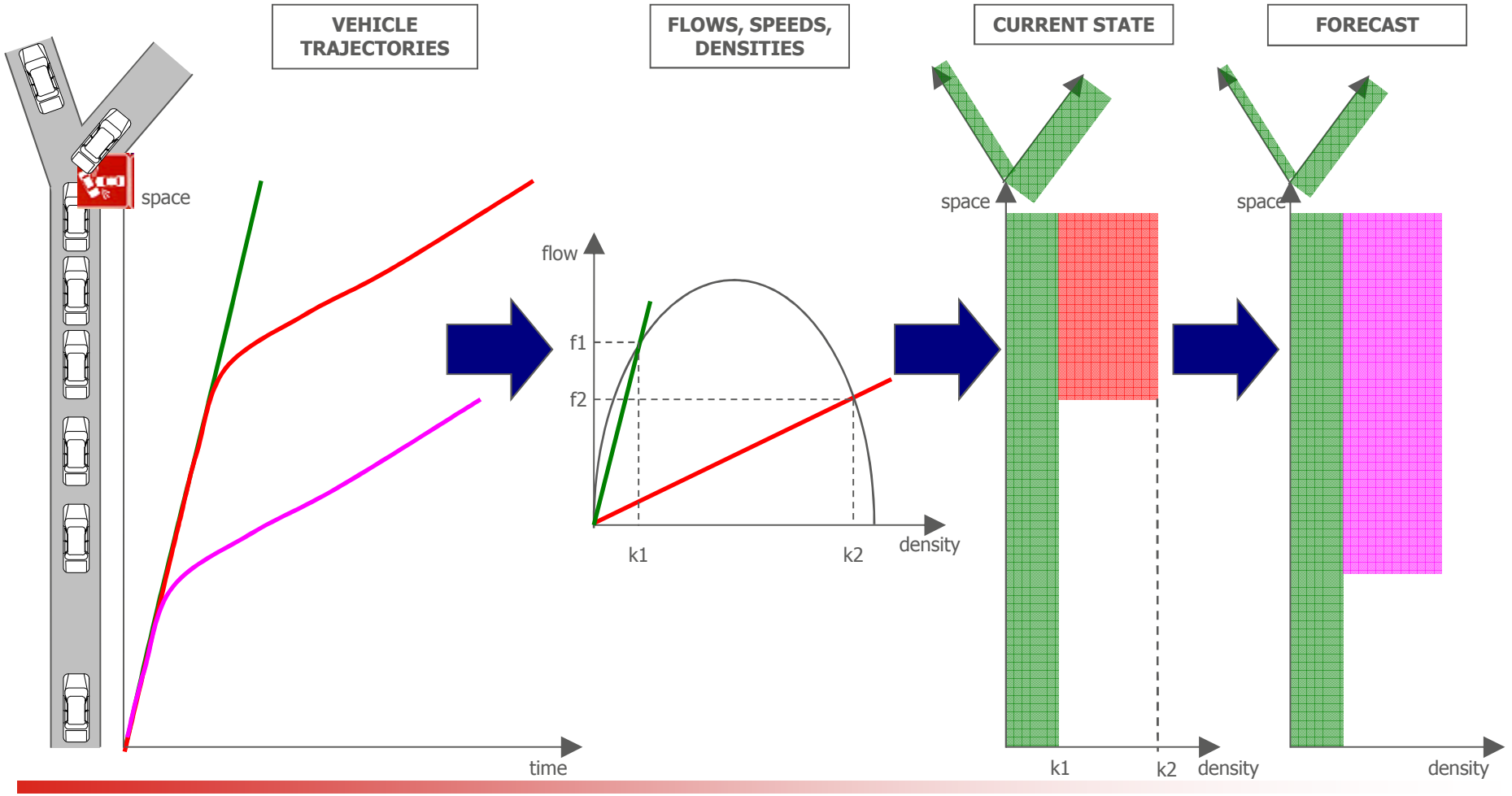
Data Object	What for?	When Needed ?	How is the data used?
Traffic Sates	Situational Awareness Incident Detection Forecast	Continuous real time data input	a. On-line correction (or calibration) of the real-time traffic estimation and forecast model, in order to adjust the simulation to reproduce and then predict actual traffic conditions b. Incident detection triggers
Events	Situational Awareness Incident Detection Forecast	Planned events should be imported before they are active. Unplanned incidents should be manually or automatically detected and introduced	Used to update network supply constraints (capacities, speeds) within the real-time traffic estimation and forecast model
Trajectories	Situational Awareness Incident Detection Forecast	Continuous real time data input	These data are transformed into Traffic State data and used accordingly
Signal Control Plans / ITS Strategies	Situational Awareness Forecast	Stored in the predictive modelling platform and updated continuously	Used to estimate current or expected delays and capacity restraints at signalised junctions within the real-time traffic estimation and forecast model
Signal Control Status	Situational Awareness Forecast	Stored in the predictive modelling platform and updated continuously	Used to estimate current or expected delays and capacity restraints at traffic junctions within the real-time traffic estimation and forecast model

Available Data interface overview

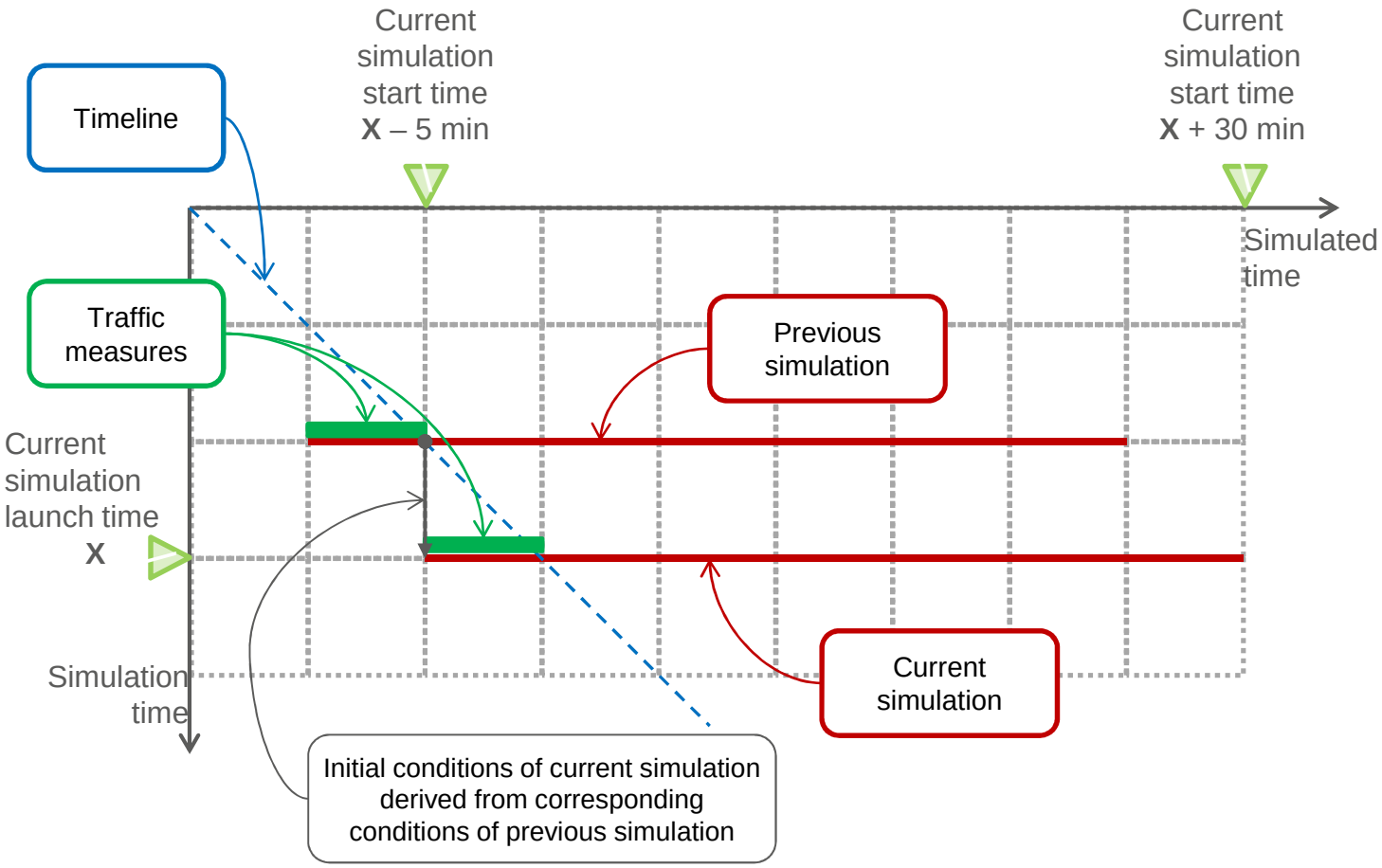
Input Data types	Location reference type	S.I.MO.NE. xml REST	ORCA 1 xml SOAP	DATEX II xml REST	WFS / DB xml json REST
Detector data	Count location ID	X	X	X	X
Measured traffic state	Link & FromNode Ids / TMCs	X		X	X
Green & Cycle	Lamp ID	X			(X)
Green & Cycle	Signal plan/group		X		X
Green & Cycle	Turn ID				X
Events	DATEX I / II	X (Datex I)	X (Datex I)	X (Datex II)	

