New Information Technologies on the Brenner Freeway

Bergmeister K.
Autostrada del Brennero S.p.A.

Benesperi C.
Università di Trento

Cavestro R.
Autostrada del Brennero S.p.A.

Mauro R.
Università di Trento

All drivers contribute to the formation of traffic. Their number, driving conditions and above all their habits are the main factors influencing traffic evolution. However, drivers behave like independent elements, only influenced by their surroundings and their visual field. So, they are not able to predict traffic evolution, resulting from phenomena and events occurring on the road ahead.

In order to optimise traffic management on its tract, the Brenner Freeway set up a traffic monitoring system, integrated with variable message signs, able to provide drivers with information in real time. Traffic detectors posted on gantries will record the vehicle flow, continuously monitoring the entity of traffic, its typology and its evolutions. Based on the collected data, the variable message signs posted on gantries, will display information and indications for the users. These will be informed about possible impending dangers and about possible alternative routes in case of congestion. Moreover, in case of intense traffic, the emergency lane, opportunely dimensioned, will be opened to traffic as a “dynamic lane”, making the road a 3-lane freeway. The variable message signs will also tell drivers by proper pictograms whether it is allowed to occupy the dynamic lane or it has to be cleared.

The gantries will be installed at about every 5 km, in order to provide drivers with continuous information. The messages will be displayed in two languages, in order to be understood by the totality of the users of the Brenner Freeway. The new monitoring and information system will allow a real time control of traffic and change the role of the user on traffic: from passive and unaware to active author of its evolution.

The ideation of such a system implies a quantitative characterisation of the vehicular flow and the definition of the control strategies of the infrastructure operational conditions. In this paper the main characteristics of the system are described, and the approaches for the intervention management are analysed.

New Information Technologies on the Brenner Freeway

PREFACE

The Brennero Freeway (A22) connects Italy to Central Europe inside the European freeway corridor E45 (Göteborg-Gela).

At present it features two travel lanes for each travelled way and goes through, starting from the Brennero Austrian border (A13 – Innsbrück-Brennero – interchange) the Bolzano, Trento, Verona, Mantova e Reggio Emilia provinces with an overall length of 314 km. There are 21 toll-houses, at an average distance of 15 km, while the junctions are with the A4 (Milano-Venezia) and the A1 (Milano-Roma), at Verona Nord and Campogalliano road junctions respectively.

For its function and territorial position, the Brenner freeway is constantly occupied, along its whole route, by heavy traffic flows and, on specific tracts, by intense seasonal tourist flows. These tourist flows are prevalently directed to Lake Garda, Trentino and Alto Adige resorts and to the Adriatic Riviera.

The most severe operative conditions of the infrastructure are related to the tourist flow peaks and so during these periods poor level of service or oversaturation conditions can be recorded.

Together with these characteristics, we notice that A22 traffic is, in all its components, systematically growing and it is consistent with the national freeway network trend.

To take into account these traffic needs, some interventions aimed at road safety have already been adopted and others are on the way. The former consist of: work zone signalling procedures (they also include specifically equipped vehicles) and no overtaking by heavy vehicles on certain tracts of the route; the latter consist of: the construction of safety ways to connect the A22 to the ordinary road network and to be used to bypass the blocked freeway tract (i.e. for a car accident).

Another important point is the project to use the emergency lane as an additional travel lane (dynamic lane) to add to the two existing ones when traffic demand is near or exceeds the freeway capacity in those tracts where the most severe seasonal travel demand increases have been recorded.

This paper will show, at a preliminary development level, the main infrastructural and control interventions to improve the Brennero Freeway operating standards and we will outline the system management approaches.

INTERVENTION DESCRIPTION

Infrastructural interventions
They are mainly about the possibility of temporary using the emergency lane as an additional travel lane. The tract to fit with a dynamic lane- in both ways – is 128 km long, from (progr. Km 102+000) to Verona Nord (progr. Km 230+000) (Figure 1).

The tract cross section features a 24.00 m total width and it consists of: four 3,75 m travel lanes; two 2,50 m emergency lanes; 3,00 m central reserve = median + inside edge strips; 0,50 m right shoulders.

Given this configuration, to enlarge the emergency lane to 3,50 m – so as to use it as a travel lane when necessary- without varying the current cross section total width, we have thought it right to intervene on the central reserve, reducing its width form 3,00m to 1,10m.

The result is a current cross section featuring the following modules: four 3,75 m travel lanes; two 3,50 m emergency lanes; 1,10 m central reserve; two 0,50 m right shoulders.

Several structures have already been adjusted to the cross section – or they are going to be by 2005 - and similar interventions are scheduled on 16 targets such as bridges, viaducts and underpasses, amounting to 54216 sm deck.

