PAPABILES

Projet Autoroutier Pilote Aubonne - Belmont pour une Initiative Lausannoise d'Evaluation par Simulation

Simulation-based evaluation of the impact of telematics in the Lausanne area: a pilot study

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At the present time, variable-message signs (VMS) and variable speed-limit signs are in frequent use for traffic control, especially along urban motorways. The Lausanne by-pass is partially equipped with these and should be fully equipped in the near future. This study is made to evaluate the effects of such systems, either on the efficiency of the road network or the security of its users. The PAPABILES pilot-study deals with the evaluation of the potential effects of such control systems on the performance and safety of the network, using a state-of-the-art simulation tool (MITSIM), developed at the Massachusetts Institute of Technology.

In this paper, we present the scenarios that have been tested and comment on the results. Preliminary analysis of the impact of variable speed limit signs made it possible to emphasize the following elements:

a) The reduction of the speed limit in the case of high-flow scenarios did not produce a significant increase in the performance of the motorway network, usually limited to 120 km/h. For limitations lower than 100 km/h, it actually seems to decrease. Admittedly, some results tend to show a slight improvement of the performance for speeds around 105 km/h. However, the magnitude of these improvements is too low to justify the installation of such equipment for the sole purpose of increasing the performance of the network.

b) About the question of road-users' safety in the presence of high flow, a lower speed limit decreases the probability and the severity of an accident when the traffic breaks down from a normal regime to a congested regime. As mentioned above, this safety improvement does not significantly affect the system's performance in terms of throughput.

c) In the case of an incident that notably reduces the capacity of the motorway, simulations carried out up to now show that the application of various speed limitation scenarios does not improve the performance of the network. The capacity of the network is governed by the capacity at the incident location and the actual speed is already below the limitation. Again, the role of speed limitation is more beneficial for safety than throughput.

We emphasize that, due to the limited calibration of the model, the results must be interpreted with care. We believe that their interpretation is valid, but that their actual impact must be analyzed in more detail. This will be achieved in subsequent phases of the project.

Keywords

ITS – Telematic –Variable Speed Limit – Simulation – Swiss Transport Research Conference – STRC 2001 – Monte Verità

1. Introduction

At the present time, variable-message signs (VMS) and variable speed-limit signs are in frequent use for traffic control, especially along urban motorways. The Lausanne by-pass is partially equipped with these and should be fully equipped in the near future. This study is made to evaluate the effects of such systems, either on the efficiency of the road network or the security of its users.

The PAPABILES project is divided in two phases. The first has been completed and its results are reported here.

Phase I: Preliminary study. The main aim is to demonstrate the relevance of the methodological approach and the possibilities of the simulation tools used, based on an analysis of the whole process from the modelling to the evaluation of possible outcomes. This preliminary study is restricted in space (one portion of the road) and time (a few significant periods).

Subsequent phases: A full model, with a wider scope in both space and time will be developed. A more systematic calibration will be performed in order to benefit also from quantitative results from the MITSIM simulator.

2. MITSIM

MITSIM (MIcroscopic Traffic SIMulator) has been developed at the ITS Program of the Massachusetts Institute of Technology (MIT), U.S.A. It is specifically designed to simulate traffic flow in road networks that incorporate telematic technology for traffic control and information to users. The movements of individual vehicles are explicitly simulated, using car-following and lane-changing models. MITSIM has been designed for the evaluation of dynamic systems of traffic control (Yang and Koutsopoulos 1997, Yang 1997).

The modelling of the transportation supply (i.e. the network) and demand (i.e. OD matrices) is briefly described:

2.1 Network

The network was coded using an existing database, the Swiss road data bank STRADA. Since the format of the code is not that used by MITSIM, a semi-automatic method was developed to transform STRADA format into MITSIM. The geographical situation of the network under consideration is sketched in Fig. 1 .

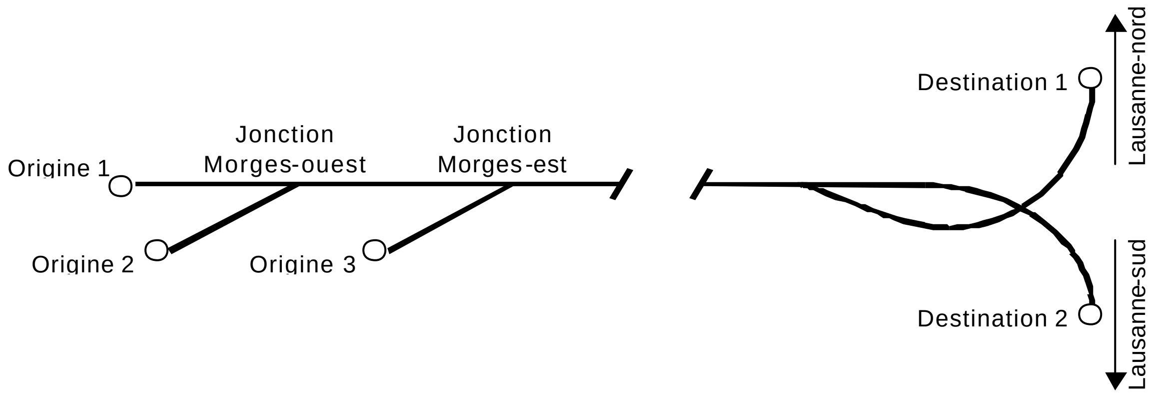

Fig. 1 Schematic view of the network showing its points of entry (origins) and exit (destinations))

2.2 *Origin-destination matrix*

MITSIM requires the entry of time-dependent origin-destination (OD) matrices defined for each type of vehicle classified according to parameters such as acceleration and decelerations capabilities.

The first phase of the study described in this paper is based on a single time-dependent origin-destination matrix. It has been calibrated using data collected on Tuesday, 2nd November 1999, from 7h00 to 8h00 in 5-minute intervals. In each interval, the distribution of the entries of vehicles is assumed to be governed by a random Poisson distribution.

3. Evaluation of speed limit scenarios

The aim is to analyse the effects on safety and on throughput, of the implementation of various scenarios of speed limitation. Limitations from 60 to 120 km/h, in steps of 10 km/h, were applied to the whole section. Because of the stochasticity of the simulation software, a set of 5 "runs" has been achieved for each scenario.

Six data collection location were determined, three at each of the junctions Morges-ouest and Morges-est. In both cases, these "sensors" were simulated as illustrated in Fig. 2 . The sensors provide average values over intervals of 5 minutes.

