The project planning of the highway network – traffic microsimulation tools –

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ABSTRACT

Always more often, preliminary design phases for an highway infrastructure (mobility and traffic studies, feasibility studies, preliminary design, and so on) need a decision support system able to evaluate the design options not only on the basis of territorial, environmental and economic reasons but also considering safety, impact on viability and infrastructure management.
In these cases, through a traditional approach to transport planning, based on macro simulation models, it will not be possible to work at the requested detail level. Such tools are not able to supply useful elements of evaluation related to specific design choices (junctions, roundabouts, traffic light regulation and so on) or to estimate the direct effect of a yard on the existing highway or the geometrical correctness of the design.
A solution to these problems can be found thanks to dynamic micro simulation tools, that now can be used to implement extensive and complicated traffic networks.
Micro simulation tools can represent the dynamic traffic evolution in a more punctual, precise and reliable way. They take in account the detailed geometrical design of the infrastructure, the car characteristics and the real behaviour of the driver.
The purpose of this paper is to introduce such innovative analysis methodology - already used abroad in very important places like Manhattan, Miami and the Silicon Valley – through practical examples of some case studies recently developed in Italy, such as:

- a part of the belt highway of Rome;
- the whole A10 motorway (from Ventimiglia to Genova);
- the highway network of Alessandria.

This paper will explain the implementation methodology, the detailed analysis available for the design, the reliability grade of simulations and the tool potentiality in all the study and design stages, including public agreement.

Project Planning of Highway Networks and Traffic Micro-simulation tools

INTRODUCTION

The highway infrastructure management and development done by competent bodies is normally based on three phases: planning, scheduling and design. This approach should allow a coherent and aware development of mobility infrastructures, so determining the resources optimisation and the maximum effectiveness of interventions.
Whereas the design phase usually has no particular unknown elements, planning and scheduling phases could be developed through several methodologies, starting from the totally political and financial one, up to the one where strategic decisions are supported by technical and functional verifications concerning the highway network and the mobility in general, which is, probably, more effective; in this case, traffic simulation tools play an important role.
Unfortunately, in most cases several difficulties don't allow a correct application of the methodology above; also, the process is hedged about exogenous uncontrolled elements: different territorial scales, distributed competences, local circumstances.
In this context, we have to consider that the traditional technical and functional network verification is restricted to the functional scheme of the network, and does not go into a proper detail level, allowing the following design phase. This is often due to traditional traffic simulation and planning tools, generally known as micro-simulators.
The limits of such a planning process are evident: at any territorial scale, results are often unsatisfying if related with the titanic efforts done in finding and processing data. For example, in the urban domain, the application of traditional methodologies to the setting up of Urban Traffic Plans has been transformed, in several cases, into a purely theoretical exercise, which is hard to apply and not related to the urban context and to the design phases.
Similarly, at a wider territorial scale (Province and Region), the application of macro-simulation tools may not produce very interesting results, in particular if they are used to compare different design proposals.
For these reasons, Public Administration might leave the practice of using simulation tools for highway network planning.
Therefore an innovative approach is required, by analysing operational contexts and by choosing proper simulation methodologies, taking into account their limits.
As a consequence, researching and testing new methodologies is an important factor, allowing us to find effective solutions, adequate to the planning goals.
Even if traditional simulation tools are still valid, and sometimes producing good results, using more detailed and sophisticated tools, like the ones proposed in this paper, allows to assume another application perspective: simulation tools are not limited only to planning phases, but also allow project planning and management. They can be used for the earlier evaluation stages as well as for detailed verification phases, in cost-benefit analysis, project verification (junctions, roundabouts, traffic light regulation), in work in progress phases (temporary viability due to yard presence) and so on.

TRADITIONAL APPROACH TO TRAFFIC PLANNING: MACRO-SIMULATION

The traditional approach to analysis and evaluations of mobility and related highway infrastructures was done (and often is done still today) using macro-simulation tools, consisting of a set of models able of estimating demand, supply and their interaction.

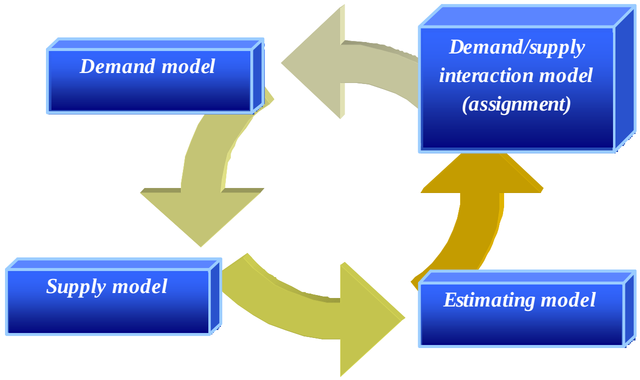


Figure 1 – Simulation-models components

Macro-simulation tools are based on a synthetic description of both the Origin/Destination (O/D) matrix, summarising travels related to a certain time gap, and roads/highways geometrical-functional features, in simplified terms of arcs and nodes. The model considers only average evaluations related to traffic flow (speed flow curves, average cost per kilometre or hour, and so on).

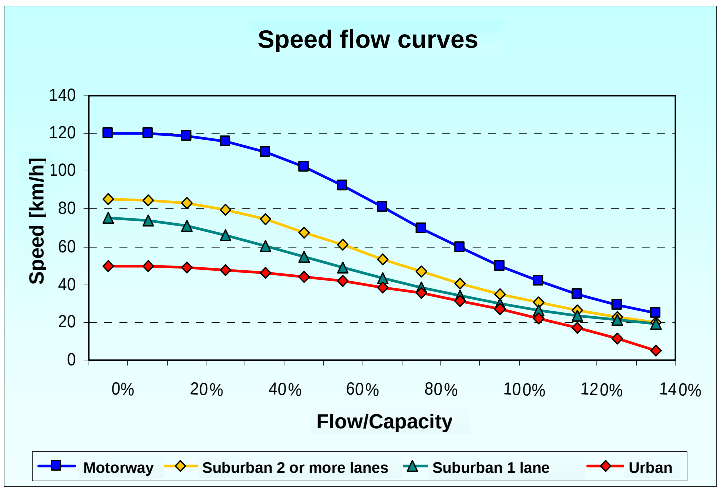


Figure 2 – Example of speed flow curves description

The analysis is based on average evaluations and simulations of traffic volumes per hour and average travel times on arcs, based on the geometrical and functional features of highways and, if possible, on existing traffic volumes. Usually they are supported by stochastic or deterministic choice models, allowing us to determine the per cent allotment of flows on, based on drivers expected behaviour, divided into classes.
The traffic allocation on arcs implies some changes on the related travel time and generalised travel cost, upon which is based the path choice. An iterative process allows to determine the equilibrium between traffic flows and generalised travel costs.

Macro-simulation tools: results and limits

The simulation process described above is considered separately for light and heavy vehicles, for rush and off-rush hours and allows to derive a set of average information on forecasted traffic flow per hour and per day on arcs, average speed, flow density, levels of service, saturation indexes and so on.

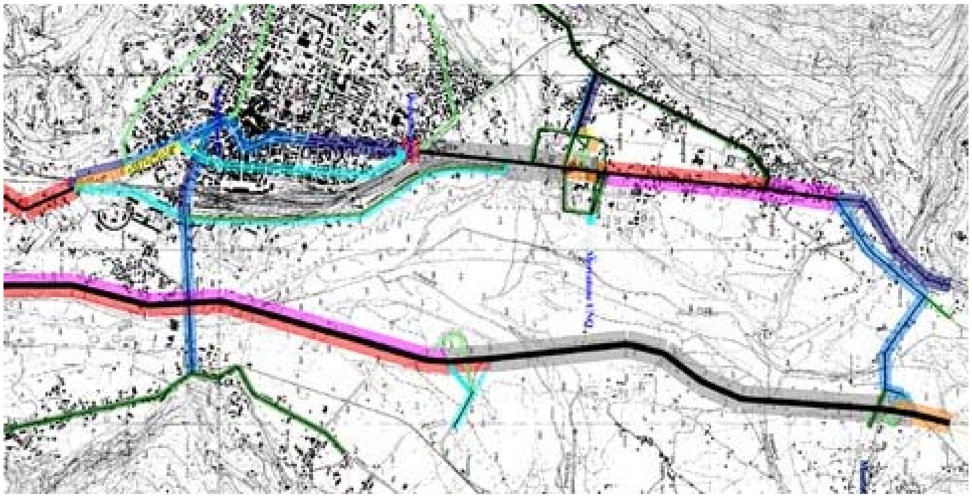


Figure 3 – Average traffic flow on arcs

Traditional planning approach is based on a set of tools and methodologies that we can define as “simple”. Data used in simulations are “average” information: traffic flows, density, vehicle speed and arrivals distribution are related to an “average” time period, usually one hour. This input data and, as a consequence, results approximation lead to a “static” vision of the entire simulation process, like as the real vehicle behaviour or their distribution on the network are not taken into account. Vehicles are not individually simulated, but they are only considered in terms of average flow. This means considering vehicles as an uniform fleet moving at the same speed (uniform motion) and at the same distance (Figure 4).