Output Data types	Location reference type	S.I.MO.NE.	ORCA 1	DATEX II	WFS / DB
Forecasted traffic state	Link & FromNode Ids / TMCs	X	X	X	X
Traffic state	Link & FromNode Ids / TMCs	X		X	X

Focus on:
Taking into account measures



Focus on: Sequential simulation



Focus on:
En route adaptive route choice

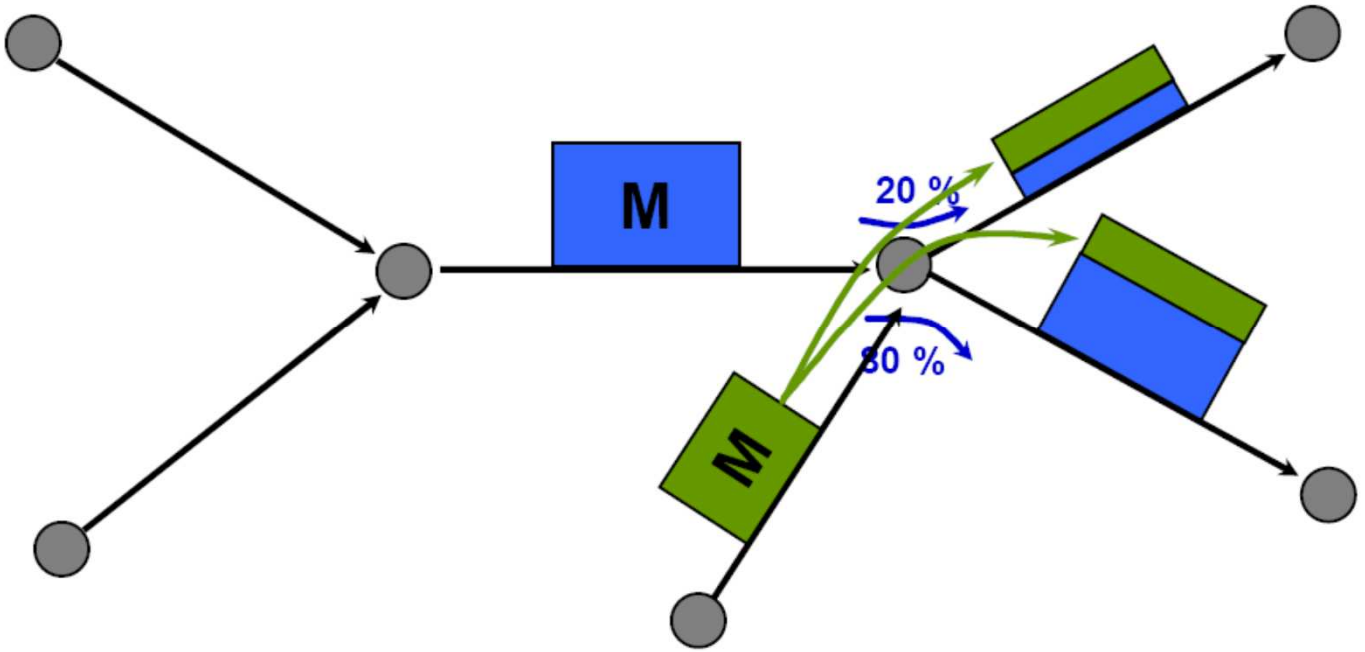
- Objective
  - Take into account user reaction to unexpected events
  - Significantly affecting network travel times
- Within the Sequential Dynamic Network Loading procedure
  - A fraction α of the total demand periodically reconsider its route choice
  - Accordingly with a LOGIT route choice model
  - Based on “current observed” link travel times
    - i.e. calculated by the model during a PAST time interval of suitable extent
  - This demand share α is propagated on the network accordingly with above splitting rates
  - While the rest of the demand (1 – α) is propagated accordingly with BASE splitting rates
    - i.e. calculated off-line by the DUE - Dynamic User Equilibrium procedure

Module SDNL - Sequential Dynamic Network Loading

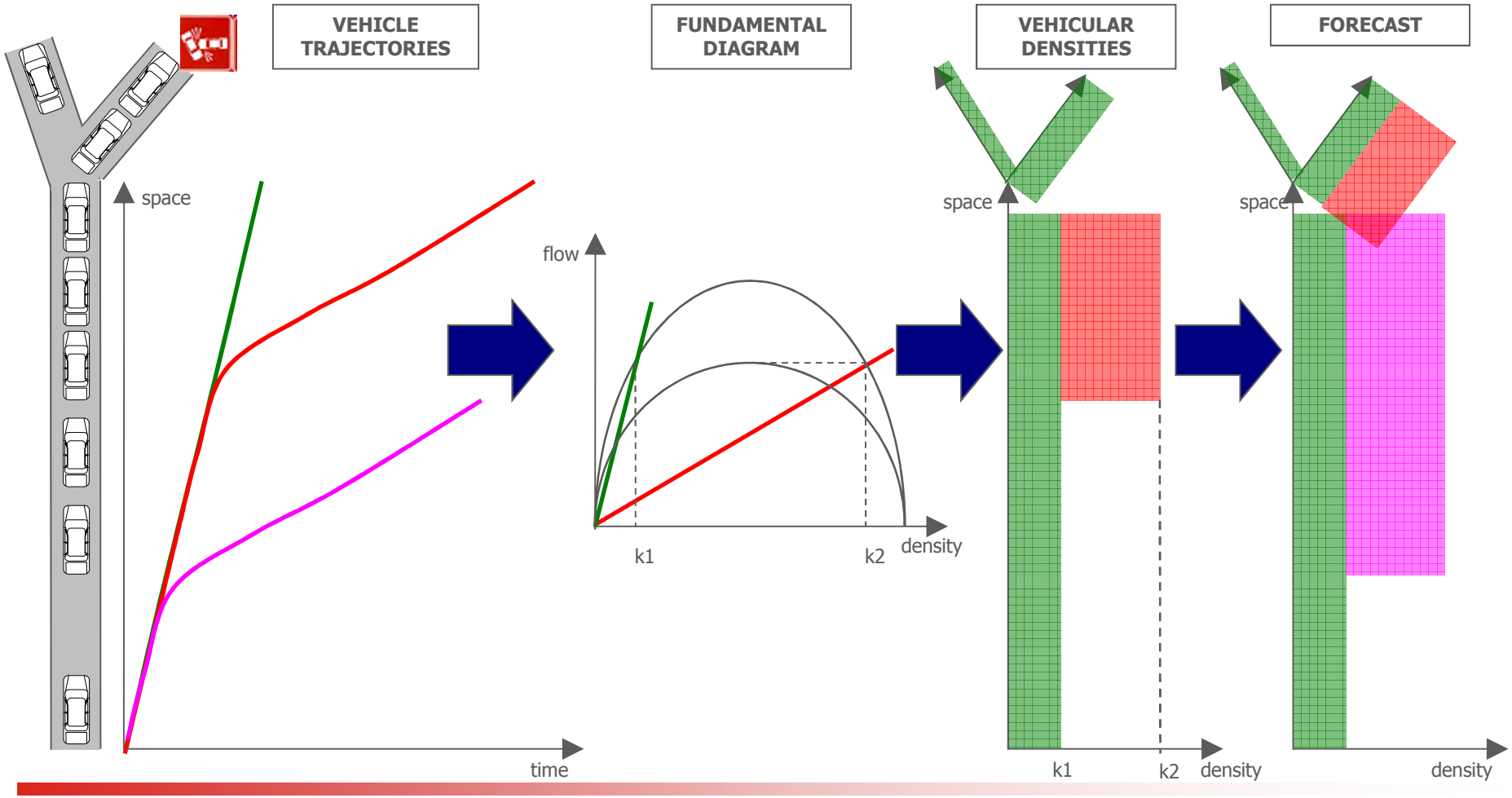
- Network flow propagation model with rolling horizon
- Produces a traffic flow estimation and short term forecast
- Based on real-time traffic measures and events
- Model outline
  - Based on a macroscopic flow model named General Link Transmission Model (Gentile, 2008)
    - evolution of models based on the Simplyfied Kinematic Wave Theory
  - Transforms traffic measures (vehicle counts, trajectories, …) into density and capacity measures
  - Propagates on the network OD flows locally corrected by measured density coherently with base and measured capacities
  - Thus it extends punctual measures
    - In space (to the whole network)

Flow Propagation

Time varying diversion probability at nodes (splitting rates)