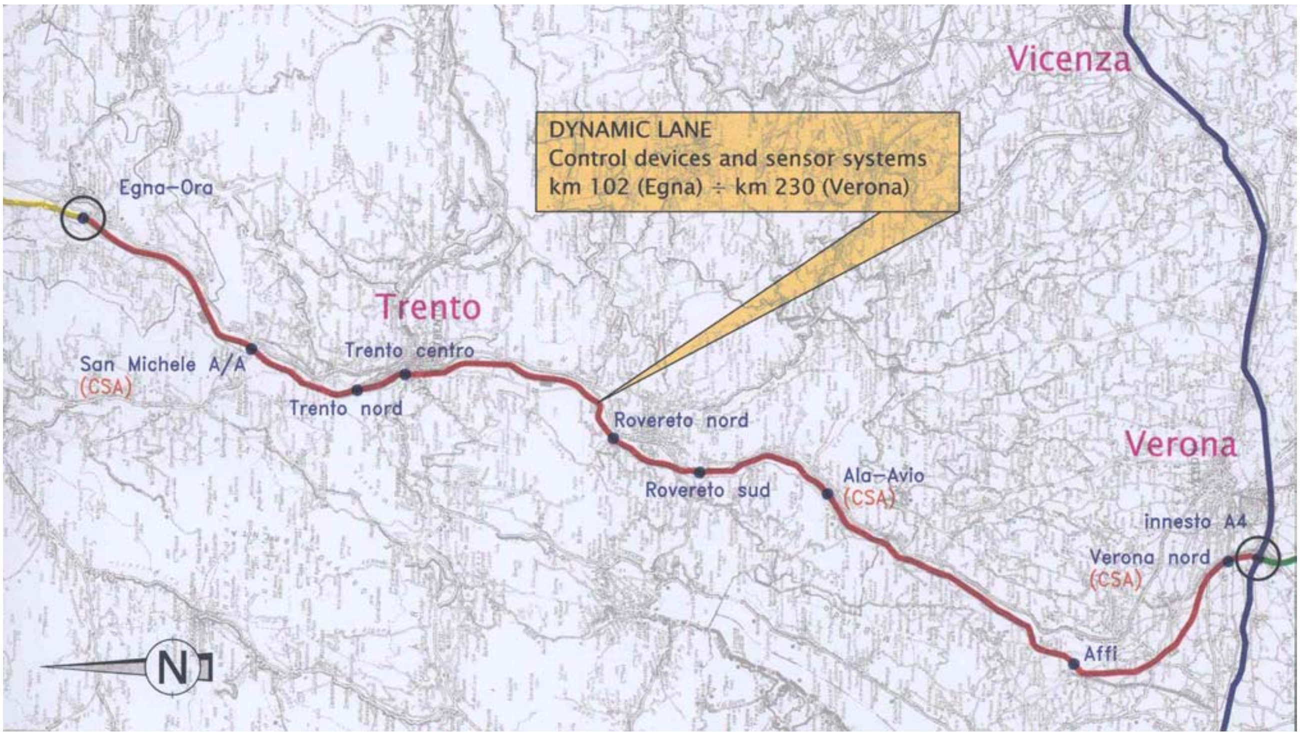

Figure 1: Chorography

As for the bridge over the Adige river in Trento it has been scheduled the rebuilding of the span of 171 m and a 4104 sm deck extension. To allow a correct use of the emergency lane in a dynamic way it is also scheduled the acceleration and deceleration lane enlargement related to the toll-houses and service stations on the tract in question.

They are in all 27 acceleration lanes and 27 deceleration lanes with a longitudinal development of about 8100 m.

Finally, in the tract between Affi tolling house and the progr. Km 230+000, totalling 23 km, an antifog system is located in the median which is also to adjust to the new roadway width standards.

Management and control interventions

To operate the infrastructure in an efficient and safe way some further interventions are necessary besides the cross-section adjustment.

They concern the management and control of transitory conditions (opening/closing of the dynamic lane) and final ones (open/closed dynamic lane), besides other operative ordinary conditions of the infrastructure such as work zones and car accidents.

The system features a "telematic assisted route" for the user and the continuous acquisition of pictures and adequate traffic measurements.

The following facilities are scheduled:

a) traffic detection systems;
b) closed circuit monitoring systems;
c) variable road signs;
d) offence detection systems;
e) call boxes;
f) high speed backlane;
g) control center.

The following information on the above list are related to the present preliminary system definition. The subset devices a) b) c) and d) will be posted on online gantries (Figure 2). They are of two types, depending on their position: type 1 gantries will be placed before interchanges; type 2 gantries (Figure 3) will be placed along the axis in the tracts between subsequent interchanges. Regardless of the type, the gantry frequency inside the tracts will be of 5 km.

The interchange gantries, placed along the freeway acceleration lanes (Figure 4), will be added to the current ones.

Thanks to the traffic detection subsystem we can effect, for each of the three lanes, the calculation, classification and survey of the circulating vehicle spot speed.

Figure 2: GantryType 1

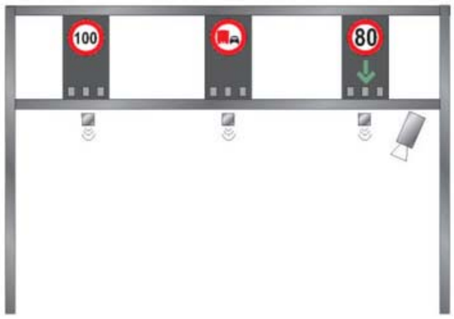

Figure 3: Gantry Type 2

Figure 4: Gantry on acceleration lane

Every vehicle will be then linked to a record – sent in real time to the control center – along with the above-mentioned identifying parameters. To acquire information it is scheduled the use of innovative sensors, placed for the complete monitoring of the tracts on at least all the existing gantries (at about 5,5 m above the ground level).

The closed circuit monitoring subsystem is based on dome type flag-like zoomable video cameras, installed on special poles and on all type 1 and type 2 scheduled gantries. To video monitor the entire tracts the video camera frequency is of one each km.

During the dynamic lane activation and deactivation phases the closed circuit monitoring subsystem will allow the functioning of a video brushing procedure of the infrastructure to check the carriageway conditions.

As far as variable road signs are concerned, the type 2 gantries (Figure 3) will be equipped with panels as to graphically visualize on each lane pictograms such as: availability/unavailability of the dynamic lane; a lane unavailability signalled by directional arrows (i.e. in case of work zones); speed limits on each lane; no overtaking by heavy vehicles (Figure 5).