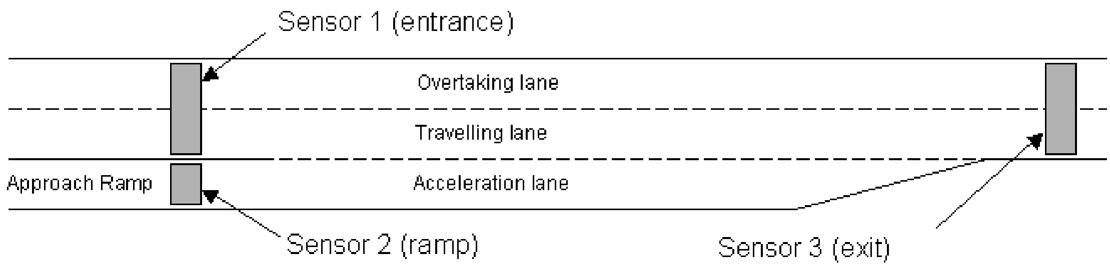

Fig. 2 Position of the measuring-points used in the simulation

On-site measurements were made by the company Robert-Grandpierre & Rapp S.A. using video cameras installed just before each of the two junctions. The position of the measurement zones of these cameras is consistent with the sensors (1) and (2). Unfortunately no count was available in a location corresponding to sensor (3).

3.1 Model validation

A comparison between simulation (MITSIM 1 to 5) and on site measurements (RGR) has been achieved. The simulations made for the junction Morges-est showed a greater difference with the on-site measurements than did those at Morges-ouest. The plot in Fig. 3 shows the different flows at the Morges-est sensor 1 (entrance) location. It shows that the simulated and actual flows were fairly matching until 7h35. At that time all simulations tend to underestimate the flows.

The plot in Fig. 4 shows the different speeds at the Morges-est sensor 1 (entrance) location. It confirms this phenomenon by showing a significant drop in speed between 7h35 and 7h40 for each of the five simulations. However, the on-site measurements show that despite a slight drop in speed at that time, no congestion arises. The visualization on-screen of each vehicle's particular path in the simulation indicates that the behavior of users at the location where the acceleration lane merges seems to be different in some respects from what occurs in reality. In the simulation, the vehicles travelling on the motorway brake too hard to allow those entering to do so, which creates a state of instability and induces congestion.