Effects of trajectory measures



Module DSPS - Dynamic Shortest Path Search

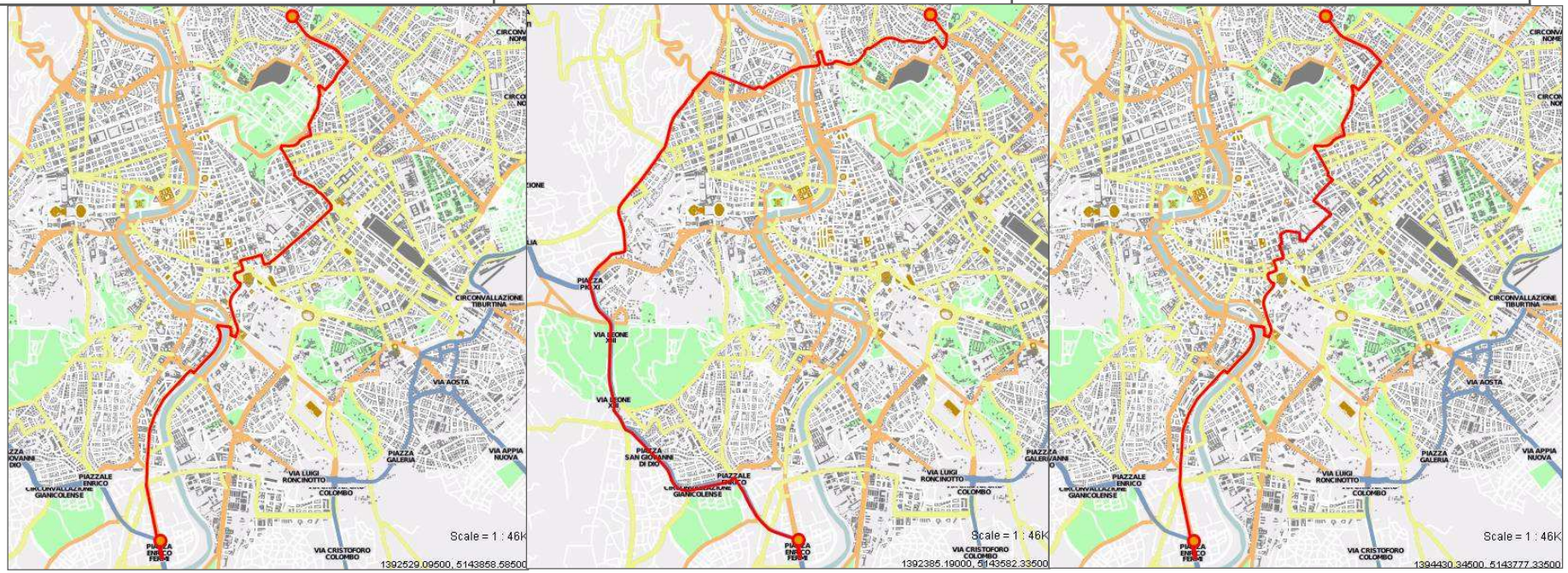
- Produces Optimal routes
- In presence of time-varying link travel times and costs
- Based on actual and forecasted traffic conditions

- Model Outline
  - Dynamic shortest path algorithm
  - Optimal routes are chosen based on evolution over time of transport network state (congestion, limited access zones, …)
  - Trajectory based: not optimal yet reasonable (i.e. acceptable) solutions
  - A*-like with some brunch-pruning heuristics