Type 1 gantries (Figure 2) will be programmed on two information levels:
- on the first level, they will feature the same characteristics and functions as the ones placed between the interchanges (previously described);
- on the second level, they will feature two graphic areas to visualize two pictograms and an alphanumeric area with three lines. This will allow to inform the users both in a graphic way and in an alphanumeric way about the most important events in the tract ahead or, in emergency cases, to advise/impose to get off the freeway at the next tolling house.

As we have already stated, the variable road signs are accompanied by panels placed on the acceleration lanes of each interchange.

Each panel features graphic and alphanumeric areas for each direction (Figure 4).

The offence detection subsystem is physically incorporated inside the variable road signs. In each sign above a lane a speed detection device will be installed (a high precision and ratified type) along with a digital camera to take pictures of vehicles and plates.

The data related to vehicles which have committed offences will be transmitted in real time to the Police Centre operating along the A22.

The call boxes already present on the freeway tract in question will be used as a supplementary device to check the presence of still vehicles during the dynamic lane opening.

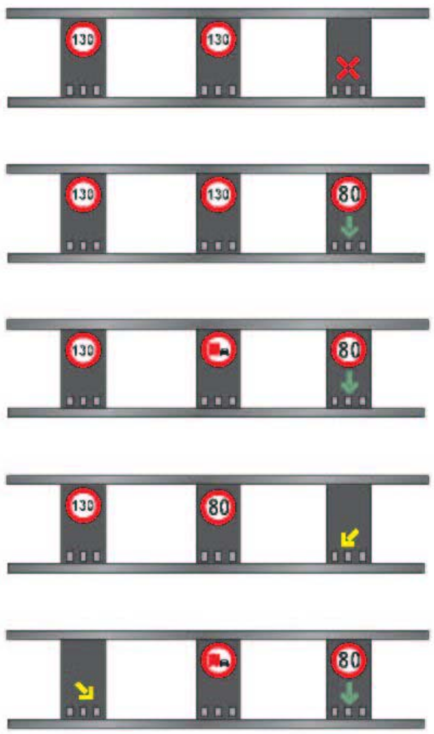

Figure 5: Example of gantries' configuration

It is worth noticing that the opportunity of having traffic data system acquisition devices in addition to the existing ones will be evaluated during the subsequent phase of the project when a first operative check of the system will be performed.

Figure 6, Figure 7 and Figure 8 show an example of section equipped for the dynamic management of the dynamic lane and show the system displacement on the standard section and on the whole section.

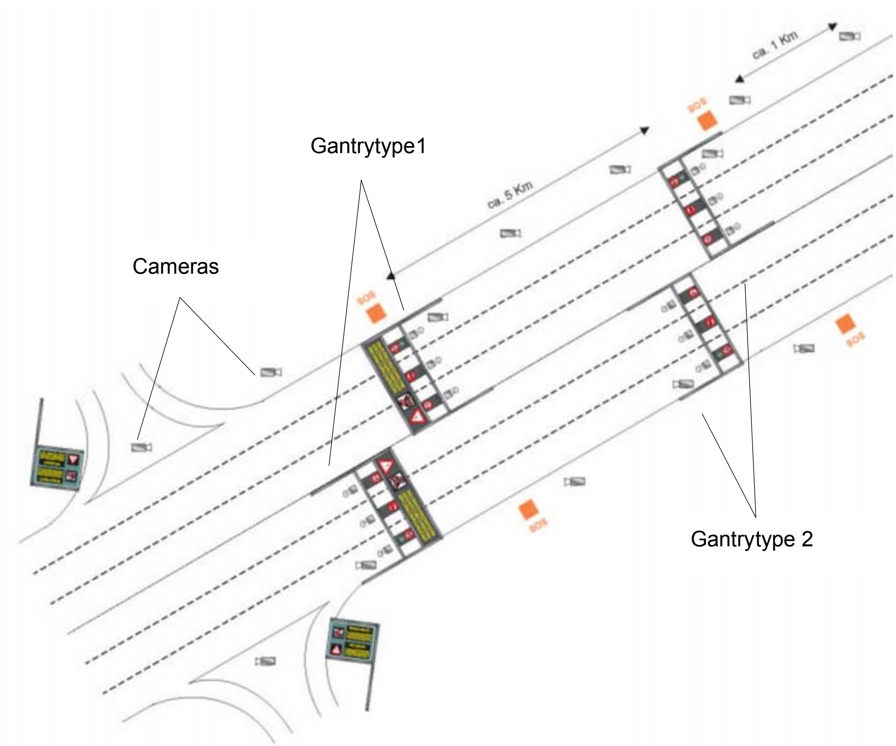

Figure 6: Example of section equipped for the dynamic management of the dynamic lane