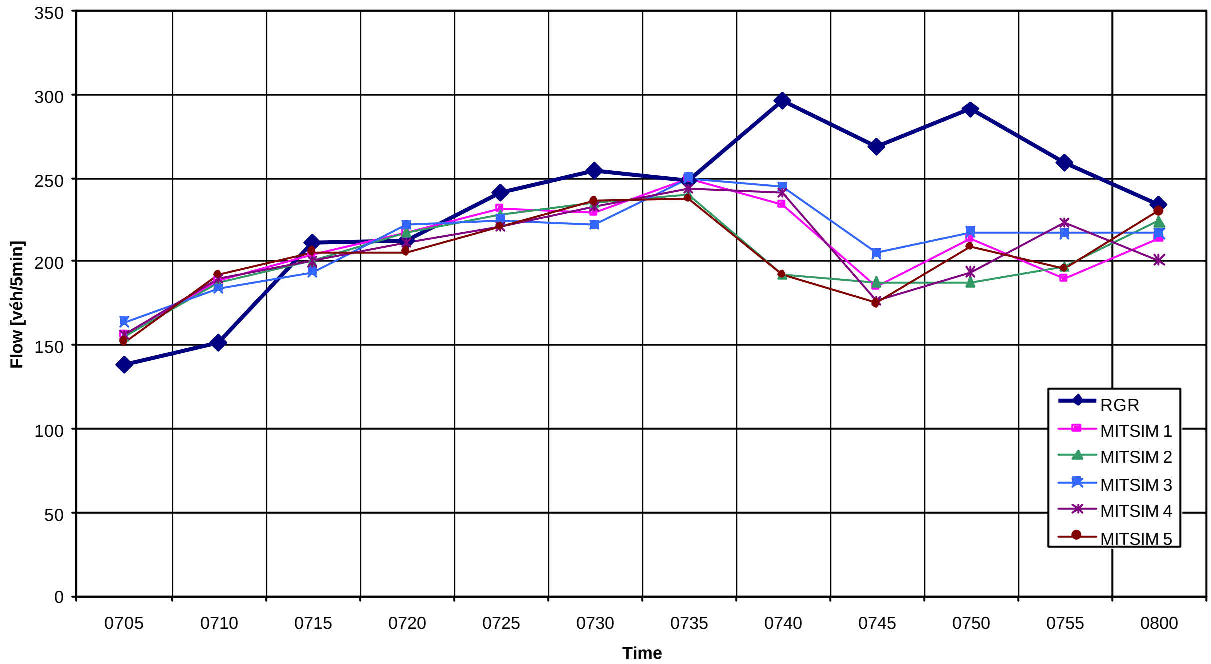

Fig. 3 Rate of flow before Morges-est, speed limit 120 km/h

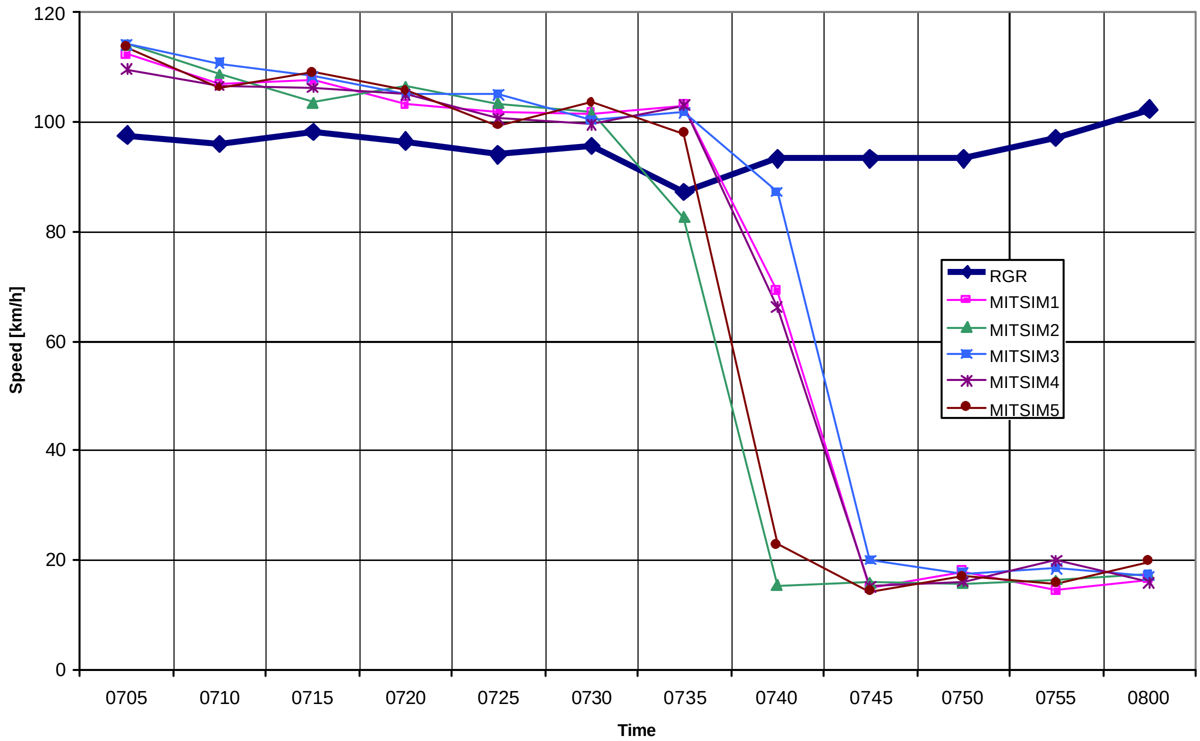

Fig. 4 Speed before Morges-est

An analysis of the behavioral parameters, especially at junctions, should therefore be made so that the models correspond better to reality. The current behavior parameters were calibrated from data collected in Boston. The formation of a traffic jam is a highly chaotic phenomenon: it is quite possible that a traffic jam occur under conditions perfectly similar to those of 2nd November between 7h00 and 8h00.

3.2 Scenarios analysis

A qualitative comparison among the various scenarios is relevant even with the limited accuracy of the behavior model mentioned above.

Our first analysis has shown that the sensitive point of the network is the junction Morges-est. For this reason, the comparison of the variants will focus on the effects produced in this zone by the different speed limits strategies.

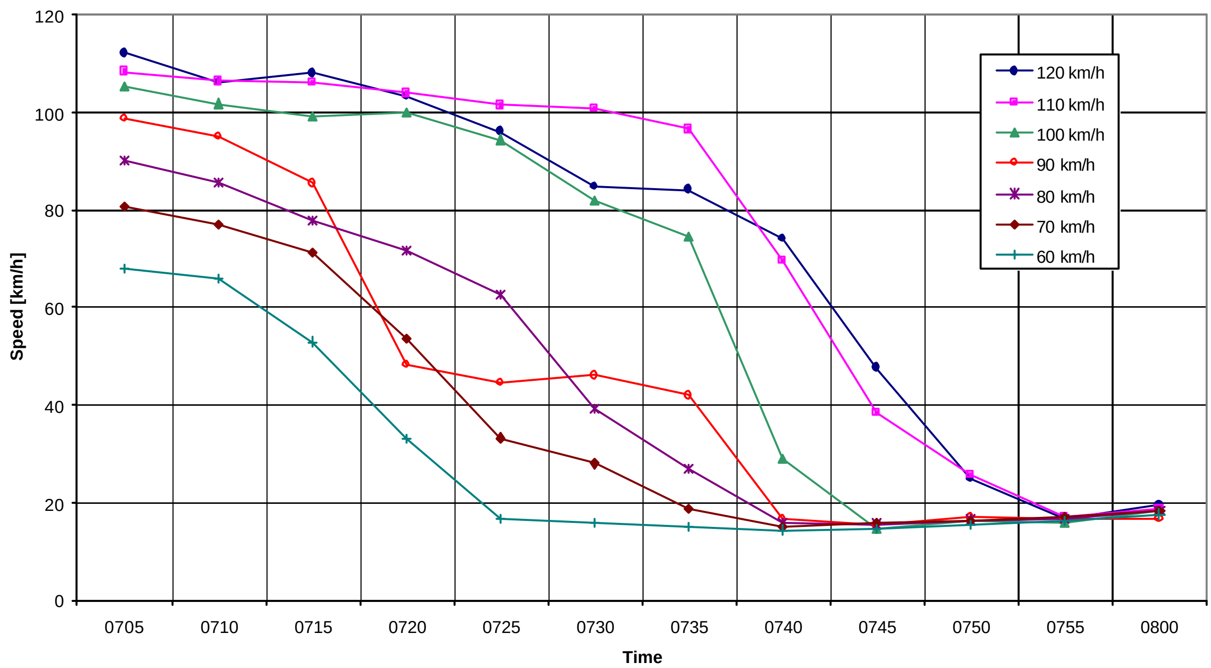

Fig. 5 Average speed of vehicles at the Morges-est entry, as a function of the speed limit in operation

The plot in Fig. 5 shows the average speed of vehicles, over 5-minute intervals, measured by the junction entry sensor for each value of the imposed speed limit. The points plotted were obtained using the mean value of the speeds indicated for each of the five simulations, so that each curve represents the average evolution of a simulation.

Some observations can be made from this graph:

- A speed limit of 110 km/h make congestion appears at the latest.
- For speed limits below 100 km/h, congestion appears earlier but builds up more slowly.
- Conversely, for limits greater or equal to 100 km/h, the speed drop is more abrupt ($\Delta V/\Delta T$ is greater).
- For limits of 120 or 110 km/h, the vehicles travel at a uniform speed of about 105 km/h during the first 20 minutes.
- The plot for 90 km/h shows an irregularity at 7h20, due to a high variance of the output from the five simulations.

Fig. 6 shows the average over the five simulations of the number of vehicles counted by the exit sensor at Morges-est between 7h00 and 8h00, i.e. the average flow per hour, for each value of the speed limit. The vertical lines show the standard deviation.