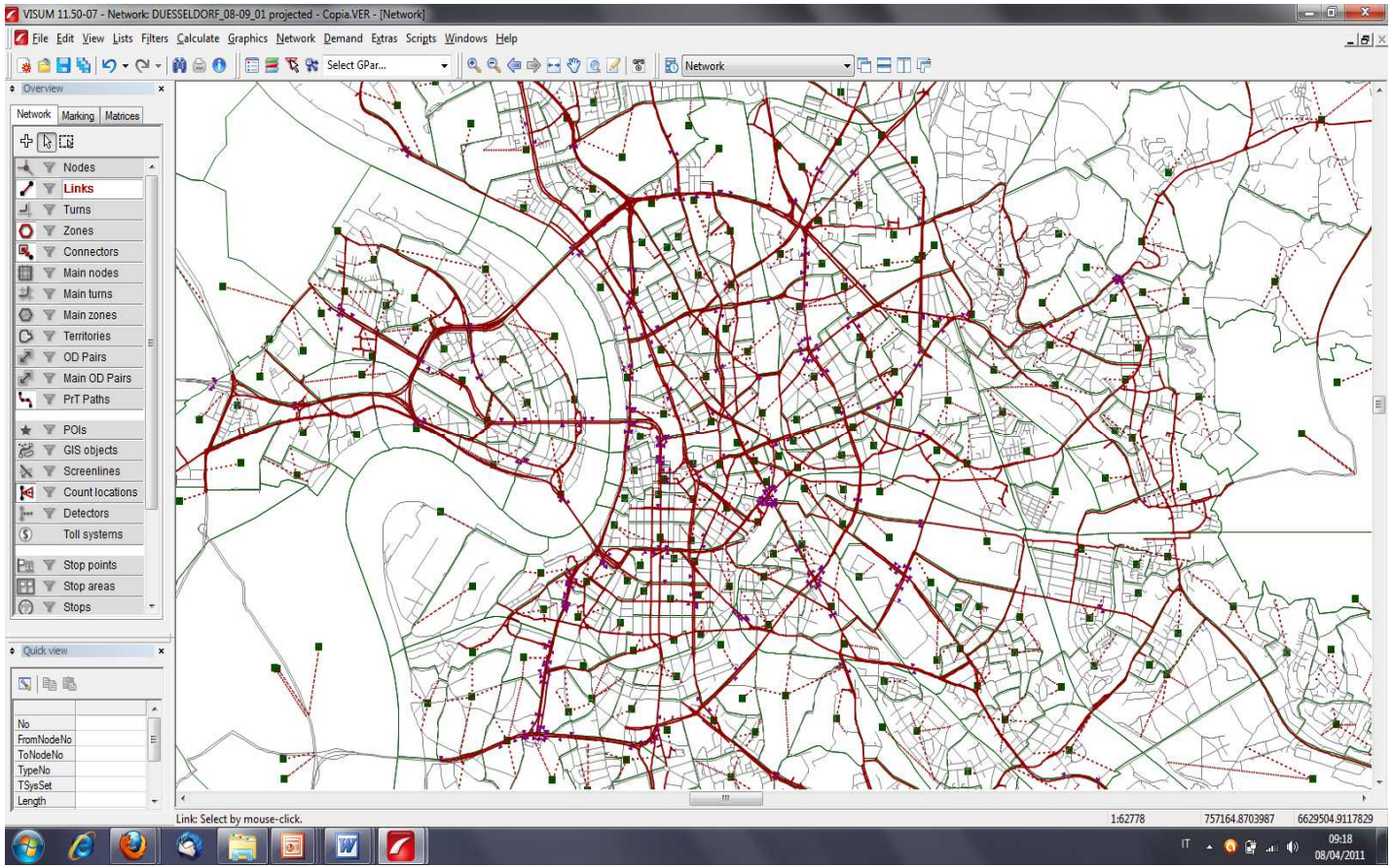
Example of Optimal Paths

- Viale Parioli – Piazza Enrico Fermi

Ore 06:00 - 20 min	Ore 08:00 - 25 min	Ore 18:00 - 24 min

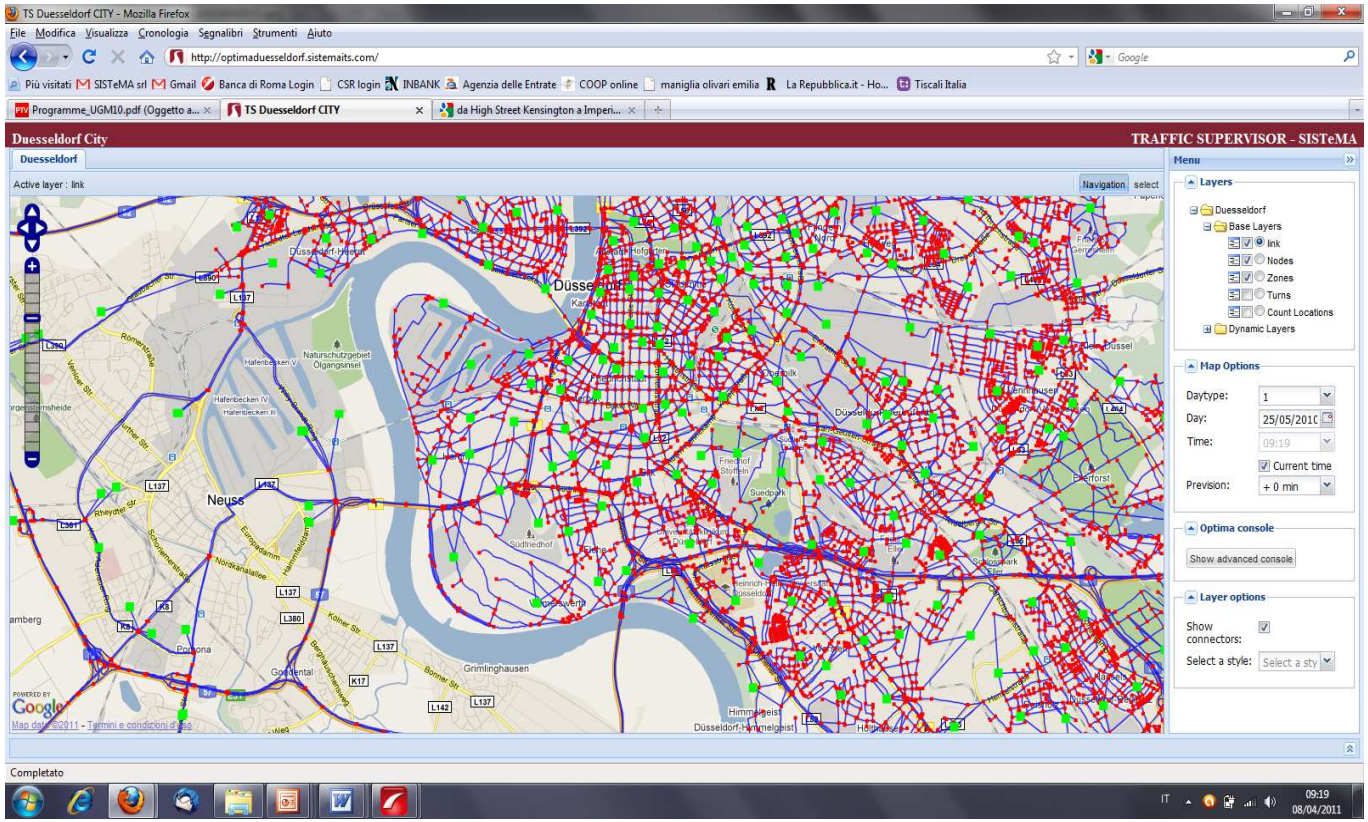


Module VISUM: Transport model setup



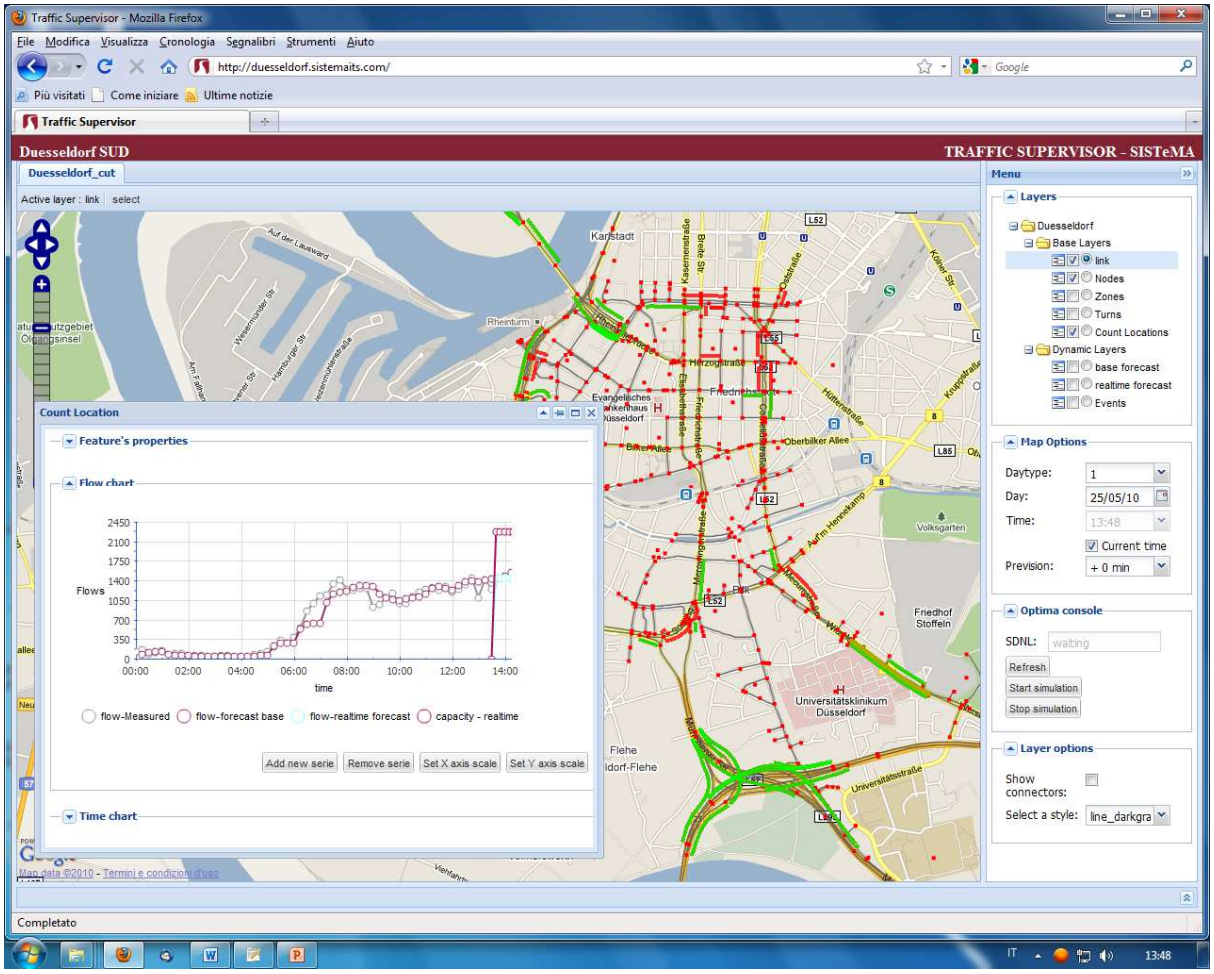
- Build, calibrate, test, update model

Traffic Supervisor: Set-up of the realtime environment



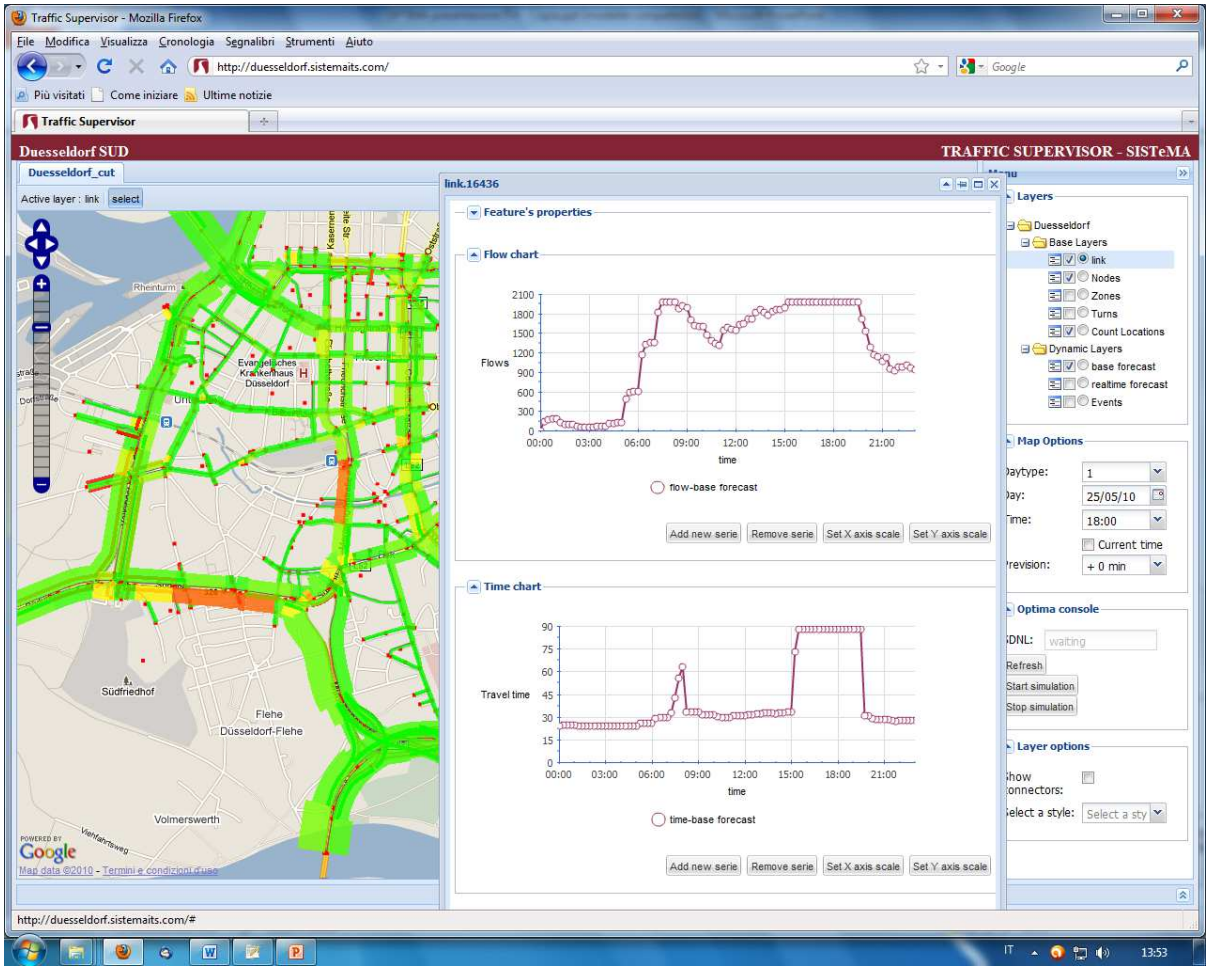
- Direct export
- From VISUM
- To the real-time web based OPTIMA environment