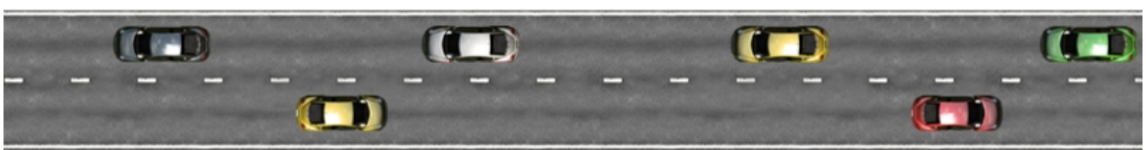


Figure 4 – Static vision

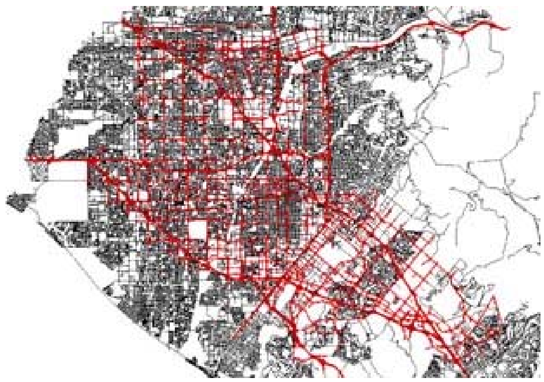
This kind of approach only allows static measurements of the whole network. Also, the schematic graph representation of the network and its junctions (nodes) precludes a detailed analysis of punctual critical situations (junctions, accesses, road sections changing, key points, ramps and so on) and, consequently, punctual evaluations of projects (junctions, roundabouts, traffic lights and so on).

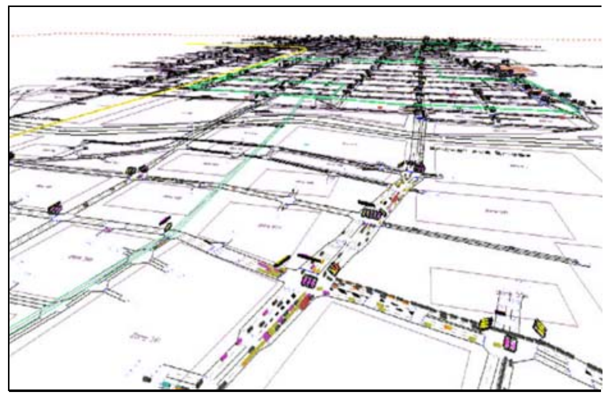
It has to be highlighted that methodologies of analysis based on macro-simulation are hardly applicable to the phases related to the mobility and transport infrastructures management, for example in yards and alternative paths management. Also, these methodologies do not provide any useful information about the best design solution.

NETWORK DYNAMIC MICRO-SIMUALTION MODELS

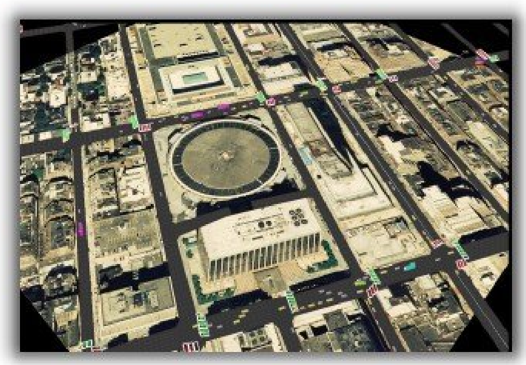
The main difference between macro and micro-simulation is that macro-simulation takes into account average parameters and measurements, based on physical rules and statistic behaviour, while micro-simulation perform a real time analysis of the motion of each vehicle, based on laws related to vehicle motion and driver behaviour (acceleration-deceleration, car-following theory, lane changing theory and so on).
Dynamic micro-simulation tools give a punctual and specific representation of traffic and of its instant evolution, considering network infrastructure detailed geometric features and the real vehicle behaviour, as determined by the vehicle-driver binomial.
The difference between the two methodologies is possibly more evident making a comparison between the different theoretical approaches related to the flow representation. Macro-simulators determine the average flow speed based on a speed flow curve (Figure 2) which must be defined by means of theoretical laws or by on-the-field observations. This approach derives from a very simplified assumption, that describes the traffic flow laws by analogy with fluid motion laws (the fluid speed is inversely proportional to its density). Possible node delays are at most considered in a separate way, and they do not concur in determining queues nor difficulties in the traffic flow.

Micro-simulators overtake the above limits, as they don't consider such simplifications: *it is not necessary to determine and to calibrate speed flow curves*, nor to indicate the arc length. Each vehicle behaves like its characteristics suggest, together with the driver characteristics, the network geometry and the nearby vehicles behaviour.
Several projects have been realised, specially in the USA, in Canada and in the UK (Figure 5), showing that, on the one hand, it is possible to implement micro-simulation tools even for large networks, on the other hand, the micro-simulation phases are often used for scheduling traffic and infrastructure management.
In the case-study, has been used the *Quadstone Paramics V4* software, one of the state of the art micro-simulation tool nowadays available.





Anaheim (Disneyland), California **Miami Transportation Master Plan, Florida**



Manhattan, New York City **Edinburgh, Gran Bretagna**

Figure 5 – Applications

Micro-simulation theory

Dynamic micro-simulators are based on models able to represent each vehicle motion as determined by the Car-Following theory, the Lane-Changing and the Gap-Acceptance rules: drivers try to travel at the desired speed within each road section, even if the driver behaviour is affected by external factors (preceding vehicles, adjacent vehicles, highway geometry, traffic signs, traffic lights and so on).
Simulation time is divided into small steps named simulation cycles or *simulation intervals* (Δt). At each interval (normally 0.5 s), each vehicle position and speed are updated, according to laws mentioned above, as described in the following.
Micro-simulation provides a *dynamic vision* of the phenomenon as the instant characteristics of each single vehicle motion are taken into account (flow, density, speed and so on). By means of micro-simulation, it is possible to represent different classes of movements (Figure 6) with different behavioural parameters (acceleration, deceleration, aggressiveness, reaction time and so on) and different vehicle types (maximum speed, dimension, emission parameters and so on). Skilled drivers have smaller reaction time: they can drive closer to previous vehicles, easily find insertion times, quickly accelerate and, hence, quickly move.

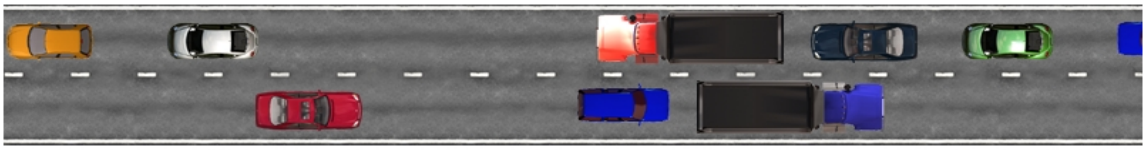


Figure 6 – Dynamic vision of flows and different vehicle types

A brief basic algorithms description follows.

Car-Following
Each driver tries to drive at the desired speed according to her/his driving behaviour, to the vehicle features and to the geometric characteristics of the highway; if a preceding vehicle is reached she/he will decelerate or, if it is possible, she/he will change lane and overtake it.
Three parameters are used to estimate the maximum desired speed within a section:

- vehicle maximum desired speed;
- vehicle maximum accepted speed;
- speed limit for section or turning.

Lane-Changing
Each driver determines, for each instant, the lane-changing opportunity, on the basis of motion necessity, desirability or possibility.

Gap-Acceptance
Each driver determines if a movement (lane-changing, crossing an intersection, joining in a traffic flow, enter a roundabout and so on) is possible or not, evaluating if the necessary gap time exists, taking into account the relative speed of the other vehicles.