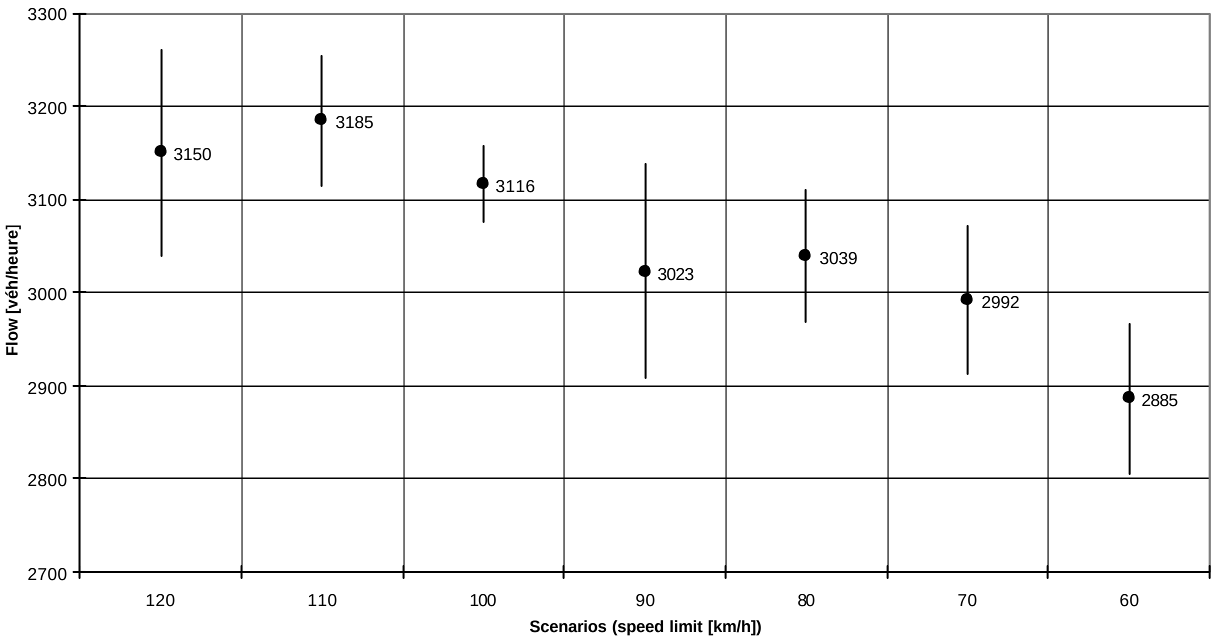

Fig. 6 Hourly flow rates at Morges-est exit, means and standard deviations over five simulations for each speed-limit scenario

It appears that the 110 km/h speed limit allows most vehicles to pass and, therefore, seems to be the most efficient in terms of throughput. This remark must be tempered in view of the relatively small difference between the scenarios, especially between those with speed limits of 100 to 120 km/h. The size of the standard deviations also shows that values may overlap.

To understand the users behavior in the merging section, it is necessary to analyze the evolution of their speed as a function of their origin, as shown in Fig. 7 for a simulation using a speed limit of 90 km/h. Only those vehicles that reached one of the two destinations during the simulation (i.e. before 8h00) are shown here.

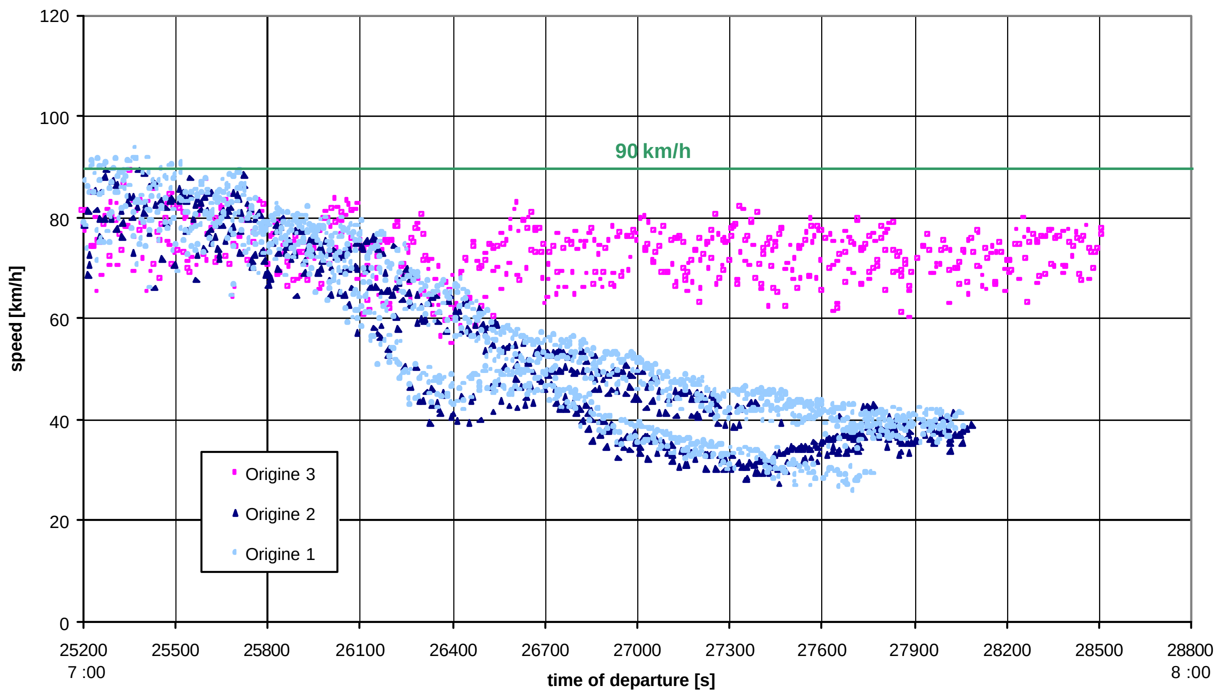

Fig. 7 Average speed of vehicles in the network as a function of their time of departure and of their starting-place (origin), with a speed limit of 90 km/h

As described before, it is clear that the traffic-jam stems from the many times the users in the right-hand lane of the motorway have to brake to let in vehicles entering. Once on the motorway, there is little perturbation and traffic can then proceed "normally". This confirms that the behavioral parameters used by the simulator give too great a priority to vehicles entering the motorway as compared with those already on it. The length of the congested zone through which vehicles have to pass explains the speed decrease. Note that vehicles travelling in the right-hand lane have to brake more often, to let flow from the on-ramp access the main stream. The on-screen visualisation shows that vehicles in the left-hand lane tend to travel faster than those on the right.

3.3 *Modification of the behavioral parameters*

The observation of the different simulations on-screen indicated some anomalies:

- proportionally too many heavy goods vehicles are in the passing lane;
- there is as much overtaking on the left as on the right (American model);
- the behavior of vehicles coming from the access ramp into the right-hand lane is too "aggressive".

Modifications were made:

- Since the size of vehicles in Europe is smaller on average than those in the States, the density of vehicles in a jam was raised from 210 to 300 vehicles per mile, i.e. 1 vehicle every 5.33 meters.
- The probability of vehicles coming from the access ramp adopting an aggressive behavior (forcing entry) was lowered from 0.5 to 0.1.

As a result of these modifications, the behavior of vehicles on-screen became more like the observed behavior, although a more detailed study would be necessary to obtain results that reflect reality more precisely.

3.4 Conclusions

Lowering the speed limit in the network has only a slight positive effect on the maximum flow attainable before congestion. Limits under 100 km/h even seem to produce the opposite effect, diminishing the throughput of the network.

According to the simulations, the queue forming at the junction Morges-est is caused by too much slowing-down in the right-hand lane to accommodate vehicles coming from the access ramp.

The behavioral parameters, in particular those concerning the priority given to vehicles entering the motorway, must be modified to correspond better to the behavior actually observed.

Considerable work must be done to calibrate the software to correspond to European behavior.

4. Capacity and safety analysis

The objectives of these simulations are:

- to focus more specifically on the problems of capacity in the region of the Morges-est junction;
- to refine the conclusions obtained from previous scenarios by means of the modification of the behavioral parameters introduced in MITSIM;
- to better analyse the stochastic nature of the values given by MITSIM;
- to quantify more precisely the capacity gain which might result from a decrease in the speed limit, albeit without dropping below 100 km/h;
- to understand the advantages and disadvantages of these limits on the safety of road-users.