Traffic Supervisor: Loop detectors and FCD realtime monitoring



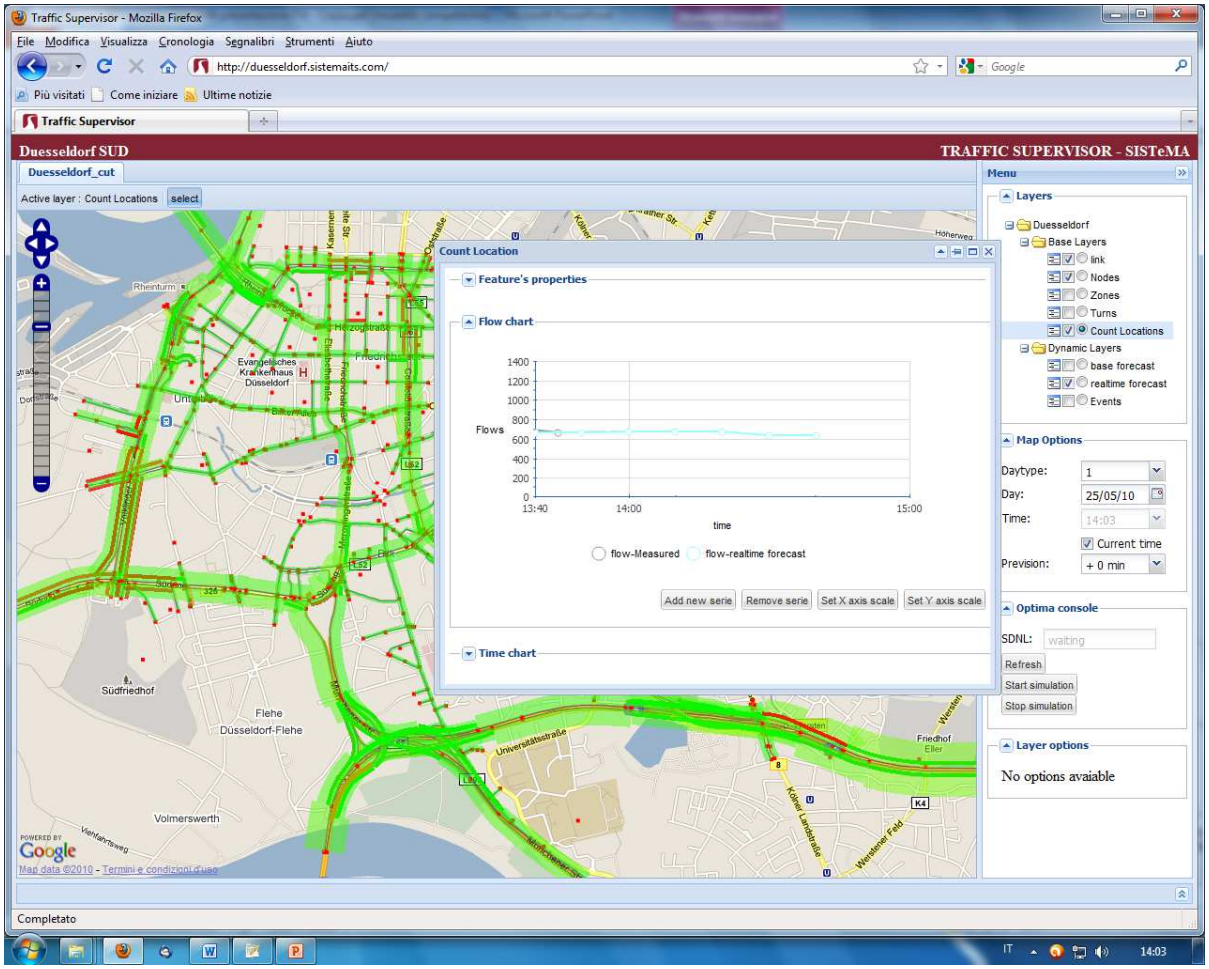
- Fixed and moving probes
- Don't cover the whole network
- Allow forecast only when easy
- They can be integrated with transport models
- For realtime data completion and traffic forecast

Traffic Supervisor: Daytype base forecast
Dynamic Traffic Assignment



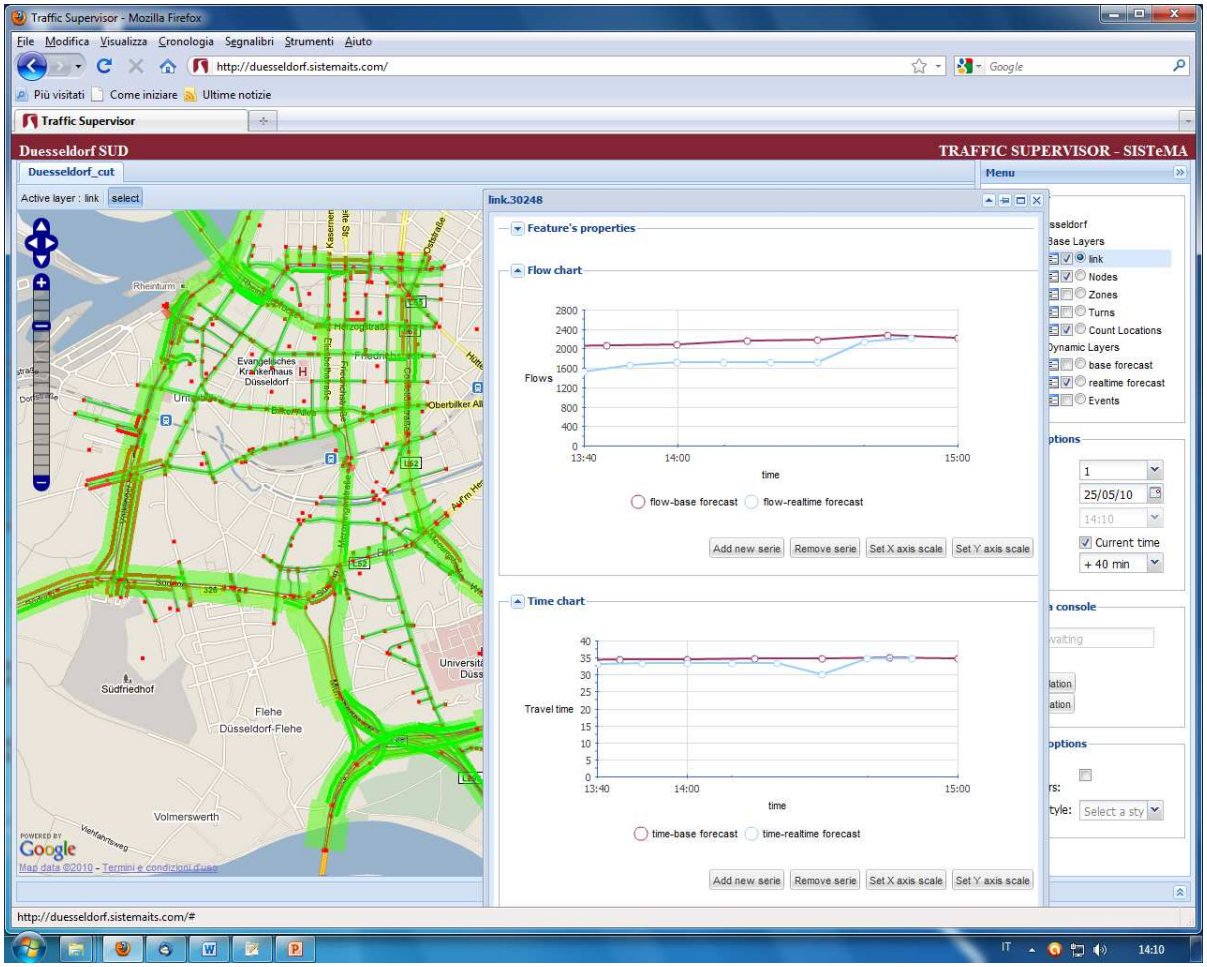
- Dynamic User Equilibrium
- Variables are functions of time
- Travel demand Origin-Destination matrices
- Road network with speeds and turn capacities
- Macroscopic flow model can reproduce queues and spillback
- Yields route choice as splitting rates