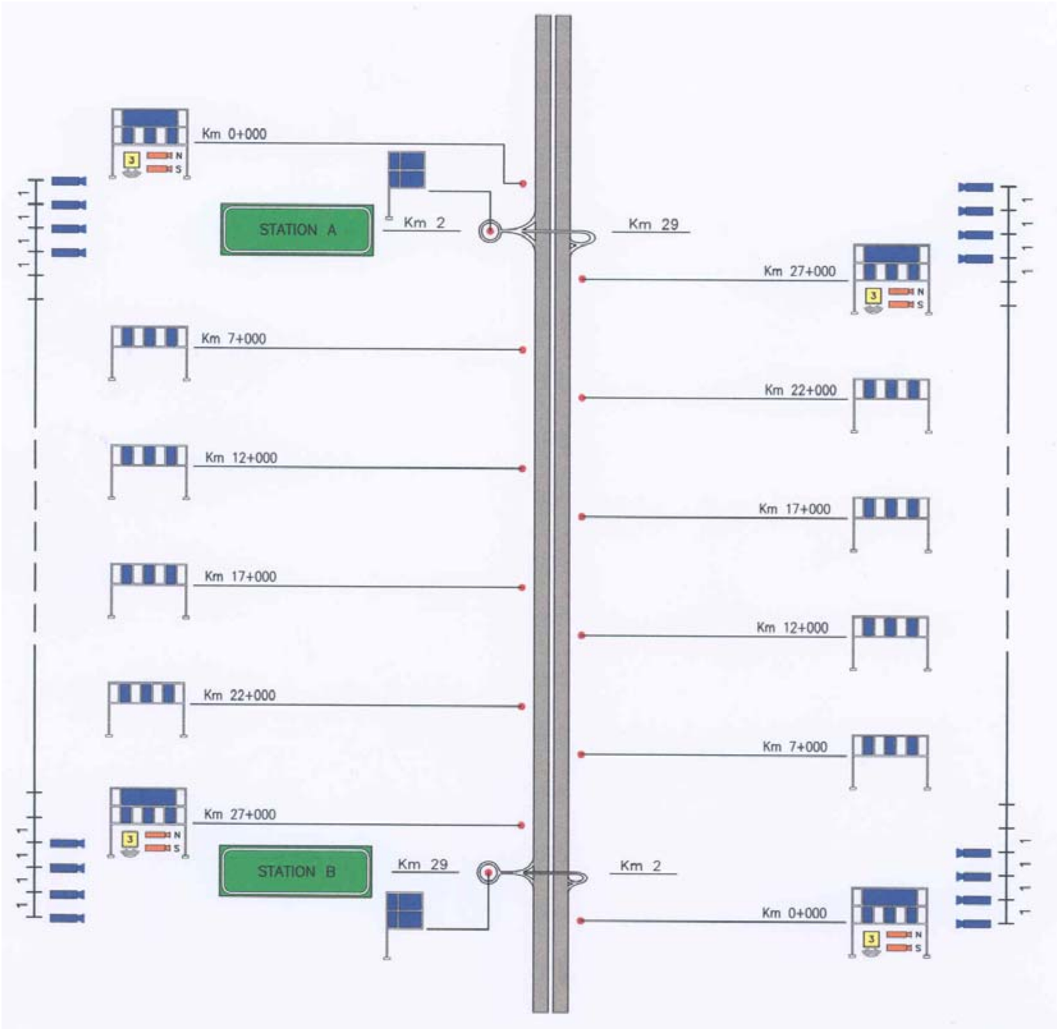

Figure 7: System displacement on the standard section

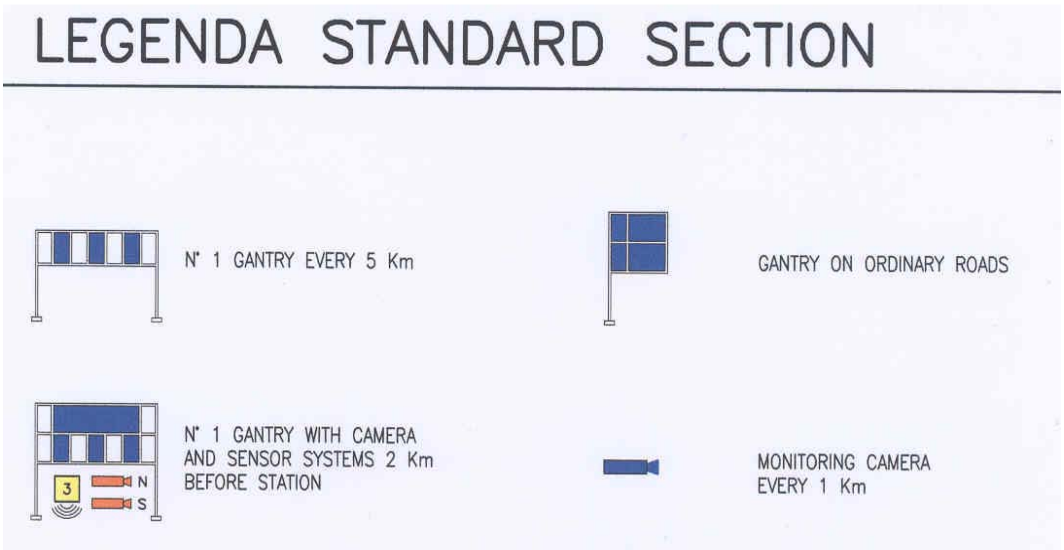

Figure 7: System displacement on the standard section

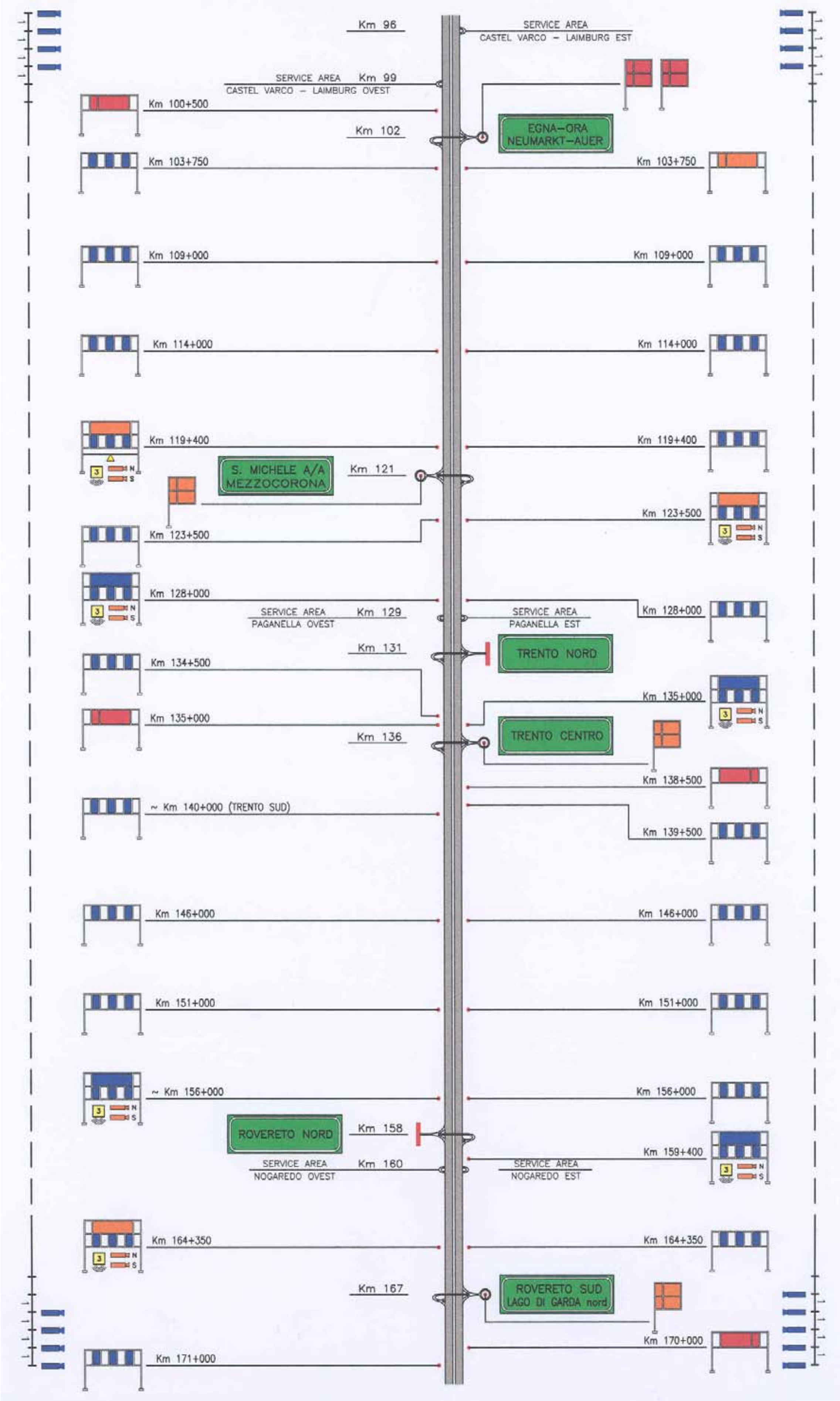

Figure 8: System displacement on the whole section

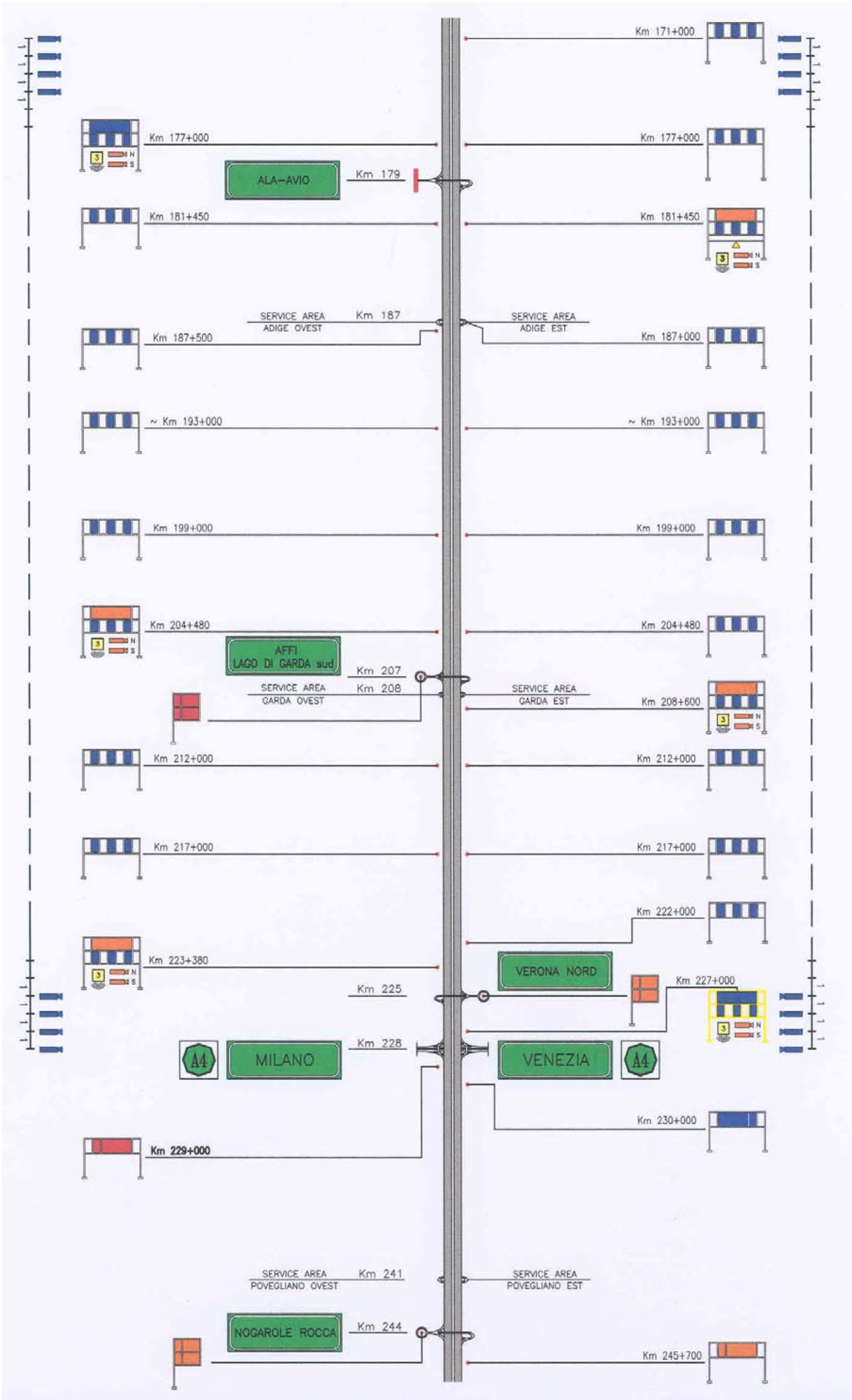

Figure 8: System displacement on the whole section

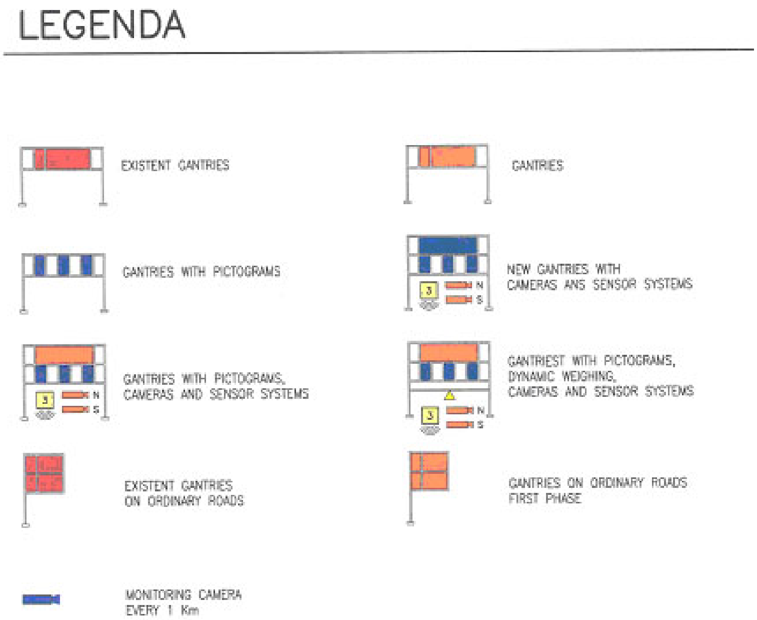

Figure 8: System displacement on the whole section

SYSTEM CONTROL AND SYSTEM MANAGEMENT APPROACHES

The aim to create along the tracts a telematic assisted route for the users travelling along the A22 implies the interaction with them by means of variable road signs installed on the gantries.

The contents of the variable road signs should fundamentally perform the following tasks: stabilisation of traffic flow; warning of queues or of difficult road and traffic conditions because of bad weather; traffic condition modifications in spatial situations such as car accident interventions or infrastructure maintenance plans (for example, work zones); temporary activation of the