Model applications and results

Using micro-simulation implies a strong effort for a punctual representation of the network geometry and of demand dynamic distribution.
However, the model is intrinsically able to describe vehicles behaviour in a more real way, even if a static estimation of demand parameters is given.
Supply must be described in terms of highways and intersections plano-altimetric geometry; the graphic interface automatically transforms intersections into operation areas, by simply indicating, for each lane, the allowed turning movements.
Further geometric representations (radius of curvature, junctions and so on) can be manually introduced, to reach a better simulation quality, even if it is also satisfactory just with “standard” information.
The micro-simulator provides a great variety of results, including all the traditional parameters provided by macro-simulators (speed, flows, service levels, criticality indexes and so on) also at a punctual and instant level (Figure 7 and Figure 8), together with additional information on each vehicle, path, public transportation vehicle, vehicle flows, queues, criticalities (Figure 9), parking and accidents.

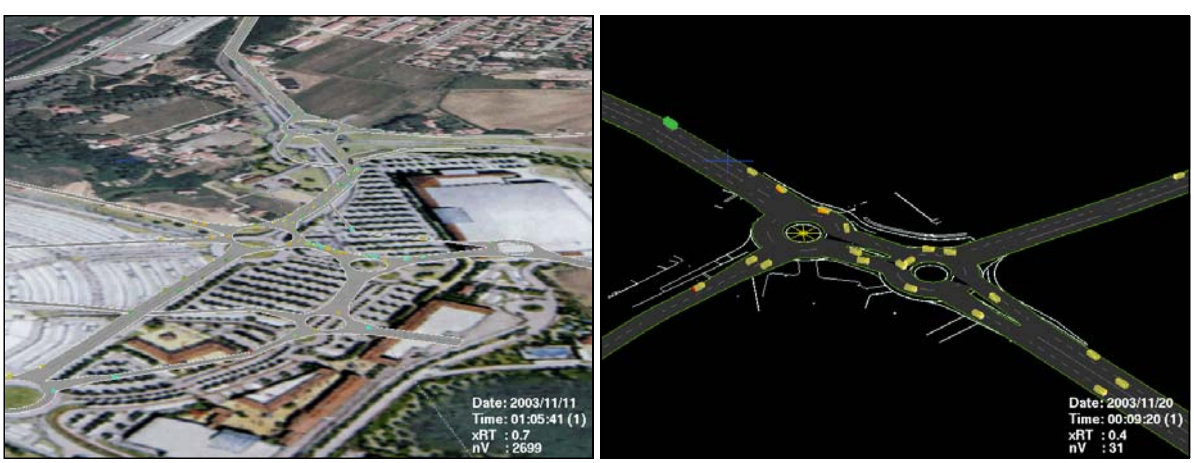


Figure 7 – Intersections, traffic lights and roundabout details

Figure 8 – Complete representation of the network and the vehicles in motion

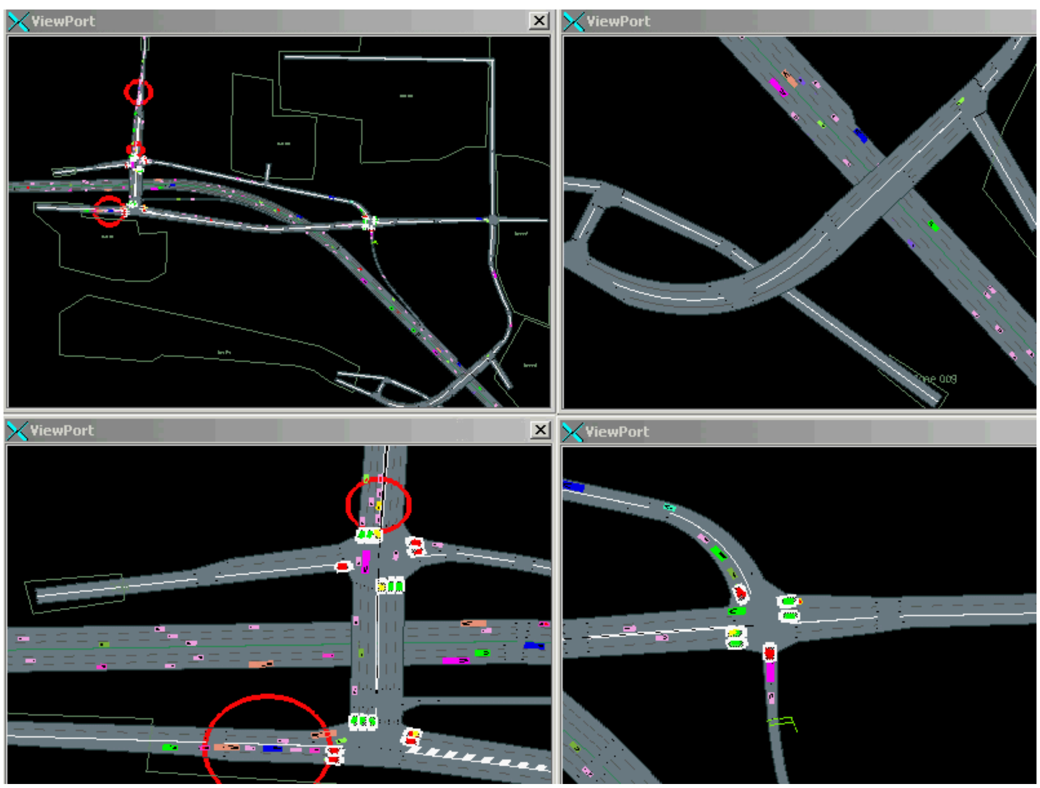


Figure 9 – Criticalities location and queues evaluation

All informations can be provided at any desired time basis, thus allowing, for example, a detailed analysis of flow parameters showing that, within one minute, the traffic flow on a given arc could be more than twice the theoretic capacity per hour. (Figure 10)

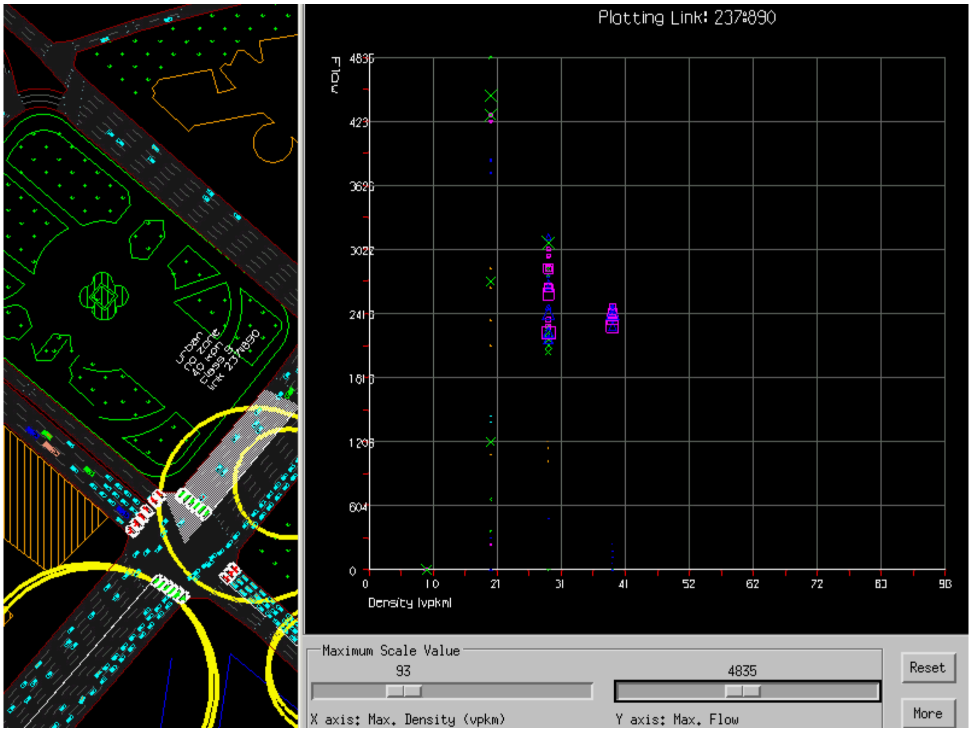


Figure 10 – Instant flow speed (per minute) related to traffic load (vehicle/minute)

PROVINCE OF ALESSANDRIA WIDE AREA STUDY

The study considers a relevant portion of Alessandria Province (Piedmont – Italy) of more than 500 km^2. Within the area, three main actions have been identified:

- finishing of Alessandria bypass;
- building of an additional arc to the ex S.S n.10 “Padana Inferiore” connecting Alessandria to Spinetta Marengo;
- Pozzolo Formigaro and Novi Ligure bypasses construction.

Micro-simulation put in evidence some interesting effects concerning the expected allocation of traffic on the network, the expected utilisation of new infrastructures (that is very important for cost-benefit analysis) and the verification of the project coherence to the general mobility scheme. Also a road-yard impact evaluation has been performed, that will be open on an existing stretch of the bypass of Alessandria, to build a new junction. The preliminary projects of the three actions above and of the yard to open are available.