Traffic Supervisor: Realtime data completion



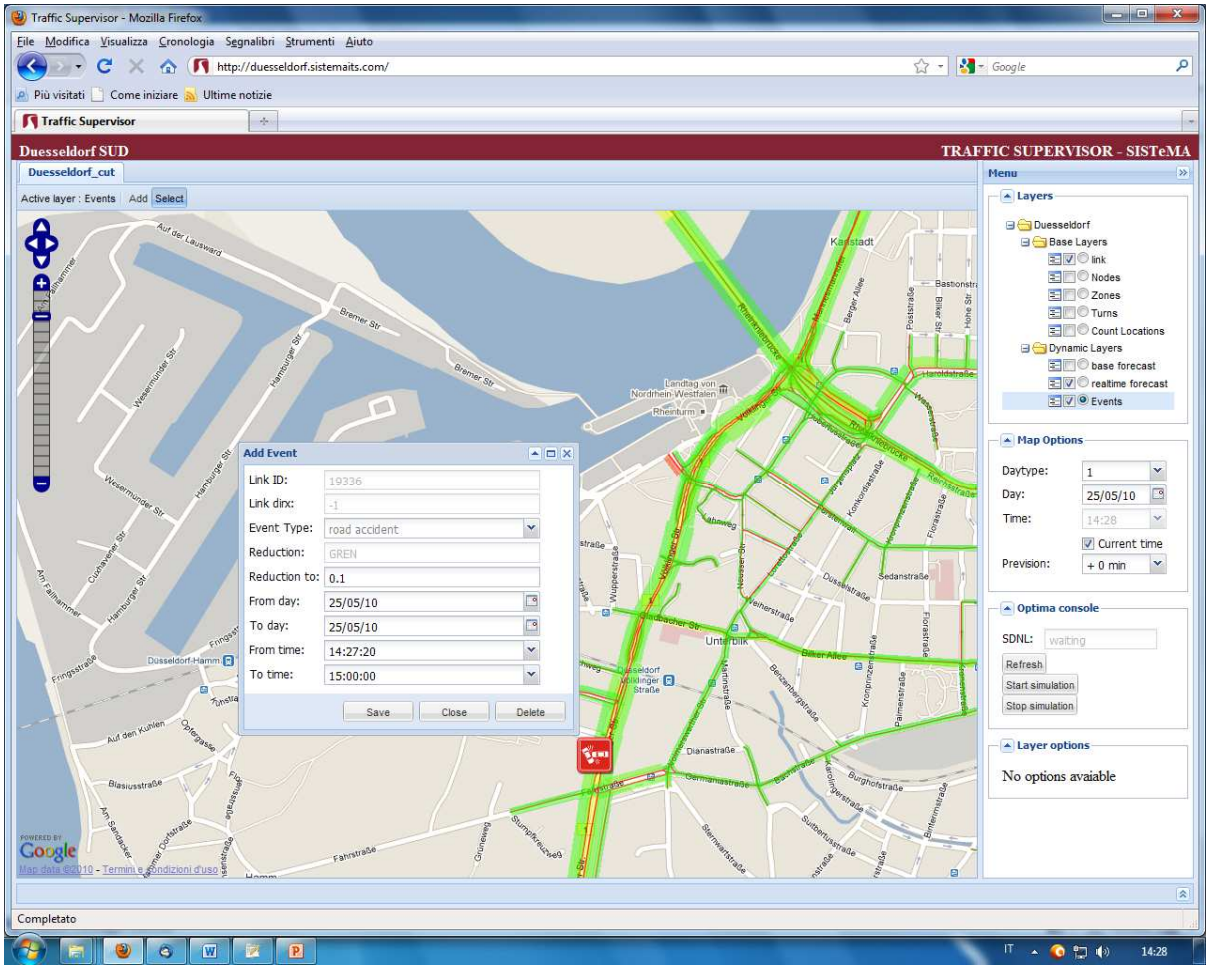
- Flow and queue corrections on monitored links
- Propagate on the network based on day type time varying splitting rates
- This allows to estimate congestion on all links

Traffic Supervisor: Realtime traffic forecast



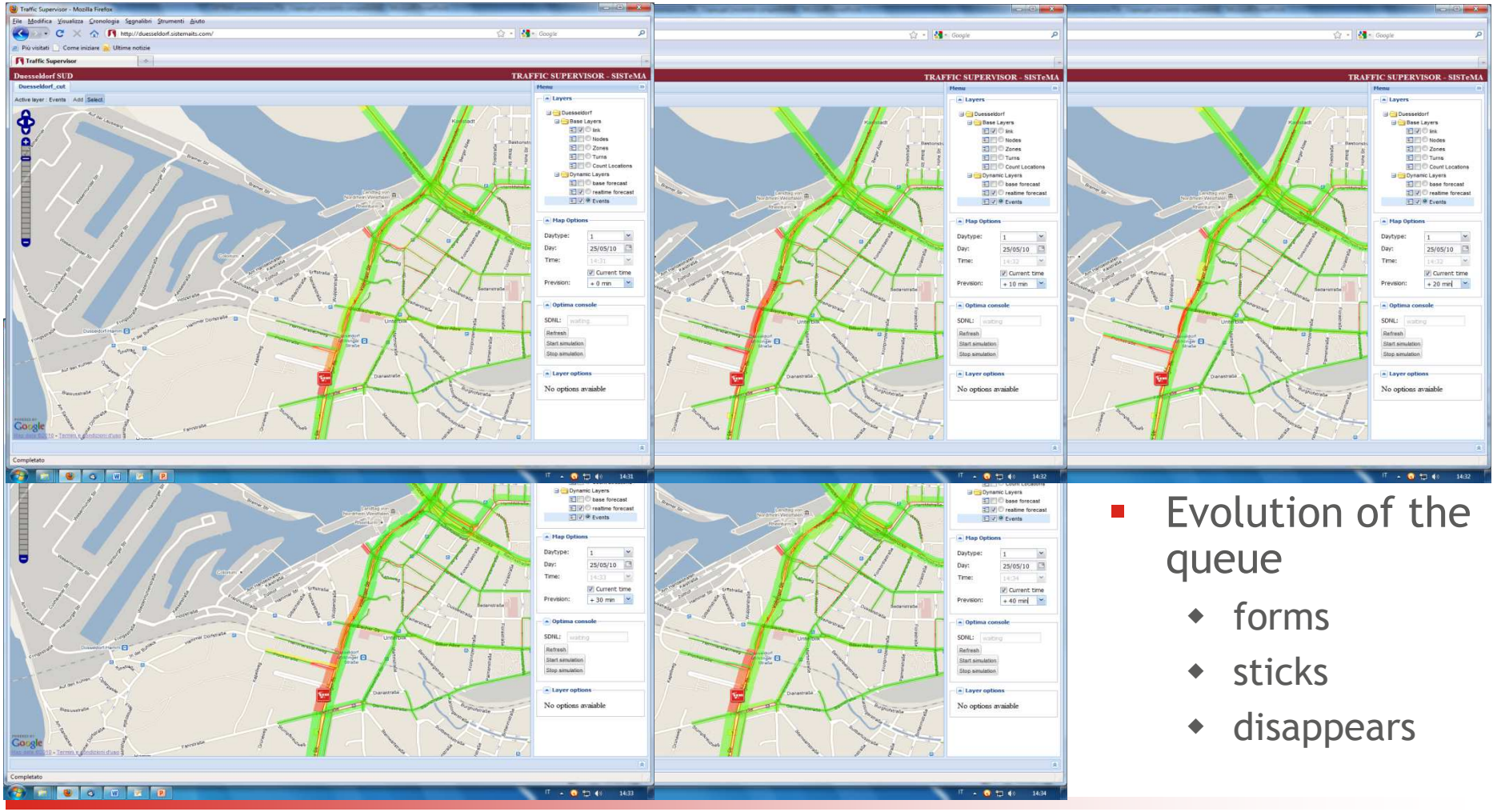
- Rolling horizon simulation
- This allows for within day forecast
- Queues are persistent and last more than vehicle travel times

