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Decision Support Tool for traffic management centre in urban environment

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Abstract:

The European Opticities[1] project develops and tests particularly innovative ITS tools in an urban environment: Innovative tools to collect data, control multimodal traffic in real time, provide multimodal information in real-time, and strategic Decision Support Tools (DST). Coordinated by the Metropole of Lyon, it was launched in 2012 and concluded in October 2016 and has 25 partners in 7 European countries. One of Opticities' activities is to integrate one-hour traffic prediction into the traffic control systems of Metropole of Lyon and the city of Birmingham. The company SPIE, tasked with developing the traffic control system for Metropole of Lyon, is partnering with the Opticities project on that development. SPIE created for Metropole of Lyon a fully integrated decision support tool using Aimsun Online simulation system to forecast the traffic 1 hour ahead of time

Keywords: DECISION SUPPORT TOOL, TRAFFIC MANAGEMENT, URBAN ENVIRONMENT

Goal of the project: When it comes to traffic control, real time is already too late

Each of the means of data collection makes it possible to detect abnormal traffic situations with increasing efficiency. However, in general, the operator is notified too late to allow effective action against traffic. OptiCities moves away from reactive management based on real-time situations, towards proactive management based on one-hour traffic predictions. The system must always be several steps ahead in order to be able to anticipate and react to congestion. From a strategic viewpoint, the goal is to avoid or smooth out congestion, and therefore better use the road's capacity over time, as public space is a rare commodity in an urban environment. In 2013 and 2014, Metropole of Lyon, in a partnership with other private actors, created one-hour traffic prediction tools that are now 80% reliable. On this basis, SPIE is working in Opticities on building tools aimed at offering traffic operators the best traffic signal timing scenario or delaying upcoming congestion or limiting its impact. Advisability studies have shown potential savings of 20% of road capacity, which is considerable.

Going beyond optimising the current systems, with a breakthrough in traffic management: One-hour predicting, evaluating, deciding

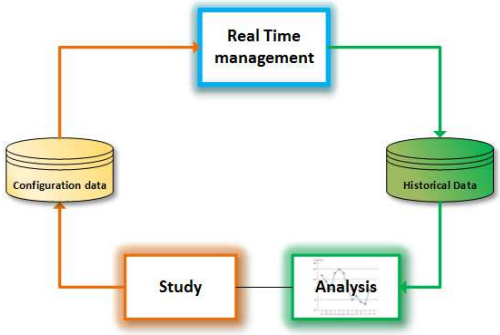

Figure 1 - Virtuous cycle of adapting the configuration of traffic light controllers.

A survey in Metropole of Lyon TMC was conducted and 3 different points were found:

- Operators do not conceive the impacts of their regulation action.
- Operators cannot be aware off all traffic problems at the beginning of the peak hour.
- Operators cannot test different solution to the current traffic situation.

To address these 3 problems, Metropole of Lyon has implemented a Decision Support Tool (DST) that integrates a traffic prediction facility into the TMC. The solution developed is based on a mesoscopic traffic simulation on an urban area, which uses real time traffic data i.e. traffic sensor, traffic lights functioning, traffic events etc. This tool is totally integrated in the actual Metropole of Lyon TMC.
Its dynamic, high-speed simulation of large areas allows traffic operators to anticipate congestion before it happens and then select the best mitigation measures. It needs 3-5 minutes to produce comprehensive traffic predictions for the next hour.

In Metropole of Lyon the TMC has deployed the DST tool. This DST tool is composed of 2 parts:

- A mesoscopic modelisation of Metropole of Lyon inner city
- An operator interface to this mesoscopic simulation to control the results, be alerted to abnormal traffic situation and to manually test some different strategies. This operator interface is fully integrated within actual TMC HMI (light red is the modified/added functionalities or software in the following Figure 10).