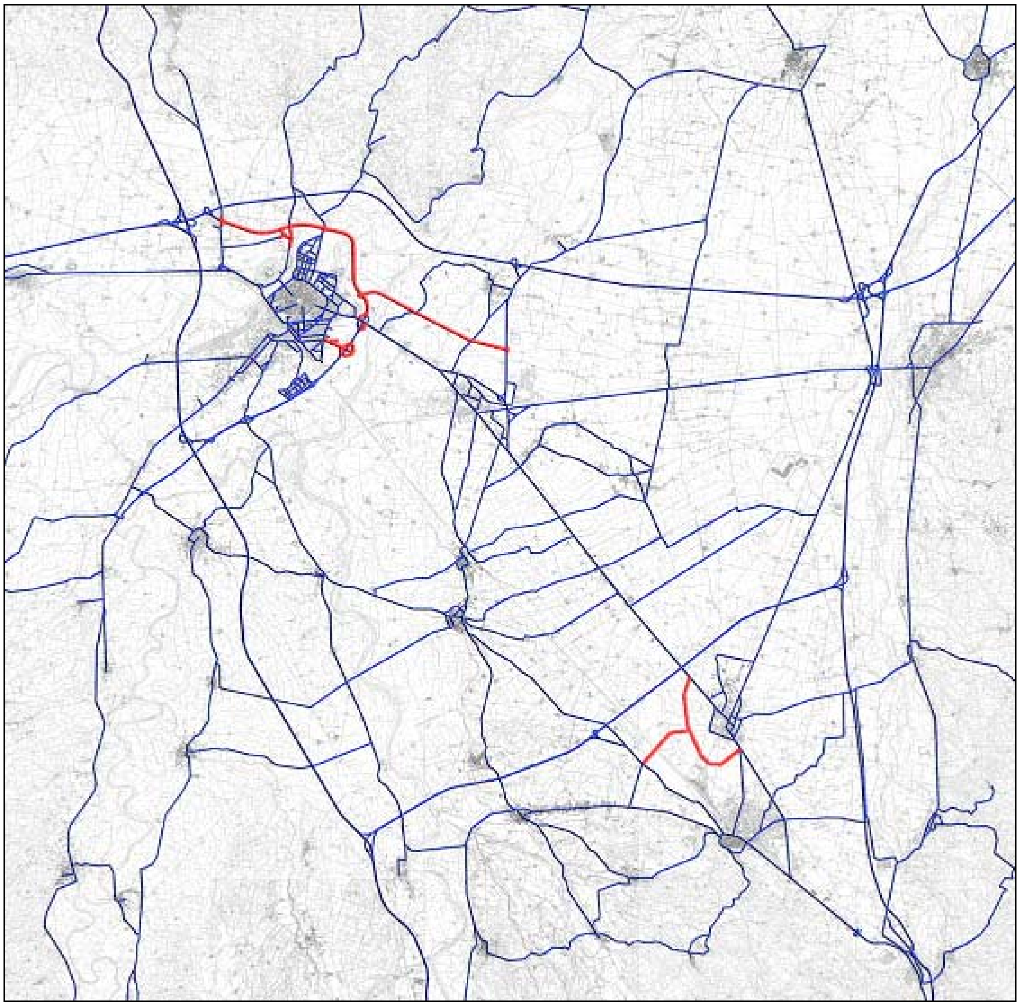


Figure 11 – Study area and actions

Model implementation

The main highway network has been codified, including about 100 km of motorway, 130 km of ex-S.S. (highways) and more than 500 km of other roads, like S.P. and S.C. (secondary and minor roads); 24 traffic lights intersections have also been defined and codified, together with a dozen roundabouts. Demand has been estimated based on ISTAT 1991 information (Italian census), suitably calibrated by means of available traffic data on primary and secondary highway network.
Simulation takes into account the morning and evening rush hours; the model has been implemented on a PC equipped with a Pentium 1.5 GHz and Windows 2000 and it has simulated over 36500 vehicles at the same time, taking 10 minutes of simulation time to simulate 1 hour of real time, with a time interval of 0.5 s. In the two morning rush hours, 65300 vehicles run in the network, covering a total of 744000 km.
Either during and after the simulation, some critical situations, concerning queues and delays, have been displayed.
Also, the representation of flows on single highway arcs and the possibility of making a comparison among different simulations allow us to evaluate a new and better traffic allocation for different scenarios.

Actual situation

The actual highway network has, at the rush hour, some critical points, normally localised on the main highway arteries to access Alessandria urban area, due to a strong preponderance of traffic flows directed to the city and to a series of intersections where relevant conflicts take place, leading to delays and queues. In particular, the model detects relevant criticalities on the ex S. S. n. 10, both in the South and in the North of Alessandria. On some road stretches, the ex S.S. n.10 presents traffic flows leading to queues as far as Spinetta Marengo, which is 3.5 km far away, because of a critical traffic light (Figure 12).

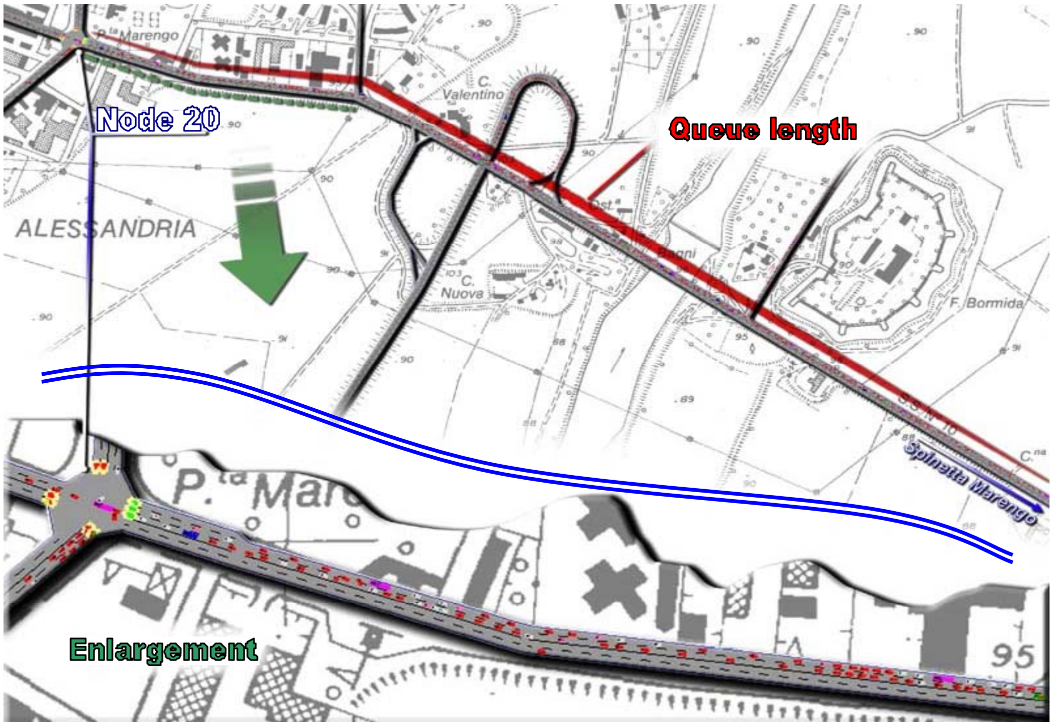


Figure 12 – Delays on S.S. 10, at the entrance of Alessandria

Also, some criticalities and frequent delays have been put in evidence on the final bypass stretch, where the bypass joins the ex S.S. n.10 through of a trumpet junction. This road stretch is very important for our study, as it will be interested by road-yards to provide a new junction before the existing one. The above criticalities are shown by Figure 13.

Other criticalities have came out in the North of Alessandria and Figure 14 reports a significant example. It shows the great potentiality of the simulation tool used, as it has immediately highlighted the roundabout inefficiency (recently adopted), due to its critical interaction with the traffic lights below.
A preventive usage of micro-simulation tools (for example at the preliminary roundabout design stages), could have highlighted the problem and suggested a suitable solution.