Traffic Supervisor: Event manual insertion



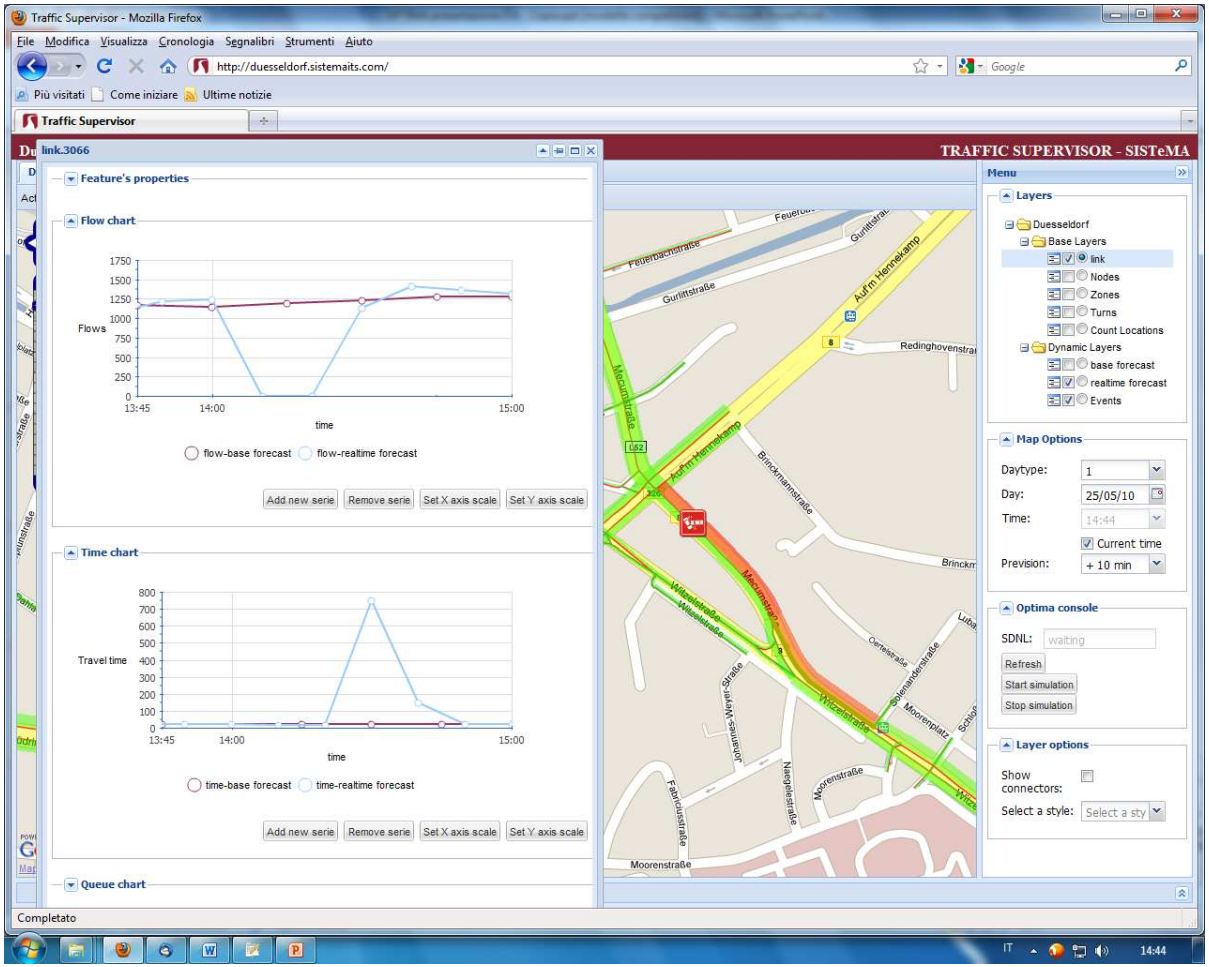
- Click on the link
- Insert
  - Event type
  - capacity reduction
  - from day and time
  - to day and time
- In this case, 30 minutes block
- Then start simulation

Traffic Supervisor: Visualize the simulated effects of the event



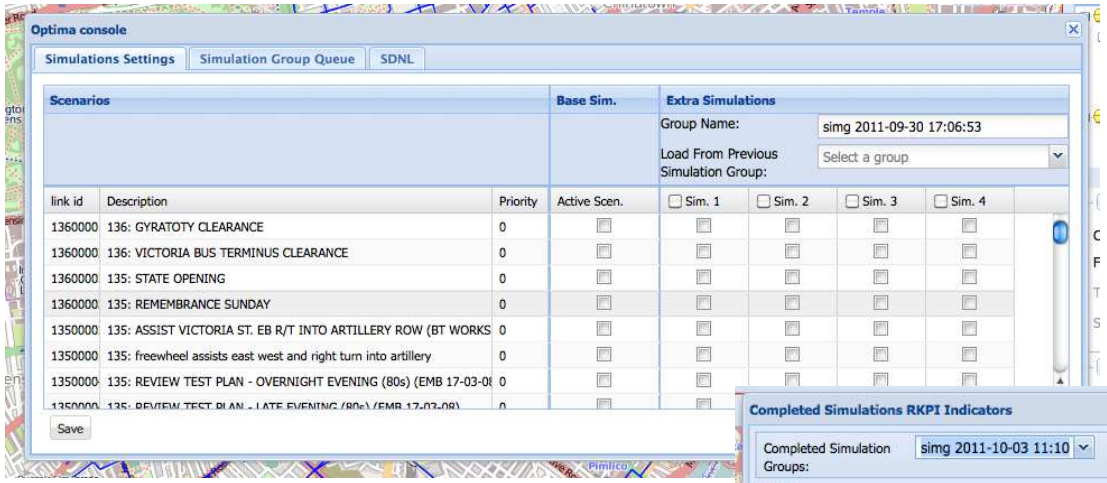
- Evolution of the queue
  - forms
  - sticks
  - disappears

Traffic Supervisor: Dynamic network loading allows short time forecast

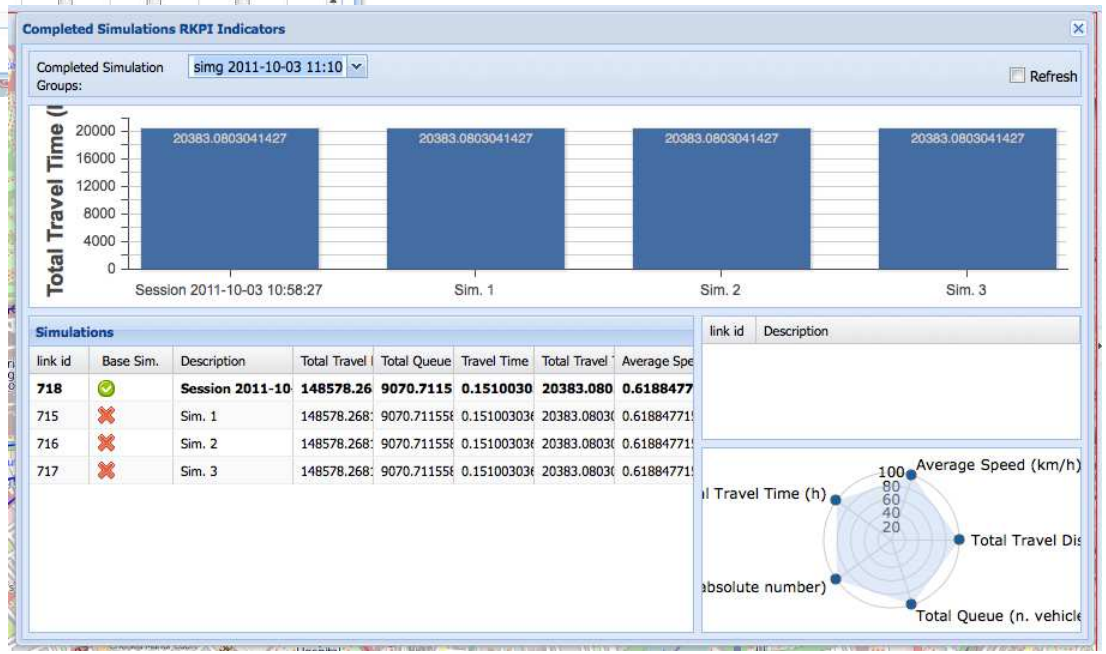


- Check on any link the difference between
  - base forecast
  - real time forecast
- in terms of
  - flows
  - travel times
  - vehicle queues

Traffic Supervisor: Scenario evaluation comparison



- Build scenarios
- Run multiple simulations in realtime (alternative + base "do nothing" situations)



- Evaluate KPI
- Compare and rank alternative solutions against base ("do nothing") situation