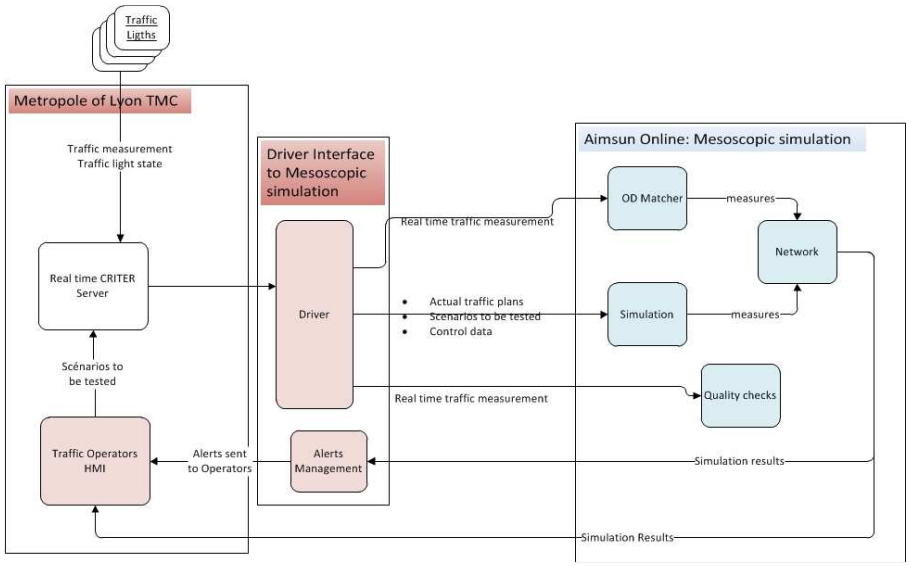

Figure 2 - Overall architecture

The services provided by Opticities to Metropole of Lyon are composed of:

- A service to be alerted 1 hour head of time on the congestion

- A service to configure different response plans and test them against the real situation (meaning in real time). These different response plans are evaluated using some specific Metropole of Lyon KPI's.

These services must be available in real time in Metropole of Lyon Traffic Management System (TMS). The results must be given to operators in less than 5 minutes. These different services are built on the same tool: the complete integration of Aimsun Online (developed by TSS-Transport Simulation Systems) into the Metropole of Lyon TMS.

From an expert Aimsun model to a fully integrated solution for TMS operators

Study scope and network

The scope of the project's study, and therefore the network modelled for the simulations, includes the cities of Lyon and Villeurbanne, rounded by the beltway, as well as highways A6 and A7 which pass through Lyon. This scope represents about 60km2 and 600,000 residents. It is therefore particularly broad, in order to test all possible traffic situations.

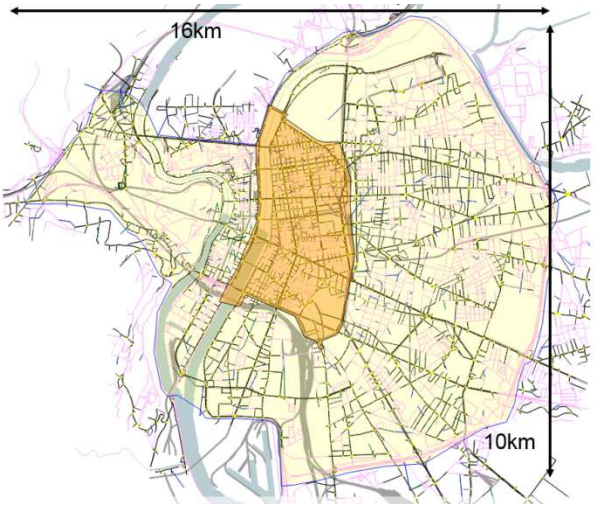

Figure 3 - Scope of study and action

The figure 2 shows the mesoscopic simulation scope in yellow (836 intersections, 441 detectors and 2900 traffic lights) and the scope of action in orange (266 intersections, 170 detectors, and 800 traffic lights) in which it is possible to make changes to the light timing plan in order to affect traffic based on events and alerts, so as to contain the effects of the solution's changes within the simulation scope.