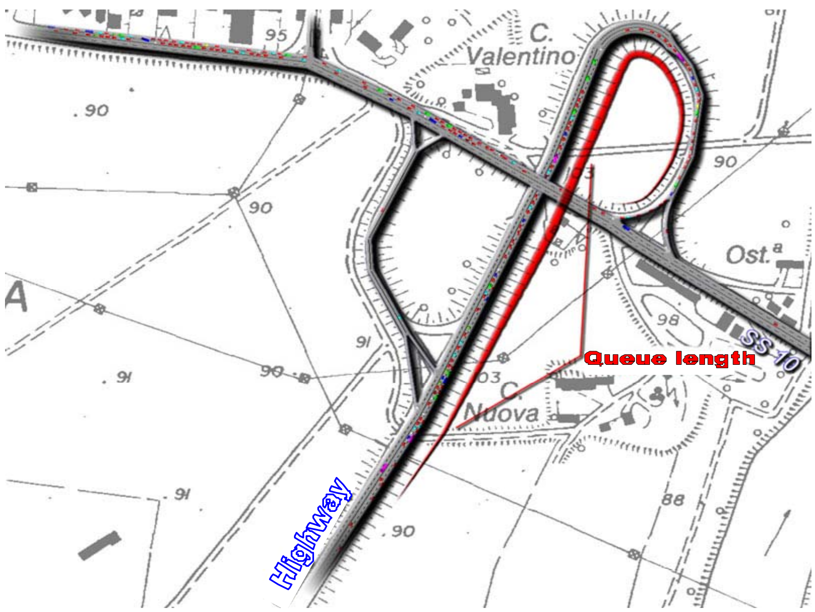


Figure 13 – Criticalities in the final stretch of Alessandria bypass

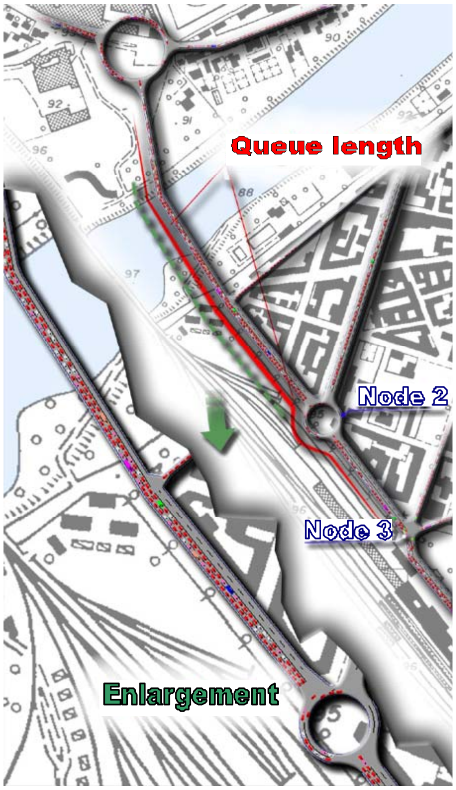


Figure 14 – Urban criticalities related to traffic lights

Bypass yard phase simulation

The yard phase has been simulated by closing a half carriageway bypass and by arranging the other half as a two-lane carriageway (one lane per way). The speed on the yard stretch (500 m of length) is limited to 50 Km/h.

The related simulation shows that queues and delays are the same that we can find in the final bypass stretch in the actual situation (Figure 13), even if they are transferred in the yard nearby. This kind of situation takes the traffic flow in the final bypass stretch back to normal levels.

Alessandria bypass completion

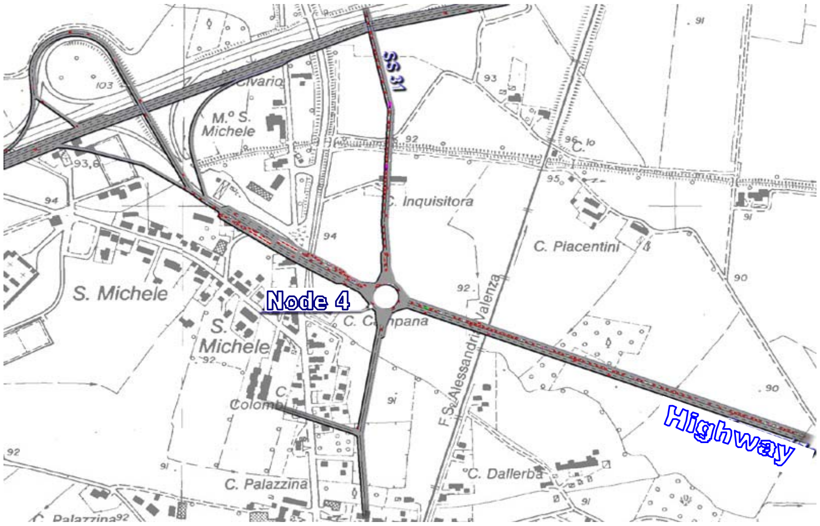


Figure 15 – Possible delays at the roundabout connecting the bypass and the motorway

The project considers the extension of the present bypass as far as the junction with the motorway A21, Torino-Piacenza. New infrastructure relieve from traffic flows East Alessandria urban network; this traffic is due to crossing flows in North-South direction and flows directed to the South of the city. As a consequence, suburban delays and queues are drastically reduced, against an about 10% increment of the traffic on the existing stretches of the bypass.
The micro-simulation puts in evidence a major critical situation on roundabout edges connecting the ex.S.S. n.31 to the new stretch of the bypass (*Node 4*), where queues and relevant delays might take place (Figure 15).

Ex S.S. n. 10 "Padana inferiore" additional link connecting Alessandria to Spinetta Marengo

The additional link intends to strengthen the connection between Alessandria and Spinetta, that now is not able to satisfy traffic flows, according to the model results. The simulation shows that the proposed layout is not so attractive, despite the criticalities of the present network, as the layout itself is not directly connected to the urban network.

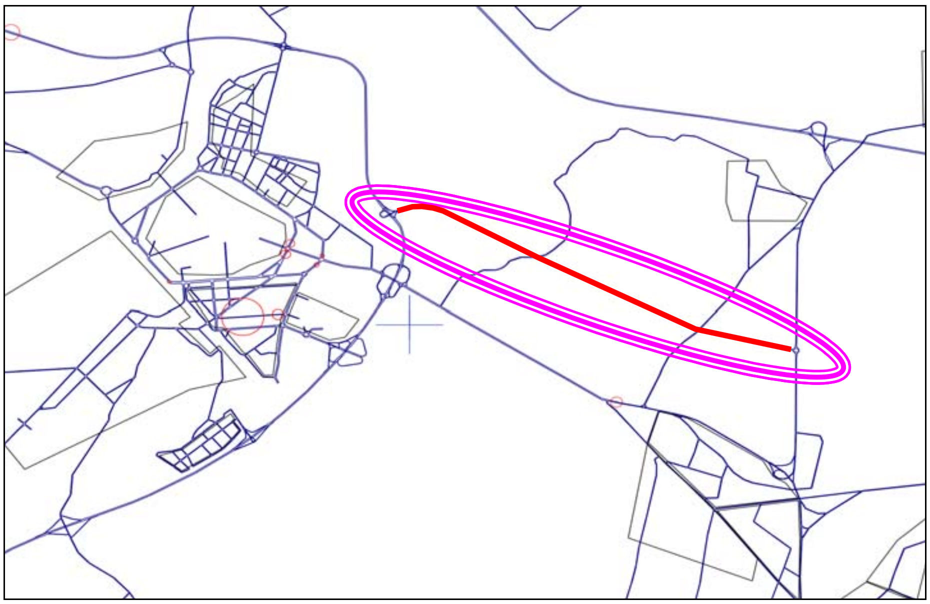


Figure 16 – Layout of the variation to the ex S.S. n.10 between Alessandria and Spinetta Marengo

PRELIMINARY STUDY ABOUT THE MERCANTOUR TUNNEL AND THE MOTORWAY LINK ALBENGA-CEVA VIABILITY IMPACT

Main aims of the study

The first aim of the study is to put basis for a further accurate analysis of the present primary transport infrastructure system in the North-West of Italy. In particular, we refer to the Liguria Region and the Province of Imperia; the goal is to highlight the main criticalities and to define the mobility development as response to some possible medium and long-term transport supply improvements.
These forecasts will be used to evaluate possible development of the socio-economic system of the area, together with the main manufacturers, tourism and service sectors.
Due to the geographical position of Province of Imperia, related mobility issues rely on a complex international context.
This study evaluates the present and potential transport demand related to passengers and goods, putting in evidence traffic flows, paths and related criticalities at the infrastructure network level. The foreseen projects are individually evaluated and altogether always in a system perspective, with the aim of providing elements to evaluate the interventions effectiveness, the priorities and the economic effects.
The study has analysed the main mobility components and the different transport modes, in particular the tourism component.
Even if scenarios under study have a national and international strategic relevance, using micro-simulation tools allowed to perform a detailed analysis of attraction and diversion phenomena caused by the new

infrastructure design. The study has considered average traffic conditions and traffic peaks flows generated by tourists during the summertime or holiday periods, when the motorway traffic instability is an important element for traffic analysis.