To achieve these aims, limits from 80 to 120 km/h in steps of 5 km/h were applied over the entire section. The OD matrix used for this new set of measurements is identical to that coded for the first set. To improve the quality of the results and to analyse more precisely the stochastic properties of the software, ten "runs" were carried out for each scenario, instead of five.

Fig. 8 shows the number of vehicles leaving the Morges-est junction during the simulation. Each small line represents the value obtained for one simulation. A comparison of the averages (full dots) obtained for the different scenarios shows that the differences are fairly small. It is only for the limits of 80 and 100 km/h that the results seem to be lower.

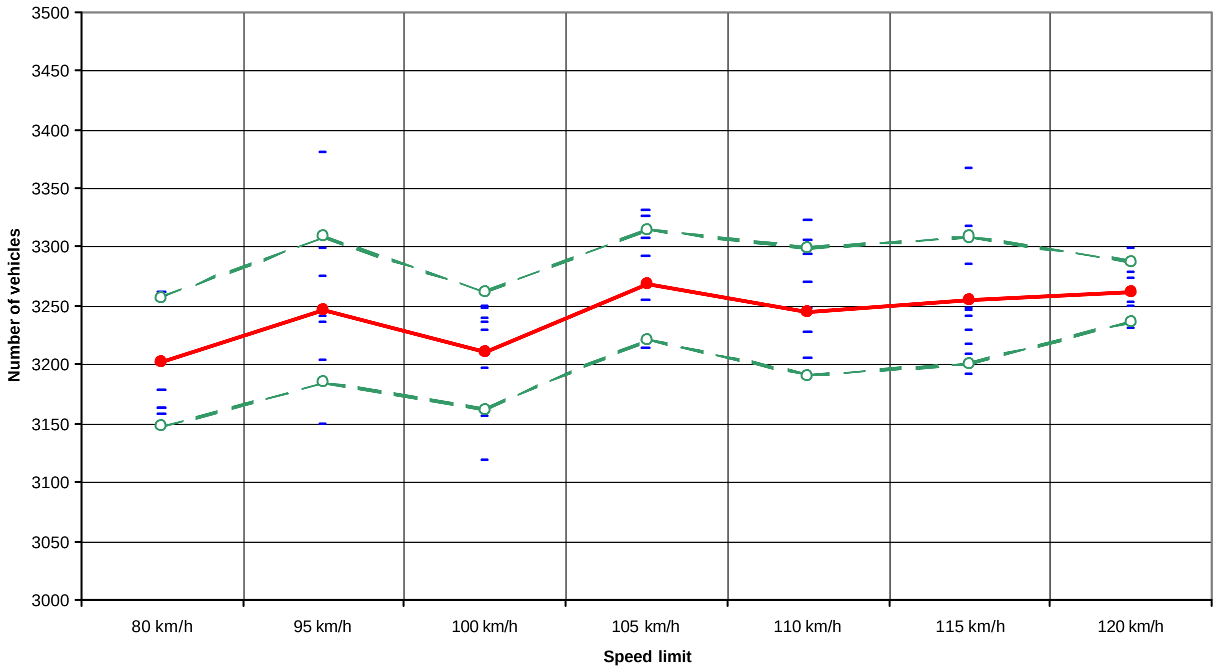

Fig. 8 Number of vehicles passing the exit sensor at Morges-est between 7h00 and 8h00 (means and standard deviations)

By comparison of this graph with Fig. 6 , it may be observed the difference across the scenarios has decreased. The reasons for this may stem from the change in the behavioral parameters, from the increased number of runs per scenario or a combination of both. The standard deviation of the results is quite low, especially for speed limits 105 and 120 km/h, compared to the other scenarios. For 95 and 115 km/h, there is one peak of about 3375 vehicles. These correspond to the two simulations in which a traffic jam did not occur! This clearly indicates the chaotic nature of the traffic flow through the junction. Nevertheless, it would be rash to draw conclusions from the fact that this only happened at limits 95 and 115 km/h. In the first set of measurements, none of the simulations produced a situation without the formation of a traffic jam. Since the on-site measurements showed the same phenomenon, it seems that the modification of the behavioral parameters were appropriate.

The formation of a traffic jam at the Morges-est junction is a particularly sensitive problem for the network so a greater understanding of this phenomenon is important. Two of the ten simulations with a limitation of 115 km/h are therefore examined more closely below.

Figure 9 shows the flow measured by the MITSIM sensors together with the cumulated demand data from the starting points 1 and 2. The time taken by vehicles coming from these two points to reach the junction Morges-est varies from one to two minutes according to their speed. This slight discrepancy is reproduced in the graphs of cumulative demand and the entry sensor.

Following the chronological sequence, it is clear that the flow rate measured by the entry sensor corresponds to the demand apart from some slight "weaknesses" at 7h22 and 7h27 stemming from the first signs of braking, which are rapidly resorbed. At 7h31 the entry and exit sensors, resulting from an apparently greater reduction of speed than the two earlier ones, indicate a considerable drop in throughput. For the next five minutes, the values of the exit sensor remain lower than the cumulative values from the entry and ramp sensors. A certain number of vehicles pile up in the junction zone and a jam occurs. The formation of the jam is detected at 7h34. From 7h35 onwards, the demand is always greater than the supply as represented by the flow rate, measured by the entry sensor, of cars travelling at walking pace. The queue thus increases. At about 7h55 - 8h00, the supply seems to return to meet the demand: it is the start of the queue dispersion phase that can no longer be observed in this simulation.