The modelled network exhibits the following features

- 1360 m of road
- 16,000 sections
- 7,300 intersections
- 700 centroid
- 172 000 veh/hr at rush hour
- 3 types of vehicles truck, car, and public transport bus

Building Aimsun Online service: Traffic patterns

Aimsun Online needs a library of different traffic patterns. These patterns are determined using traffic historical data. This library is created offline. We carried out a comprehensive analysis of historical data. The purpose of the analysis was twofold: to establish distinct traffic patterns and create corresponding traffic demand i.e., an O/D matrix per time slice and pattern identified, but also to detect and classify outliers (candidate incidents). With this background task completed, the demonstrator is able to receive a real-time data feed and through a fairly straightforward and rapid

evaluation, determine the best match with the real-time data feed (O/D Matcher) and start the process of obtaining forecasts by loading appropriate O/D matrices or, if applicable, to flag a potential Incident (Incident Data Manager).

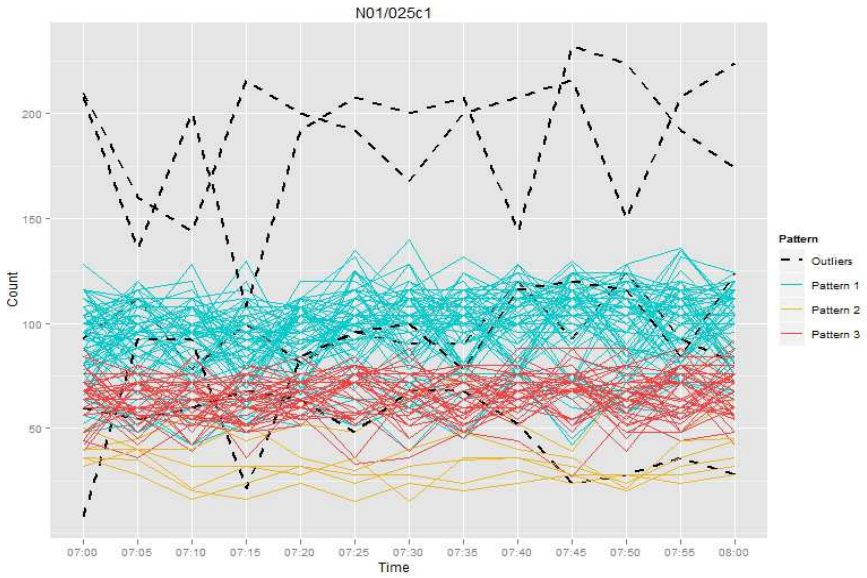

Figure 4 – a sample traffic pattern

In real time, based on static/dynamic adjustments, and with real data sets containing detection for each pattern, a process of macroscopic adjustment, time departure adjustment and dynamic adjustment will be conducted for each time slice of the day and each pattern to cover any situation within the year. Then this process will set all the initial demand files that will conform the library where Aimsun Online will pick up this element for launching the online simulations. In addition to O/D matrices (demand), in this process equilibrium routing files will be generated, also for each time slice and for each pattern. Such external routing files (.apa files) will be also input for online simulations.

Real time communication between Aimsun Online and Metropole of Lyon TMS

Aimsun Online service needs some real time information to be able to forecast the traffic situation. The information needed is:

- Traffic measurement (occupancy, flow). This information is used to pick the best applicable traffic pattern available in the library
- Traffic light state (fixed plan, green light adaptive algorithm)

To be able to react in real time, Metropole of Lyon operators needs to react in less than 5 minutes. All simulation must be calculated within 3 minutes. The physical and software architecture of the solution was designed to tackle this challenge

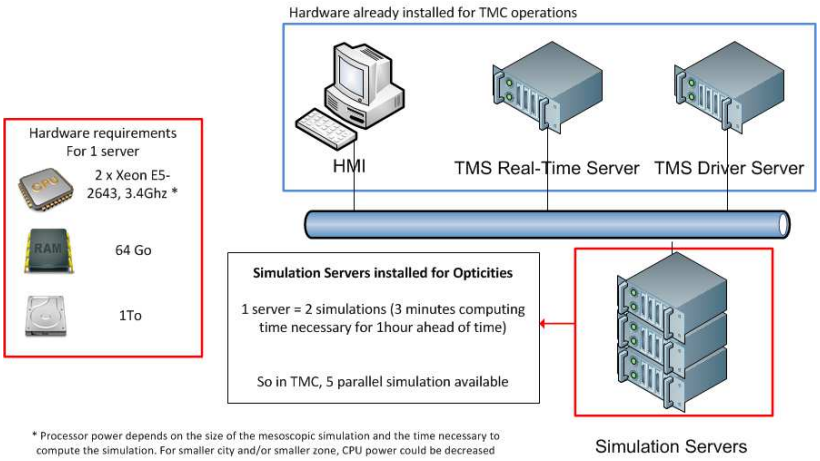

Figure 5 - Hardware architecture

Aimsun Online - Simulation method: Traffic demand:

In the first phase, based on raw detection information received in real time, Aimsun Online selects the demand that best matches the actual traffic conditions present in the network. This demand was predetermined in advance based on historical data collected by the current detection system. One to three years of historical data, aggregated into 18-minute chunks, are used to determine 5 traffic types, or "patterns". A special group-based aggregation method was developed to determine how many "patterns" are needed to represent all of the network's traffic conditions, and to extract demand profiles from them that will be useful in creating the Origin destination matrices that are used by the real-time simulator. Thus, regardless of the time of day (all 24 hours) it is possible to start running simulations based on actual traffic situation.

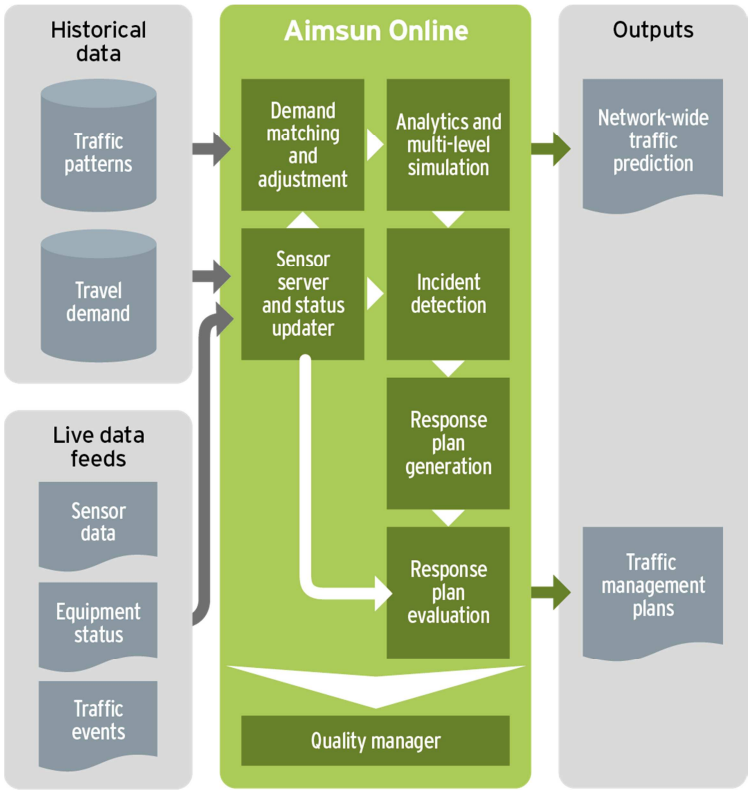

Figure 6 - Aimsun Online architecture

Aimsun Online - Prediction/scenario simulation:

Based on traffic demand, several types of simulations are launched. First, "monitoring" simulations are launched regularly (every 5-15 min). They will enable continuous tracking of traffic conditions

with the help of the predictions, thereby making it possible to trigger alerts in advance of potential disruptions. Additionally, when special events occur (closing off a stretch of highway, diverted traffic, accidents), simulations are launched to help the operator choose the best scenario to be applied. In this final type of simulation, 4 to 5 simulations are started in parallel in order to get results in 4-5 minutes relating to the change in traffic over the following hour, for each scenario.

Events and traffic alerts:
A certain number of alerts are predetermined by the needs of the city based on continuous simulations in order to notify operators when certain local or global thresholds are exceeded. These alarms assist operators in more comprehensively tracking traffic conditions within the network, thereby making it possible to foresee potential congestions/disruptions in the minutes ahead .At the same time as these alerts for traffic predictions, different types of actual events may be reviewed:

- Scheduled events construction, road geometry modifications, etc.)
- Unusual events (incidents, accidents, etc.)