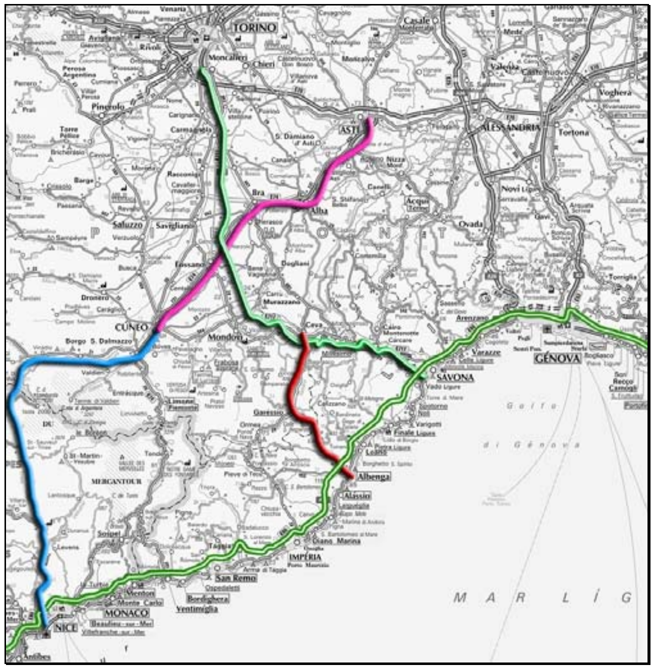


Figure 17 – The simulated infrastructures for different scenarios

Mercantour Tunnel simulation

Due to its realization costs and environmental impact, the work is object of a debate, directly and indirectly involving several stakeholders.

The simulation considers the tunnel construction together with the new motorway connecting Cuneo with Asti (under construction at the moment). The study highlights the light and heavy traffic share that might be transferred to the new infrastructure.

The new infrastructure gives an high improve to the connections between the Po valley and the South of France, even if this new link might produce some negative effects on the tourism in the West-Liguria. In fact, on the one hand this new link lowers a considerable portion of goods flows from the motorway network, on the other it further improves the Côte d'Azure attraction on Italian touristic flows. Moreover, there are no improvements to present motorway criticalities related to summer and holidays periods (Figure 18).

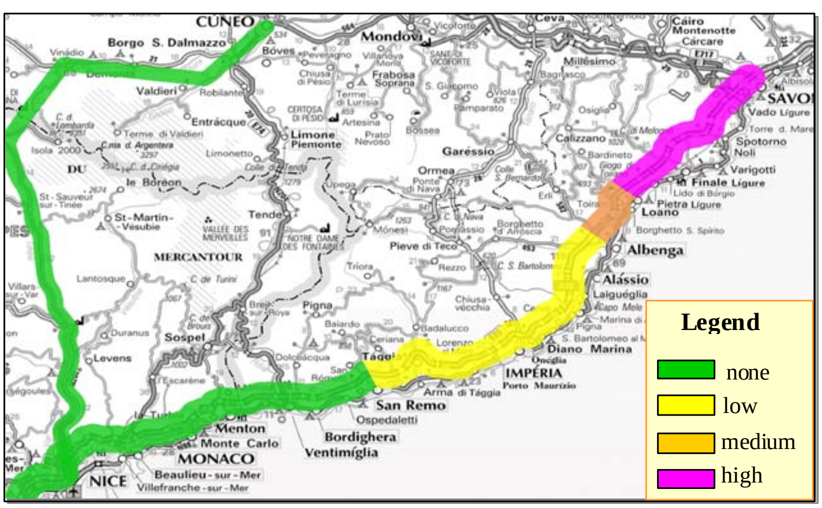


Figure 18 – Criticalities of the motorway network with the Mercantour

Albenga-Garessio-Ceva scenario

The motorway junction between Albenga and Ceva is a real and valid alternative connecting the West-Liguria and Piedmont. The simulation model shows that, lowing the Albenga-Savona motorway link from the flows coming from the West and going to Turin, usual week-end and summer traffic jam are completely eliminated. Following diagrams compare different network performance parameters in the present situation and in the scenario considering the junction under study.

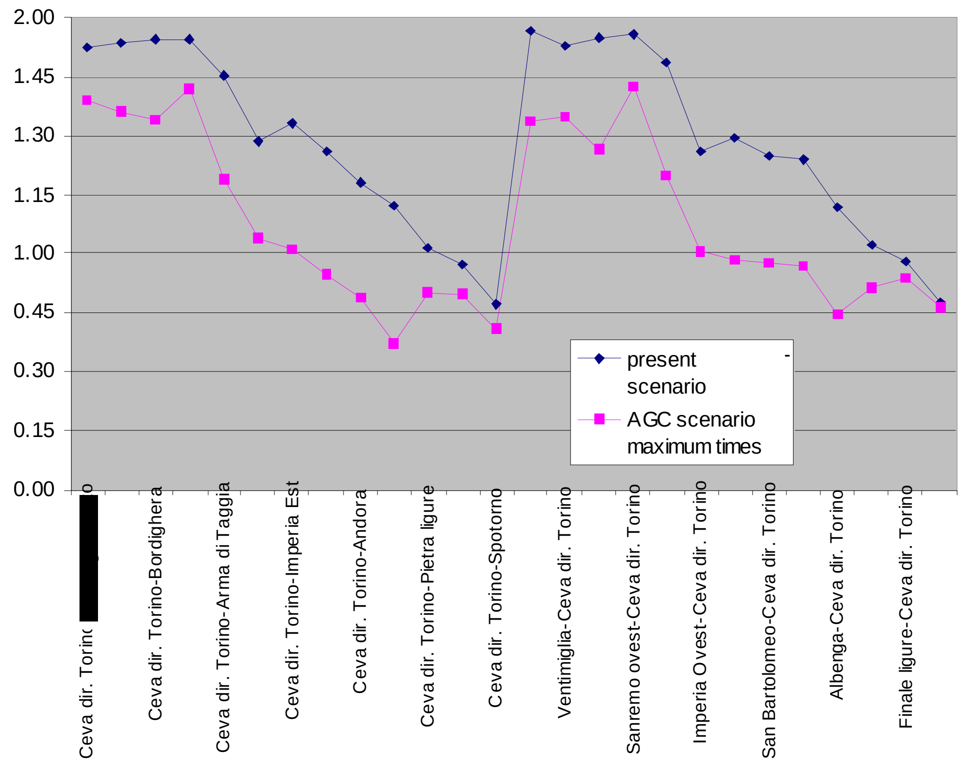


Figure 19 – Present and forecasted travel times

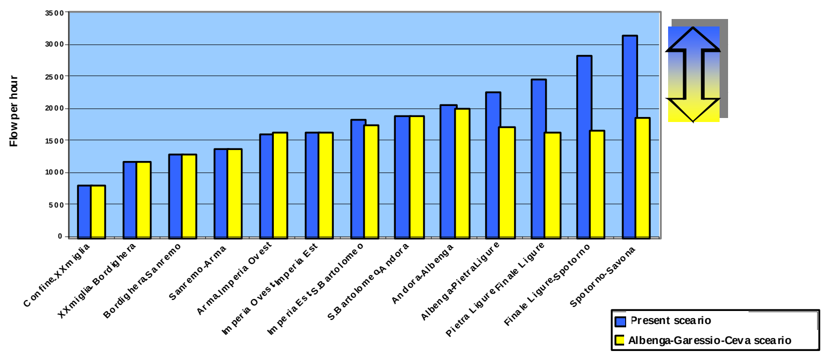


Figure 20 – Present and forecasted traffic flows

The aggregate motorway scenario

The scenario under study considers, at the same time, the Mercantour tunnel, the Albenga-Garessio-Ceva tunnel and the Asti-Cuneo motorway.

The traffic flows distribution is balanced and they could adequately increase on the A10 motorway. The diversion effects of the Mercantour are attenuated by the improvement of the infrastructures connecting Liguria and Piedmont. Moreover, we can forecast a nearly good traffic improvement on the Savona-Genova motorway, as the Asti-Nizza link becomes a good alternative for connections towards Lombardy. In the same way, at the maximum rush hour, the junction Albenga-Garessio-Ceva might represent a valid alternative connecting the area of Imperia to Lombardy.