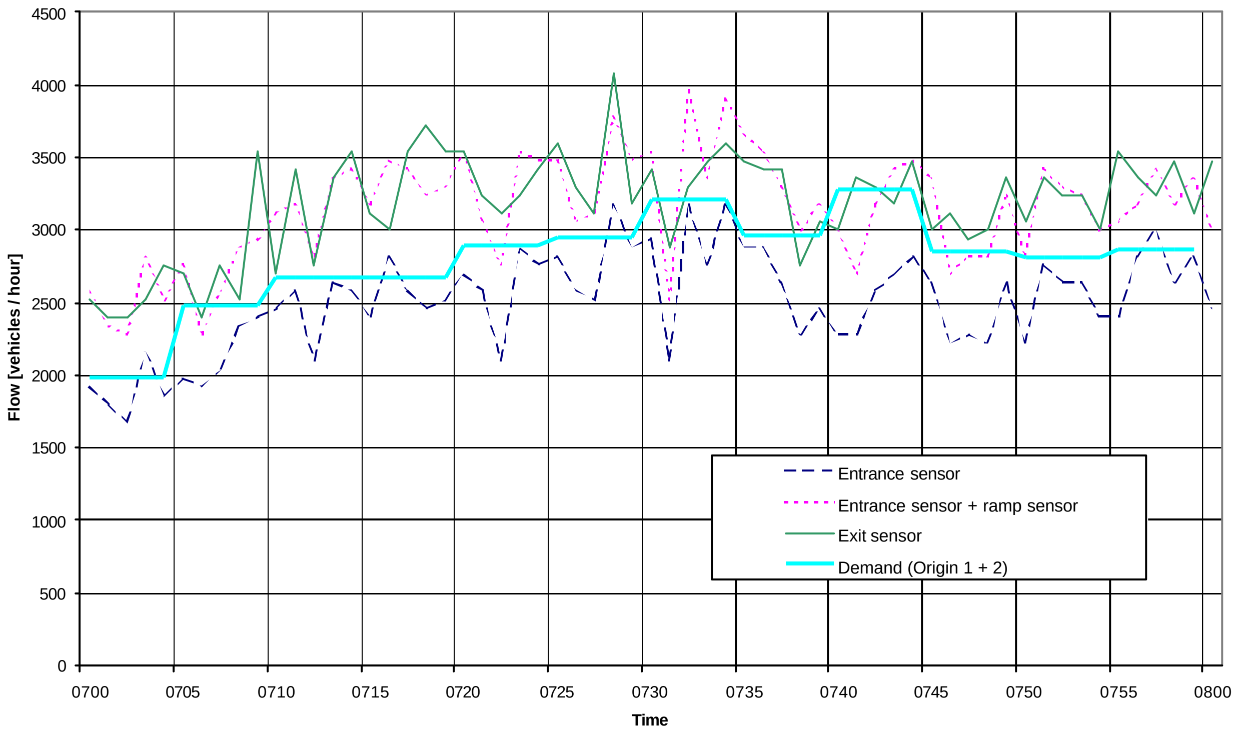

Fig. 9 Comparison of flow rate at different points of the junction Morges-est and the demand (OD matrix) for a speed limit of 115 km/h (1st simulation)

Fig. 10 shows the values obtained in another simulation also made with a speed limit of 115 km/h. The conditions are thus identical in all respects to those of the simulation shown in Fig. 9. As before, the curve of the sensor follows the demand curve with a slight time lag. There are some drops in flow but these are only moderate. Between 7h25 and 7h40, there is no perturbation of the curve of the entry sensor. The first notable slowing-down occurs at 7h41, but is rapidly resorbed. Up to the end of the simulation, the supply seems to meet the demand without difficulty. The curve showing the sum of the flows at the entry and on the ramp remains at the same height as that of the exit sensor, which proves that no "pile-up" of vehicles occurred in the junction zone. This simulation was one of the only two cases in which a traffic jam did not occur.

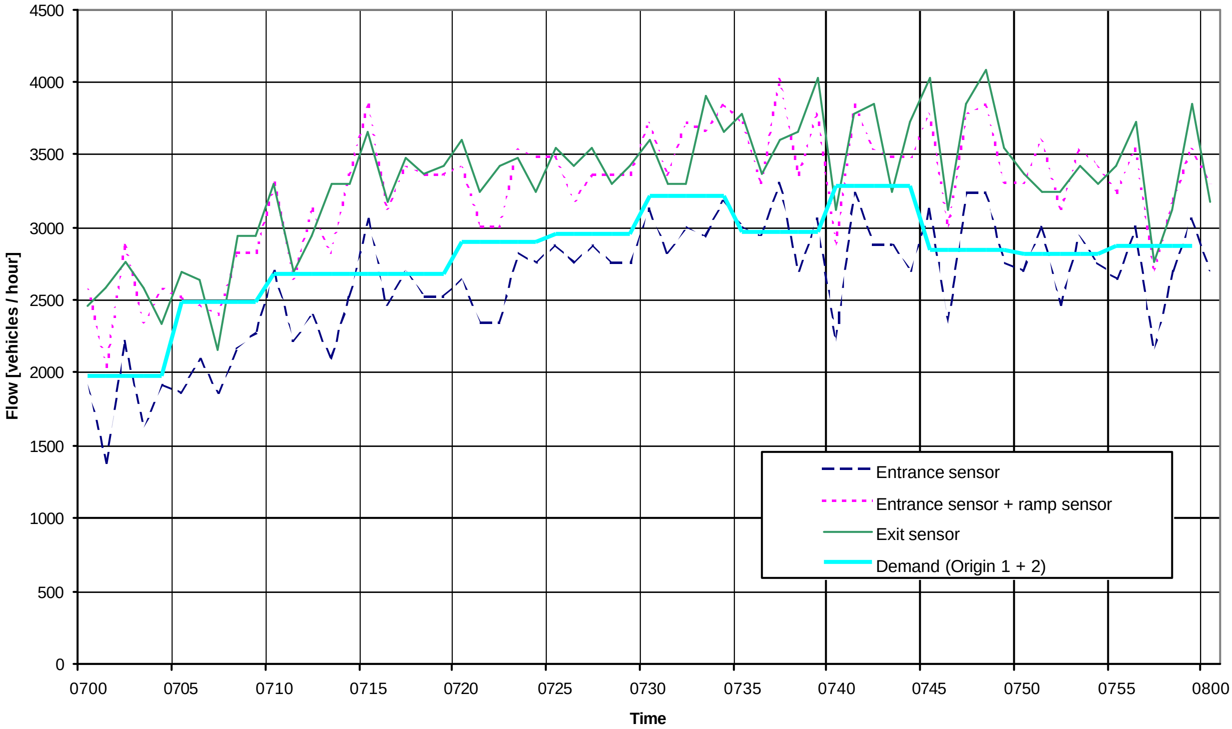

Fig. 10 Comparison of flow rate at different points of the junction Morges-est and the demand (OD matrix) for a speed limit of 115 km/h (2nd simulation)

By comparing these two simulations, it can be seen that the probability of the formation of a traffic jam at a given place depends on:

- the probability that a "mistake" (involving hard braking) occurs,
- the probability that the "mistake" leads to a traffic jam.

The probability of a "mistake" being made, like the second probability, depends directly on the flow. Effectively, the denser the traffic, the greater the drivers stress, and the greater their propensity to making mistakes. At this stage, this hypothesis is purely speculative. A detailed empirical analysis would be interesting to confirm this phenomenon.

As far as safety is concerned, it can be stated that the greater and the more sudden the drop in speed caused by a jam, the higher the danger. This can be seen from the graph in Fig. 11, which shows the evolution of the speed of the vehicles for four different scenarios. Each curve is the result of one simulation rather than the average of the ten simulations performed for each scenario. These particular simulations were chosen because they all showed a practically identical number of vehicles crossing the junction. The comparison may therefore be made between the effects of the different speed limits on the safety of users on the basis of four simulations of an equivalent level of service.