These events are received from the control centre and incorporated into the traffic simulation in order to reproduce the actual simulation conditions for each of planned scenarios. The combination of traffic alerts, which help notify operators of disruptions in the near future, and actual traffic events incorporated into the simulations for predicting the conditions of various response scenarios, makes it possible to achieve a complete, effective system and therefore reactor under optimal conditions to many types of disruptive events within the scope studied.

Decision Support Tool in Metropole of Lyon TMS

The use of the Metropole of Lyon Decision support tool needs the followings steps:

- Offline: creating alerts to be triggered 1 hour ahead of time
- Online:
    - When receiving an alert, evaluate the situation and create 1 to 3 response plans using the available traffic plans.
    - Tests these response plans, and receive the results in less than 3 minutes.
    - Check the results and pick the best solution among the tested ones using Metropole of Lyon KPI's.

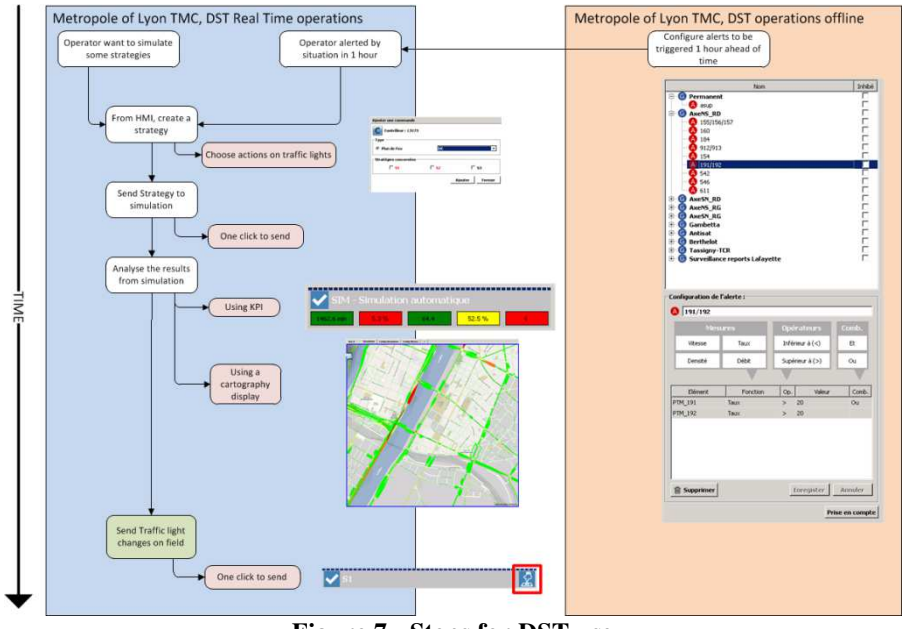

Figure 7 - Steps for DST use

Creating an offline alert
These alerts are based on traffic sensors and can operate on different traffic prediction values such as density, flow and speed. It's possible to combine multiple traffic sensors with logical operators and to define which period the alert has to run such as all day or just 06:00 to 10:00 for example. Traffic alerts are used to detect abnormal situations on a wider area. This allowed the TMC operators to adjust alert precisely and stay focused on important traffic events. These alerts are triggered 1 hour ahead of time, operators can then be alerted that the traffic will

Creating response plan
The response plans are created by TMS operators. Up to 3 response plans can be created to be tested in Aimsun Online simulation.

Receive the results in less than 3 minutes
The software and hardware architecture are designed to be able to generate 5 simulations results in less than 3 minutes to the Metropole of Lyon operators. The time necessary for these simulations is recorded in database as this is a strong challenge for the decision support tool. The simulations run in parallel in different servers. The number of parallel simulation could be increased or decreased depending on how many servers are available.