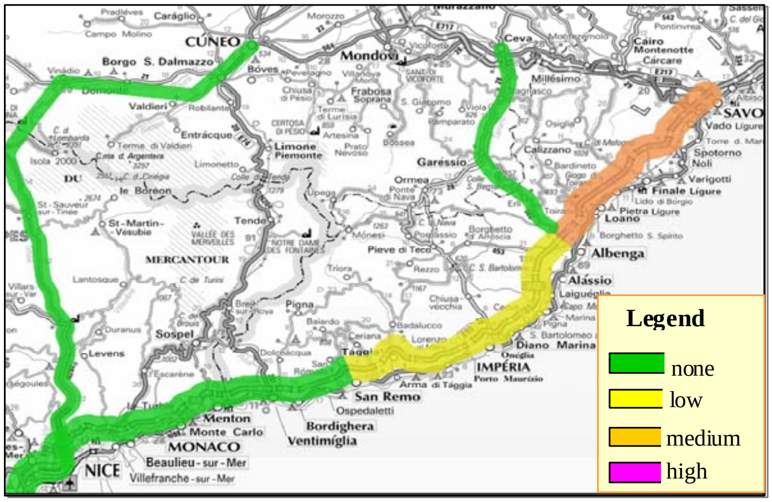


Figure 21 – Aggregate scenario: Criticalities of the I level network

ANALYSIS OF THE STRETCH OF THE ROME BYPASS (G.R.A.) BETWEEN TUSCOLANA AND APPIA JUNCTIONS

The study aims to delineate a new modern methodology to analyse the traffic flows on the Rome bypass (G.R.A.). The bypass stretch between the "Anagnina - Tuscolana" and the "Appia" junctions has been taken into account and analysed through a traffic dynamic micro-simulation tool. The methodology is able to determine the infrastructure deficiency leading to the main flow criticalities and might be extended to the whole G.R.A. and to the junctions towards the urban network, thus allowing a powerful tool for traffic analysis and monitoring and to define and verify any possible improvement of the network.
Such a tool might be the starting point for a mobility information system, capable of supporting any further territorial and/or transportation and mobility planning, by providing a general analysis of the instability of the network flows at the main rush hours.

Figure 22 – Tuscolana and Appia: junctions scheme and surveys stations

The study analyses the details of the actual junction situations, delineating the main elements that generate flow instabilities at rush hours, individuating the most critical conflict points and evaluating the impact of the design solutions under study.

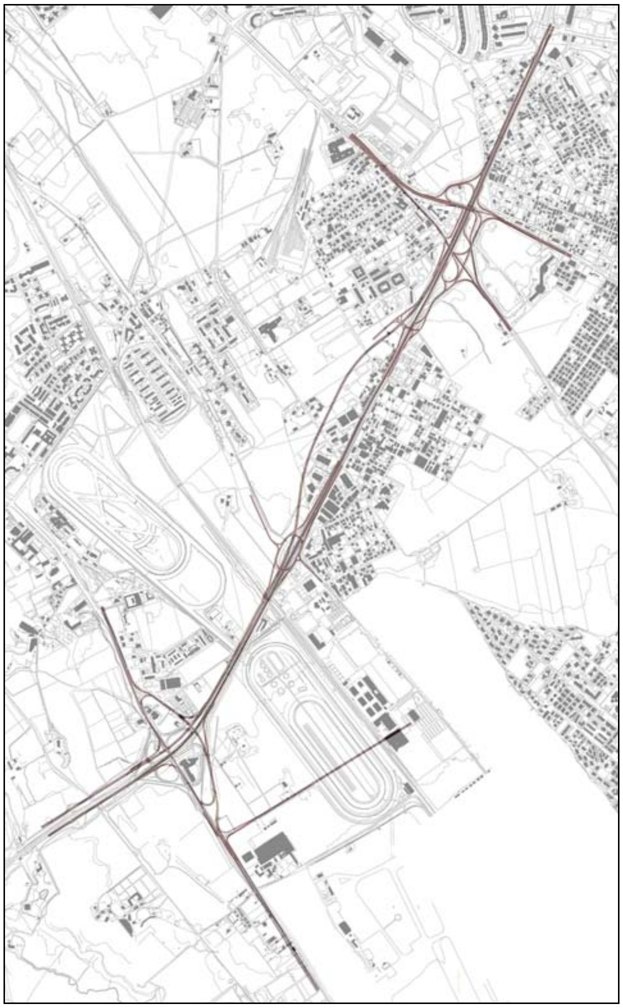


Figure 23 – The implemented network graph

Traffic flow on G.R.A. is critical in several hours, due to heavy traffic and related vehicle densities. Traffic surveys confirm that, both on a hourly basis and on a shorter time period, the highway capacity largely overcome the theoretical capacity, even by 200%.
As a consequence, instabilities and traffic jams are frequent, and they result from flow irregularities which would normally be negligible. The irregularities derives from several factors, even aleatory and unexpected. There are two main causes that can be defined and, at least partially, localised: the areas next to the junctions and the weaving areas. In such areas it is easy to observe small instabilities that immediately propagate, due to the relevant traffic density and the reduced movement space among adjacent vehicles.
The micro-simulation allow us to individuate such situations and to analyse the details, so providing useful hints for designing improving solutions.

Vehicle features

The flowing vehicles are classified into 6 different types:

- Multi-trailers;
- Single trailer;
- Vans;
- high powered cars;
- medium powered cars;
- utility cars.

Each type has specific physical features (length, width, height, weight in tons, age, maximum speed, acceleration, deceleration, equipped with trailer or not and the related length, width, height and weight) and quantitative features (total circulating vehicles percentage).

Drivers features

Drivers are also classified taking into account the main attitudes and considering the following parameters:

- reaction time;
- driving experience;
- driving aggressiveness.

Specific observations delineate very aggressive attitudes for average G.R.A. drivers: they are inclined not to respect safety distances and to behave in a easy (and often very dangerous) way in changing lane. Therefore the maximum aggressiveness parameters are used.

Main simulation parameters

The micro-simulation considers the rush hour from 8 to 9 a.m., after a 20 minutes preload, to start with a loaded network.

The path choice is assigned by a simple deterministic algorithm, that evaluates the shortest paths taking into account travel times and path lengths, as no real alternatives exist for each O/D relation in the simulated network.

The model detects queues when the distance between vehicles is less than 10 m and the speed is not greater than 7 km/h.

Main network performance indicators

The micro-simulation tool gives a wide set of parameters related to the performance level of the network and of its single components (nodes and arcs).

In particular, the main parameters we can collect and analyse are the following:

- average and instant flows on arcs and nodes (movements);
- average and instant density;
- average and instant speed both of flows and vehicles;
- average vehicles delay (delays);
- queues length and propagation;
- criticalities and level of services.

This information may be classified, collected and analysed taking into account single vehicles types or the whole set of vehicles. Information are related to a certain simulation instant or to a certain time interval (for example 5, 10, 15 minutes, one hour, one day and so on).

The project scenario

The project is related to changes on Tuscolana junction (Figure 24).

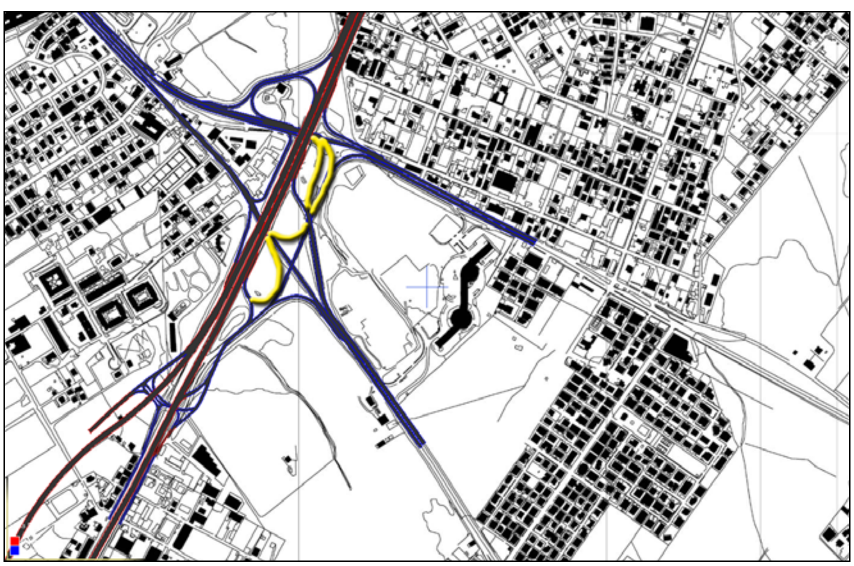


Figure 24 – Present network with the ramps to eliminate


Figure 25 – The new network configuration, according to the project

The analysis of the scenario highlights a clear improvement of the flow conditions on the external carriageway of G.R.A., which is not limited to the area next to the Anagnina – Tuscolana junction, but is extended all over the simulated stretch, showing that most of G.R.A. criticalities derive from flow perturbations induced by entry/exit movements.