dynamic lane to restrain peak travel demands; deactivation of the dynamic lane and carriageway restoration to ordinary conditions; directing of the flows to emergency routes to bypass freeway circulation blocks; substitutive variable road signs.

The overall length of the tract affected by the interventions and the high number of the road monitoring devices (sensor and video cameras) will not however allow the operators to have an effective and thorough visual control of the infrastructure conditions and of the traffic evolution.

The operators' decisions will be necessarily backed by dedicated software which can activate, on one hand, warning and forewarning signals and, on the other hand, forecast the system evolution on the base of the information continually acquired along the infrastructure.

In brief, as a result of the process, an operative procedure is chosen whose goal is the activation of a signal scheme aimed at achieving a certain effect (for example, level of actuated speed stabilization).

To exemplify, with reference to the dynamic lane, the operation sequence to transform the emergency lane in an additional traffic lane can be summed up in this way: when the system state evaluation and its evolution prediction call for it, the dynamic lane opening is effected progressively for tracts, in function, among other things, of the level of actuated speed on the adjoining lanes and it is signalled by means of the signs on the gantries by an adequate sign configuration (e.g. by a down arrow).

When, according to the evolution of the flow features and to their re-evaluation, it is considered right to restore the carriageway original condition, the dynamic lane is progressively interdicted to traffic; to perform this, adequate signals are sent from the variable traffic signs along the road.

Even in this case, to minimize the disturbing effects on the flow affected by the intervention, it is assumable to proceed adopting a time lag in the dynamic lane deactivation whose timing is function, among other things, of the level of actuated speed on the adjoining lanes.

The control loop of the system, whatever the reason for the control intervention, is shown in Figure 9.