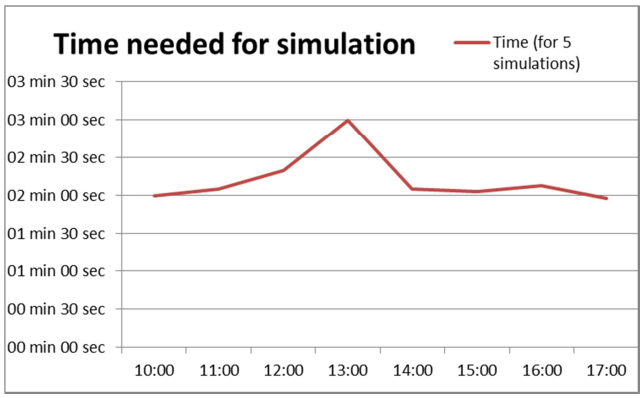

Figure 8 – Time needed for 5 simulations to complete

Evaluate the results (simulation Quality, KPI)
The results received are evaluated in two different ways:

- Simulation quality (done by quality manager in Aimsun Online)
- Functional quality: this evaluation is done by Metropole of Lyon operators using Metropole of Lyon KPI's.

The simulation quality varies over time depending on the traffic situation. The overall simulation quality is around 80 to 85%. One outcome of Opticities is that some time is needed by Aimsun Online simulation to build up better and better simulation. In fact, Aimsun Online is using real time information and also a few hours' historical data to perform the first steps of the simulation (picking traffic demands and forecasting demands). Aimsun Online needs then a few hours to be fully operational. The maintenance done on Aimsun modelisation is needed only when the model is modified (new version of the model for example).

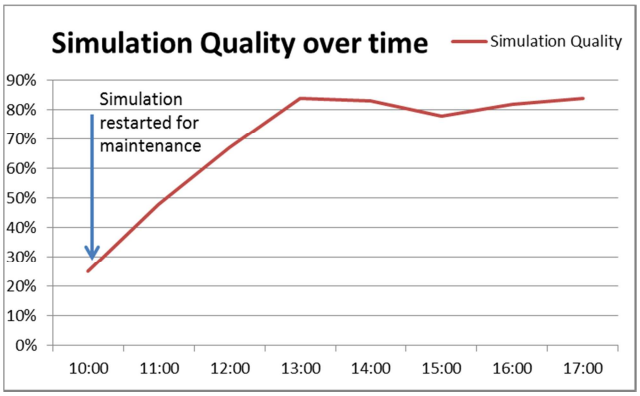

Figure 9 – Simulation quality over time

The functional quality is evaluated by Metropole of Lyon Operators using 5 different KPI's:

- **Overall fluidity** (traffic capacity warranted on the structural axes): Difference between the journey time in free condition and the one simulated.
- **Dynamic Congestion** (demand response): Evolution congestion level in the network. It penalizes congestions which remain at the end of simulation (not absorbed).
- **Respect of the network hierarchy** (preserve calmed area): Coefficient of determination of traffic values on major roads. (Comparing the traffic value of the simulation and the traffic value of analytical prediction)
- **Pedestrians comfort** (multimodal indicator): Number of pedestrian signals whose average delay is equal or greater than 20 seconds on all network junctions.
- **Number of activated alerts**. Active alerts that could be triggered by the simulation. This indicates the total number of active alerts

These KPI's are calculated on all the response plans and are presented to operators when all the simulations are finished.

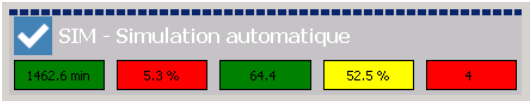

Figure 10 – KPI presented to operator on the results of a simulation

Send the response plan live

A one click action enables the response plan in Metropole of Lyon TMS. The response plan send new commands to the different traffic lights.

Summary

In Opticities, SPIE, in direct partnership with the teams from Metropole of Lyon, is developing and testing under actual conditions a decision support tool fully integrated into the traffic management centre of Metropole of Lyon (CRITER).This tool makes it possible to:

- Incorporate one-hour traffic forecasts and alert operators an hour in advance if congestion will occur in strategic intersections.
- Simulate different traffic control scenarios in realtime and when requested by the operators, with the simulation tool being developed by TSS (Transport Simulation Systems), Spie's subcontractor for that technological module
- Evaluate the impact of each scenarios, using predefined indicators and in the form of traffic state mapsat T0+15', +30', etc. +60' for each simulated scenario
- Rank the scenarios and provide recommendations too operators in a quick and simple form. Besides the purely functional aspect, the other strength of the solution is its total integration into the traffic management centre of Metropole of Lyon. This is because similar experiments from before, particularly in the United Kingdom, have shown that tools not integrated into the

management entre led to high levels of complexity, which are ill-suited to an environment where operators must monitor hundreds of kilometres of road in real time.