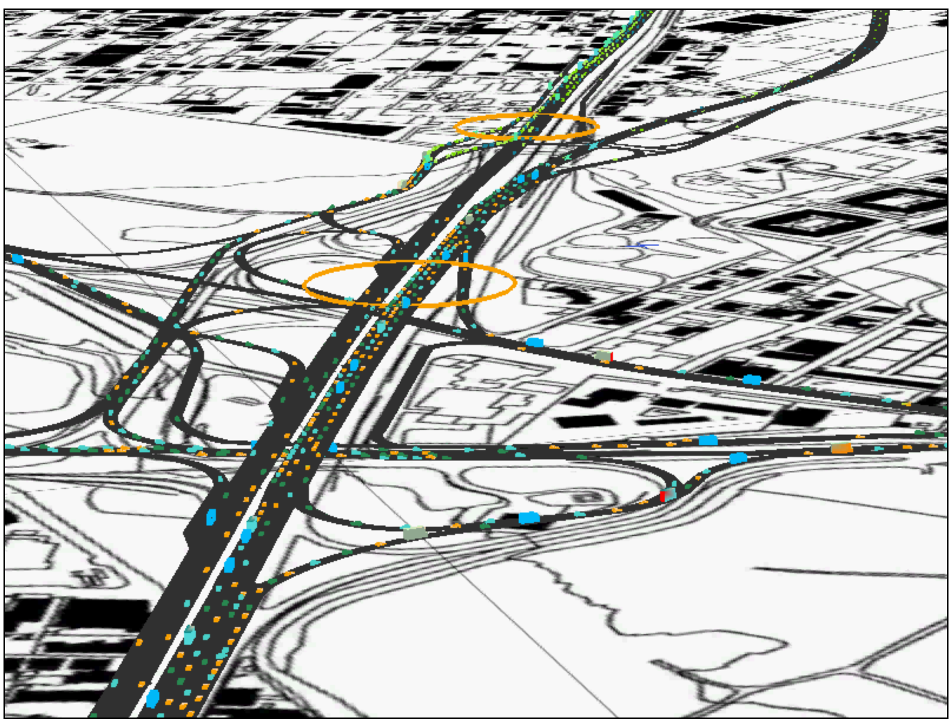


Figure 26 – Anagnina – Tuscolana junction micro-simulation

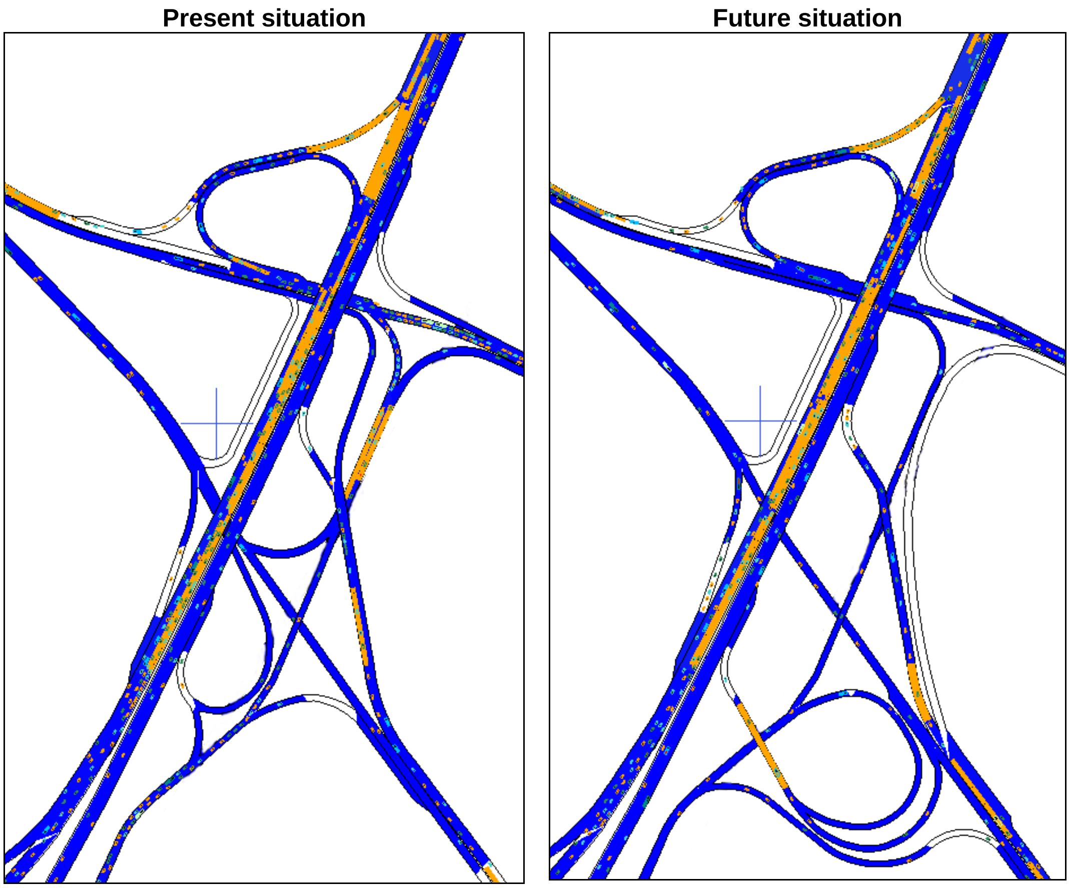


Figure 27 - Queues location: comparison between present and future situations

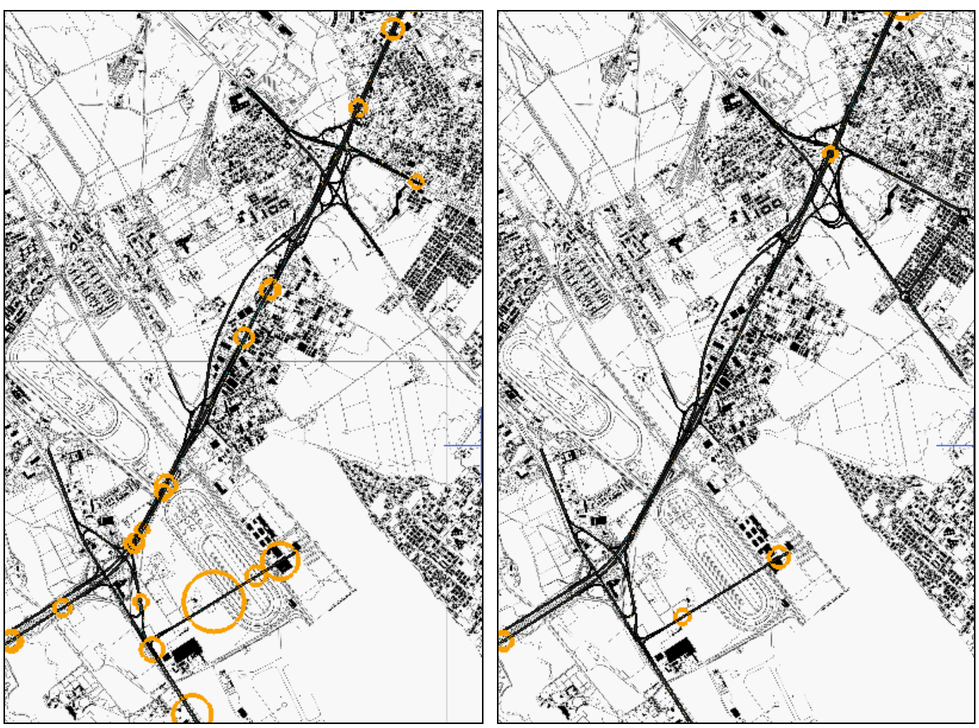


Figure 28 – G.R.A.: present state and project

CONCLUSIONS

"Dynamic" micro-simulation can be used on extended areas to very good purpose, allowing the evaluation of the present state of the network and the definition of criticalities. The analysis takes into account not only network arcs, but also nodes (junctions) and other specific network elements. Therefore micro-simulation tools might be essential for new highways and intersections projects evaluation, for a detailed analysis of the impact of yard and accidents, for the verification of environmental parameters related to emissions, the evaluation of heavy traffic impact and so on.

Several traffic situations may be simulated at a realistic and detailed level, so that the methodology may be applied to road safety analysis, providing useful information about critical points with higher conflicts between traffic flows and/or about possible infrastructure deficiency.

From a management point of view, the micro-simulation tool can quickly provide answers to questions related to road and traffic condition, problems that Public Administrations must deal with every day on their networks.

NOTE

For data property reasons, case studies reported in this work are presented in their general outline, without any quantitative information, that are otherwise available in the models implemented and used for traffic analysis.

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