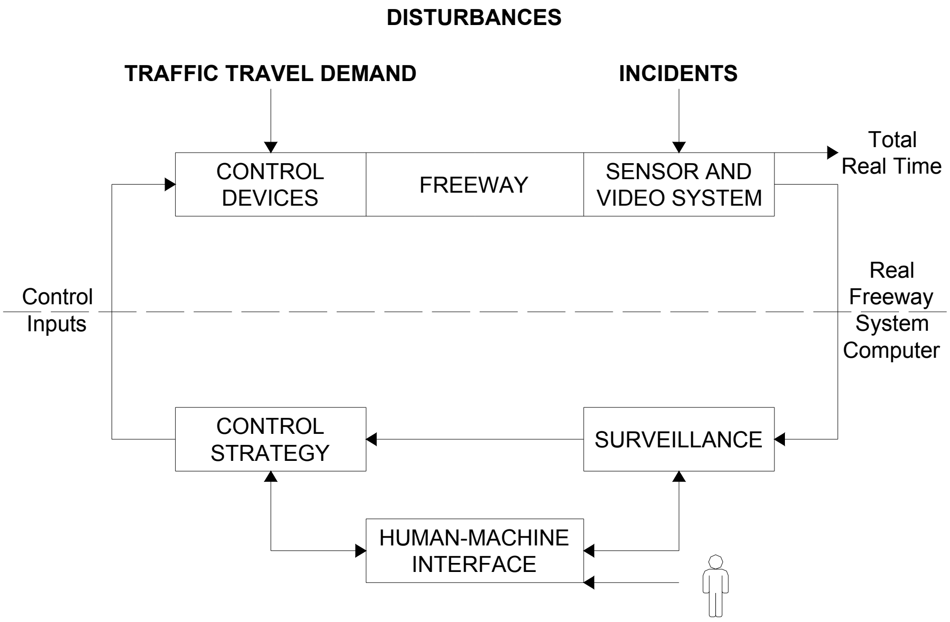

Figure 9: Control loop

As regards the strategy control, the ones used for preventing congestion on freeways can be divided into two classes. Strategies of the first class are directed towards the control of transport demand in order to avoid traffic volume on carriageways exceeding capacity, for example by metering traffic flow on entrance ramps or by modifying drivers' routes in order to divert traffic from the overloaded arcs of the network to those that have excess capacity.

By means of these strategies we can keep urban freeways under control (e.g. boulevard periferique of Paris [1]) or freeway networks (as, for example, it occurs in North America or Central Europe, where there is often a close-meshed network of freeways or freeway-type roads) [2].

The second class includes techniques aimed at the detection of the approaching of the flow instability and control aims at modifying drivers' behaviour on the road by increasing the carriageway capacity and/or by defining the timings when to activate capacity reserves [3].

In the Brennero Freeway case, the infrastructure features and the control targets discussed in the previous paragraphs call for strategies belonging to this second group.

In fact, the A22 is connected to freeways serving routes external to its own operating area and as for the ordinary network to which it is connected no type of monitoring or control to activate strategies based on alternative routes are scheduled.

As far as control targets are concerned, as we have already stated, it is essential to be able to have, under particular peak travel demand circumstances, capacity reserves represented by the dynamic lane activation.

In this case, as we have just mentioned, a crucial point in freeway traffic control is the detection of the approaching of instability and the choice of the most suitable control strategy in each case. The theory of freeway reliability [4] is a valid instrument to solve both of these problems.

Instability is a stochastic event whose occurring or not depends on the level of actuated speed sequence along the way.

The probability that this event will not occur in a certain time defines the reliability of the traffic flow examined during that time.

Besides, to define the dynamic lane activation and deactivation time and the consequences of these actions, it is absolutely necessary to predict the shock wave effects on the traffic flows affected by the interventions.

In fact, weaving phenomena occur when groups of vehicles are forced by the road layout to change lanes in one (or both) direction.

The preliminary survey for the model operative definition, control techniques and strategies, will then have to achieve the specific knowledge of the operating conditions of the infrastructure.

This basically involves the identification of the fundamental flow, density and speed relationships on homogeneous freeway tracts as well as the identification of traffic processes to achieve, among other things, the flow reliability formulations.

The control and management facilities which are scheduled to be installed on the Brennero Freeway allow the acquisition of all the data necessary for the identification of flow, density and speed relationships and for the analysis of traffic process, as well as, on one hand, the implementation of sequential calculation of reliability and, therefore, the detection of instability; on the other hand, the implementation of the models to analyse shock waves.

Figure 10 diagram sums up a feasible control model for the system currently under examination.