The drop in speed is almost identical for simulations at 120 and 110 km/h. In both cases, congestion begins at 7h35 when traffic is flowing at an average speed of 100 km/h. Furthermore, when the speed suddenly drops the gradients ($\Delta V/\Delta T$) of the curves are similar, at 12 km/h per minute.

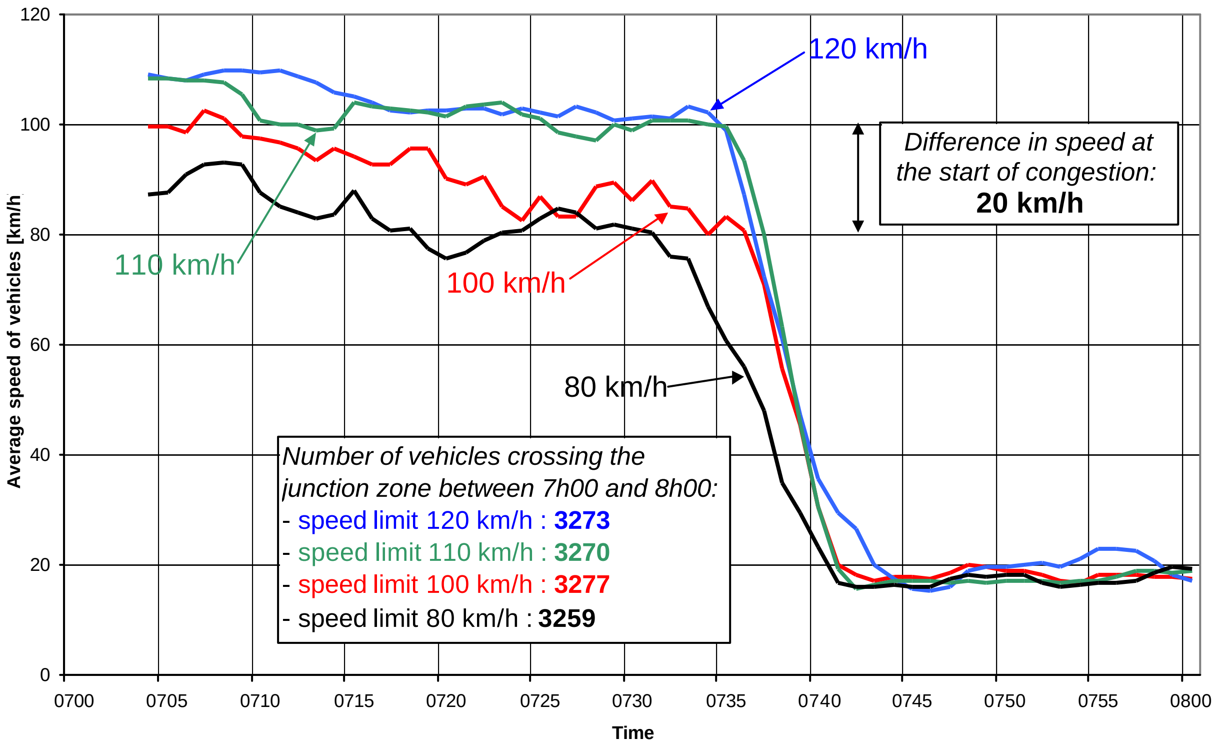

Fig. 11 Evolution of the average speed of traffic at the entrance to the junction Morges-est

The simulation with speed limit 100 km/h gives a different shape of curve. There is a greater drop in speed during the time before the jam is formed, with a loss of about 20 km/h in 30 minutes of simulation. The sudden drop caused by the jam occurs at 7h38, at which time the traffic is travelling at an average speed of 80 km/h. It is interesting to note that not only is the slope of the curve during this drop is identical for the two cases already discussed, but the curve itself passes through the same points. This remark is particularly relevant to the question of safety. It implies that, for an equivalent level of service, a speed limit of 100 km/h induces vehicles to enter a jam at a speed that is 20 km/h lower than if the speed limit were 110 or 120 km/h. In the event of a collision between vehicles at the time of braking, this difference may greatly influence the gravity of the accident. The kinetic energy of a moving vehicle being proportional to the square of its speed, the reduction in speed of 20% corresponds to a reduction of 36% in the kinetic energy.

The graph of the simulation with a speed limit of 80 km/h shows that during the first thirty minutes the average speed of traffic is greater than 80 km/h. This phenomenon is quite in accordance with reality since it is known that the lower the speed limit on a motorway, the fewer people respect it. Although the loss of speed caused by the jam appears earlier than in the other cases (7h30) it also happens more progressively. The change in the curve is much less marked than for the simulations at 110 or 120 km/h. The drop is also less steep (8 km/h per minute), which has a positive effect on safety.

Although these results tend to show that speed limits of 100 or even 80 km/h have considerable advantages for improving the safety of users, it must be noted that in these two cases, the speed curve shows quite marked variations in the phase preceding the formation of the jam. This element has a negative effect on the safety of car-drivers.

4.1 Conclusions

The positive effect of reducing the speed limits on the level of service is very limited for speeds no lower than 100 km/h. For lower speeds, the drop in the level of service as compared to the reference scenario (120 km/h) is confirmed.

The modification of behavioral parameters improved the correspondence of the simulations to the actual behavior of users, as testified by the fact that two simulations showed no jam formation, in conformation with the reality.

The congestion phenomenon observed at Morges is explained by the occurrence of a "mistake" by a driver at a time when the traffic is heavy.

Lowering the speed limit may have a positive effect on the safety of users, and this seems to be its main advantage. A limit of 100 km/h may, in certain cases, provoke a reduction of 20 km/h in the speed of vehicles at the moment a jam is formed while the level of service is maintained. It must however be noted that a reduction of the speed limit, especially down to 80 km/h, gives rise to major variations of speed during the phase immediately preceding the jam.

5. Incident scenarios

After having examined the utility of lowering the speed limits in a situation of normal circulation, this part of the study aims at analysing the effects of various limitations in the circumstance of an incident of moderate gravity on the motorway network.

The incident was modelled using MITSIM as follows:

- The incident took place at 7h10 and lasted until the end of the simulation (8h00).
- It occurred in the left-hand lane, at km 62.7, i.e. between the junction Morges-est and the interchange at Ecublens.
- The capacity of the lane was cut by 50%.
- The maximum speed allowed for passing the incident spot on the left-hand lane is 16 km/h. The right-hand lane is not disturbed.

The incident was deliberately placed in a zone that is known to have a high incident occurrence.