- Replay the different simulation in order to better understand each of the phenomena involved, to increase internal knowledge of the network and come up with new scenarios that may optimise traffic conditions within the scope studied

Following Metropole of Lyon experimentation periods a number of key recommendations for the development and use of traffic prediction algorithms and decision support tools are issued to Opticities and presented below:

- Determine the method of traffic prediction required i.e. does your urban road network suit the use of predictive algorithms (route or corridor based) or micro-simulation modelling (core city centre as demonstrated in Grand Lyon).
- For mesoscopic simulation, the input data has to be qualified. We have some problem with the quality of the inputs:
    - Road configuration (how many lanes, road direction, where can cars go when they use this traffic light, speed limit, origin-destination lane, give ways and stop not available in TMC, missing ways, PT). Due to the lack of information in TMC database, we need to manually complete this information.
    - Real Traffic information (traffic measurement)
    - Traffic light configuration (modelisation)
    - Origin Destination matrix not detailed enough for mesoscopic simulation.
    - Where possible utilise existing TMC systems and services to avoid building a costly bespoke solution
- The quality of the inputs is essential to produce a high quality simulation.
- Factor in long timescales to allow DST to stabilise and build confidence in the quality of alerts generated, generally speaking the longer this runs the better the output and the ability to self-learn
- Factor in the expertise and resource required to build responses and mitigation actions in response to DST alerts
- Responses do not have to be confined to just implementing traffic control measures (such as adjusting traffic signal timings or implementing a pre-determined control strategy) as they should all encompass media notification, updating real time traffic information systems, setting message signs and informing key stakeholders

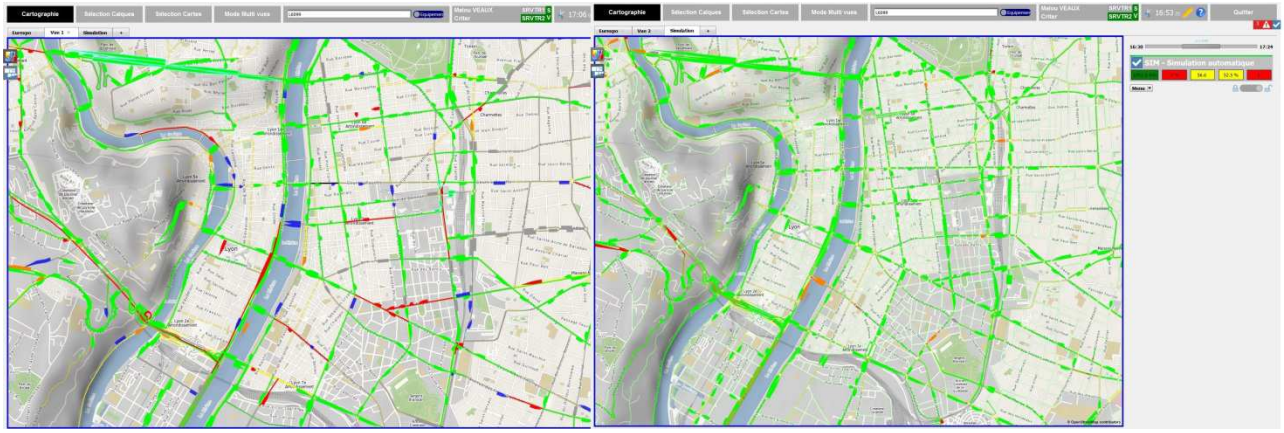

Figure 11 - Integration of the decision support tool into the management centre's real-time system, CRITER

References

1. Opticities. *OPTICITIES is aiming high, intending to develop and test interoperable ITS solutions in six different cities in order to provide urban citizens with the best possible journey conditions and to optimize urban logistics operations*. http://www.opticities.com