Tests – Performance evaluation

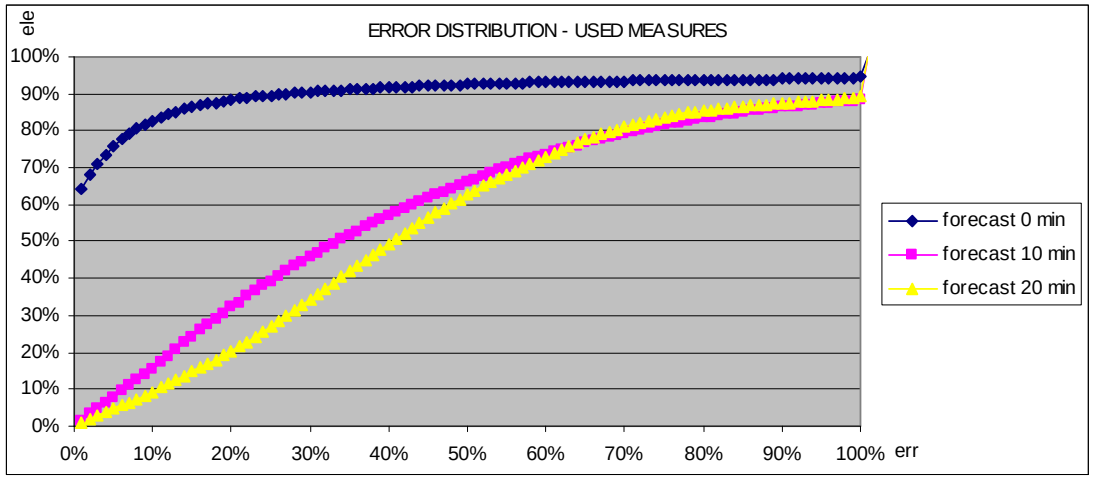
- 6 traffic state estimations and forecasts
  - up to 1 hour ahead every ten minutes

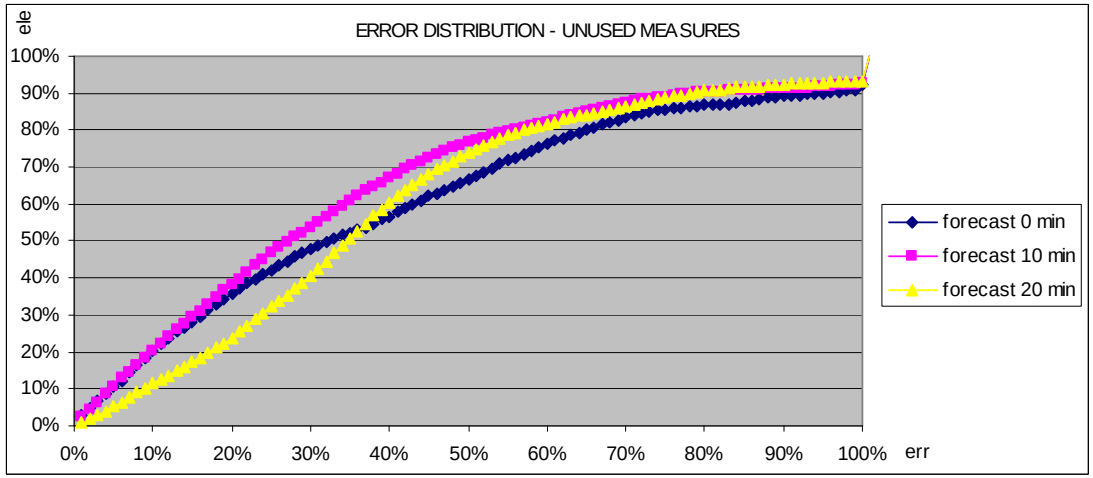
RAM requirements	
Simulation	0,5 Gb
DB	4,7 Gb
Calculation times	
Input & Initialization	4’39”
Import & Process Vehicle Counts	10”
Perform Dynamic Network Loading	1’39”
Export results into DB	19”
Total for a single run	**2’08”**

Test - Quality evaluation

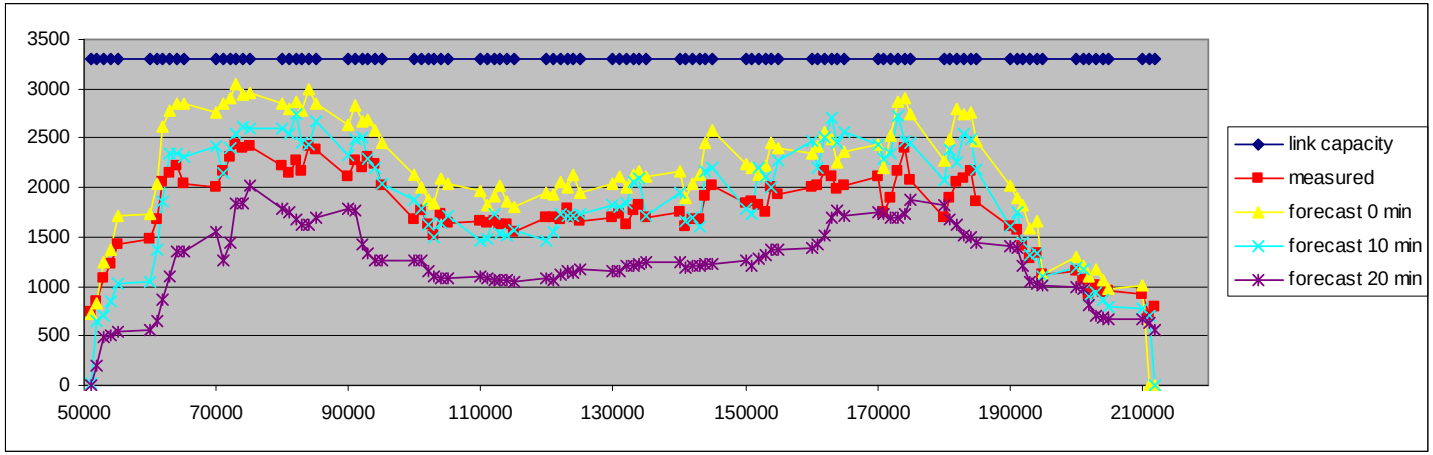
USED MEASURES	
forecast	ro square
0 min	0.95
10 min	0.70
20 min	0.55

UNUSED MEASURES	
forecast	ro square
0 min	0.81
10 min	0.85
020 min	0.59

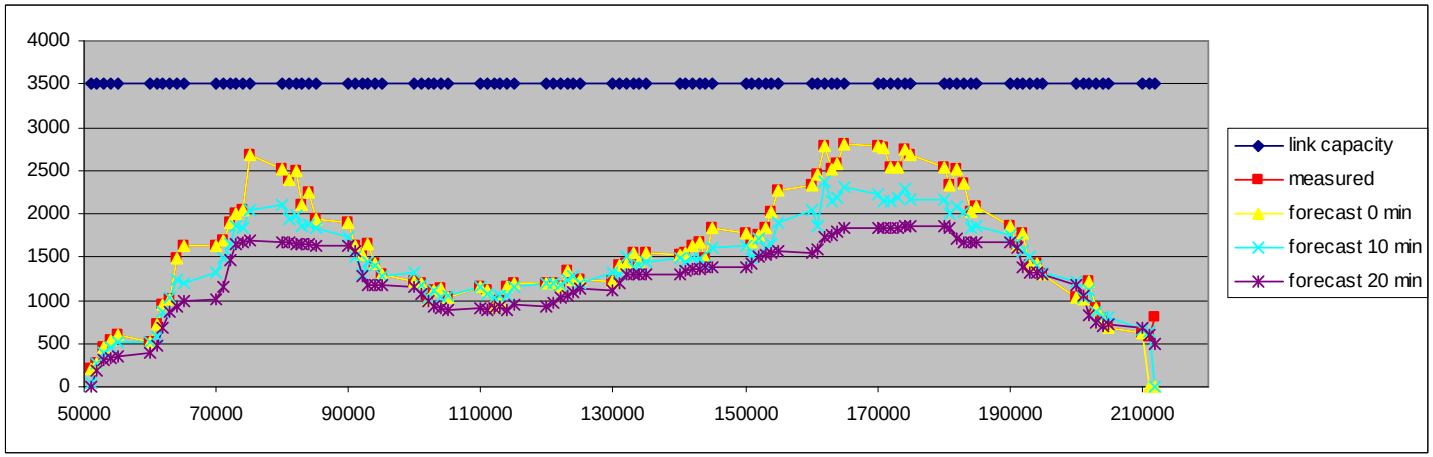




Test – Quality evaluation



Unmonitored location



Monitored location

Key features and advantages

- Suite of software applying modelling approach to real-time traffic forecast that
  - Handles large size networks in real time environments
  - Requires small sets of measures compared to “pure data” approaches
  - It uses heterogeneous measures (loops, fcd, …)
  - Is effective in predicting effects of unpredictable events
  - Allows real-time scenario evaluation & comparison
  - Allows for fast deployment of the system
    - Visum integration and possibility to use existing planning models
    - No need of significant historical data to train the system

Contacts

- Yuanyuan Wang

Senior sales manager

+86 13661537330

+86 21-63288206

Yuanyuan.wang@ptvchina.cn

PTV China-PTV Group

- Luca Paone

Global Director Business Development Realtime Products

luca.paone@ptvgroup.com

PTV Group Company