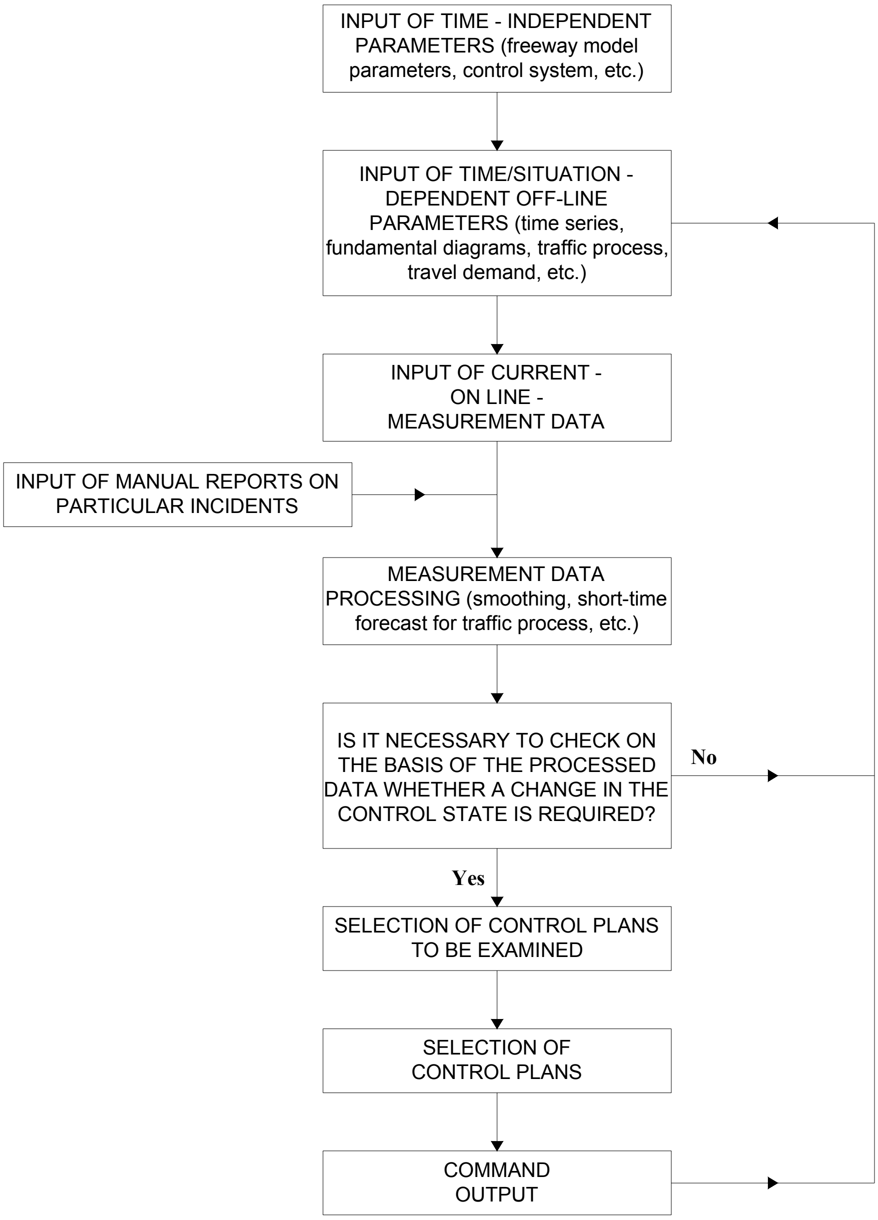

Figure 10: Diagram of freeway control scheme

Besides, we have to specify that, as regards the emergency lane use on the Brennero Freeway, it is necessary to evaluate the possibility of detecting a further control design predetermined on a historical basis. This implies the possibility of scheduling in advance the activation/deactivation of the dynamic lane, on the entire or on only a part of the infrastructure length on which such an intervention is scheduled, on given days or specific hours corresponding to the historical peak travel demand (e.g. at holidays, or at winter week-ends, or at commuter traffic peak hours).

The possibility of combining the two control strategies (the one based on the system condition experimental data and the one based on historical data), that is to say the possibility of testing and modifying in real time the programme determined on a historical basis in function of the real and instantaneous evolution of traffic demand represents a strengthening of the overall management strategy of the Brennero Freeway.

The possibility of having variable road signs posted on traffic sign gantries is an element of fundamental importance to control traffic even in presence of environment and road particular conditions, such as bad weather, work zones, poor visibility as well car crashes detection.

To give an example regarding the presence of work zones (but these considerations are also valid for the other events mentioned), this circumstance can be very dangerous for freeway circulation, not only because it causes congestions, slowdown and delays, but above all because it can cause car accidents, mainly when there are high traffic volumes and when the congestion becomes longer than the tract of the infrastructure along which the works are signalled in the usual way.

Variable road signs allow, instead, to inform the drivers about the presence of work zones ahead and about a possible slowdown or congestions with an adequate early warning both from a spatial and a temporal point of view; in this way it is possible to inform the users in advance about the circulation condition variations which will occur downstream, substantially modifying their driving habit which should become more careful and cautious.

By an adequate use of the above-mentioned models and strategies to manage the dynamic lane it will be also possible to perform a progressive closing of the lane affected by interventions upstream to the work zone (e.g. by inclined arrows near the lane which is going to be closed) and the enforcement of speed limits lower and lower on the other lanes till the restoration of normal circulation traffic downstream of the work zone.

CONCLUSIONS

This paper has described the main infrastructural interventions to manage and control an important tract of the Brennero Freeway and we have outlined, for such a system, the essential aspects to define the control strategies aimed at insuring safe and efficient operating conditions of the infrastructure, even under particular road, traffic and weather conditions.

As the design is still under development, which in this first phase tries to define a prototype which will allow, among other things, the testing of the control system architecture, it has not been possible in this paper to study in detail the more specifically model aspects of the procedures which we are going to implement. They, as we have mentioned in the previous paragraphs, are nonetheless characterized in their essential lines. The future results of the research will however been published as soon as they are available.

REFERENCES

[1] Papageorgiou M., Blosseville J.M., Hadj-Salem H. (1990) – *Modelling and real-time control of traffic flow on the southern part of Boulevard Périphérique in Paris* – Transp. Res. A 24, 345-59

[2] Hangleiter S., Schick P., Trupat S. (2003) – *Ermittlung und Bewertung der Nutzenkomponenten von Streckenbeeinflussungsanlagen im Hinblick auf den Verkehrsablauf* – Straßen Verkehrstechnik

[3] Ferrari P. (1989) – *The effect of driver behaviour on motorway reliability* – Transpn. Res.-B. Vol. 23B, No. 2 pp. 139-150

[4] Ferrari P. (1994) – *The instability of motorway traffic* – Transpn. Res.-B. Vol. 28B, No. 2 pp. 175-186