The parameters of the incident were chosen in such a way as to cause a jam to arise systematically, without reducing the capacity of the network too greatly. The analysis of the development of the jam will expose the differences between the scenarios. It would not have been ideal to study an incident which entirely blocked both lanes since this would have induced a jam to form much too quickly for a satisfactory analysis to be made.

5.1 Scenarios

In the case of an incident, it is obviously inappropriate to apply a speed limit over the whole network. Variable speed-limit signs (abbreviated to VSLS) are used to reduce the speed limit progressively to reach the required value a few hundred meters before the incident spot.

The new speed limits were posted two minutes after the incident, i.e. at 7h12. Although this reaction time is not very realistic, it was chosen in order to judge the effect on the various scenarios under nearly perfect conditions. Table one shows the exact position of the VSLS and the speed limits they show in the various scenarios. The VSLS can only show values of 100, 80 or 60 km/h, so that where the table shows 120 km/h, the VSLS is in fact off.

	VSLS 1	**VSLS 2**	**VSLS 3**
Milestone	58.440	60.095	61.780
Distance to the next VSLS	1.655	1.685	-
Distance from the incident	4.260	2.605	0.920
Speed limit for *scenario 1 (reference)*	120 km/h	120 km/h	120 km/h
Speed limit for ***scenario 2***	120 km/h	120 km/h	100 km/h
Speed limit for ***scenario 3***	120 km/h	100 km/h	80 km/h
Speed limit for ***scenario 4***	100 km/h	80 km/h	60 km/h

Tab. 1 Parameters for the variable speed-limit signs used and definition of the scenarios

To measure the effects of these scenarios on the formation of the traffic jam caused by the incident, four virtual sensors were placed at intervals of 500 meters in front of the incident spot, i.e. at 500, 1000, 1500, and 2000 meters before milestone 62.7. A supplementary sensor was placed at the incident spot itself. Ten "runs" were taken for each scenario. The values shown in the graphs below are the averages of these ten simulations.

The graph in Fig. 12 shows the evolution of speeds in the region before the incident in the case when the VSLS are not used (reference scenario). It is clear that the drop in speed is immediate at the incident spot and the speed rapidly becomes stable at about 25 km/h. Four minutes after the incident, the sensor placed 500 meters away also shows the beginnings of a drop in speed, of slightly lesser intensity (slope of the graph) than at the incident spot.

The sensors situated at 1000 and 1500 meters before the incident measure a slight reduction of speed between 7h14 and 7h20, at which time the "real" drop in speed begins. It is interesting to note that the two curves coincide perfectly in the first part of the drop although 500 meters separate the two sensors. This must mean that the density of vehicles is very high between these two points since the slowing down of the vehicles at 1000 meters is almost instantly transmitted to those which are 500 meters further back. The rate of the drop is less than for the sensor at 500 m. The curve for the sensor at 2000 meters before the incident presents a first inflection very rapidly, but this can hardly be attributed to the incident. It may be due to the density of traffic (braking). However, from 7h30 onward the real drop begins. This occurs still more slowly and the time taken from then until the queue reaches the sensor (stable speed of 20 km/h) is about half an hour.

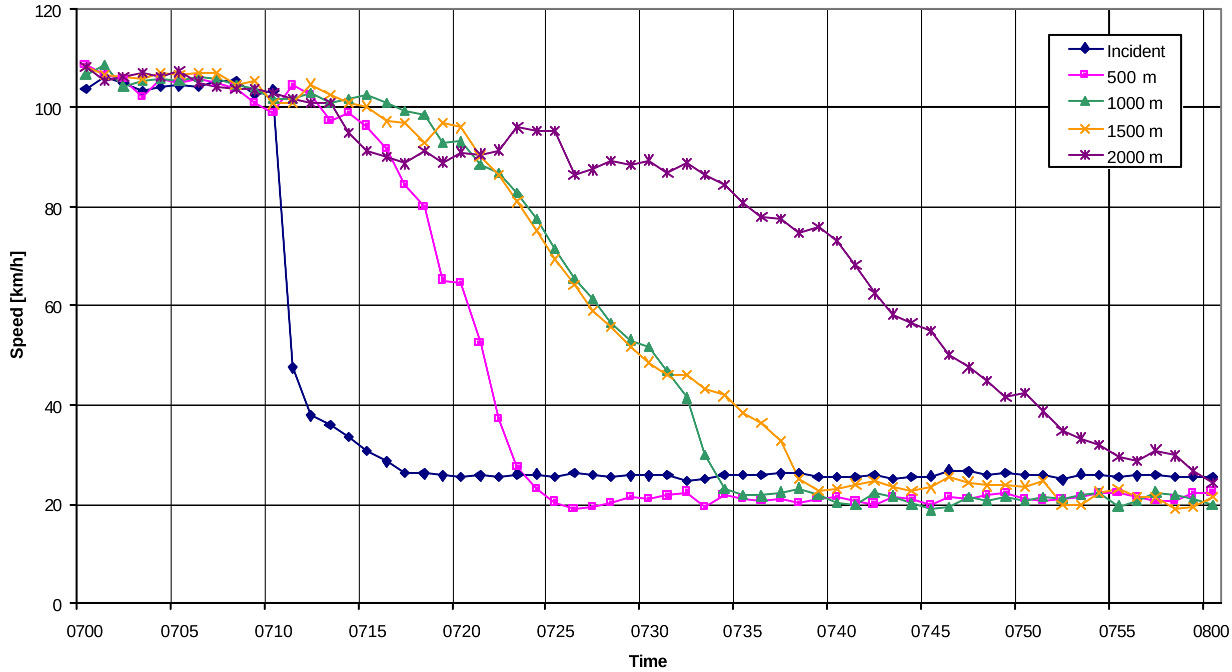

Fig. 12 Evolution of the speed of traffic measured at five different places in the reference scenario (120-120-120)

For comparison, Fig. 13 shows the results obtained with scenario 3. In order to understand this graph, it must be recalled that the 500 m sensor is situated between the last VSLS (VSLS3) and the incident (i.e. with a speed limit of 80 km/h in this scenario), that the 1000 m sensor is more or less at the same point as VSLS3 and that the 1500 and 2000 m sensors are both situated between VSLS2 and VSLS3 (speed limit 100 km/h).

These graphs clearly show the effect of these new speed limits, in operation from 7h12 onwards. The speeds measured by the sensors at 1500 and 1000 m drops rapidly from 100 to 85 km/h when the limit is reduced from 120 to 100 km/h. This phenomenon might seem surprising, since vehicles that are already travelling at the speed of the new limit would not be expected to slow down. However, it represents fairly the behavior of drivers who have an instinctive tendency to brake when a new speed limit is applied, even if they are not speeding. Although not so clearly as in the reference case, there is still a significant similarity between the curves for the 1000 and 1500 m sensors, which even coincide for some minutes.

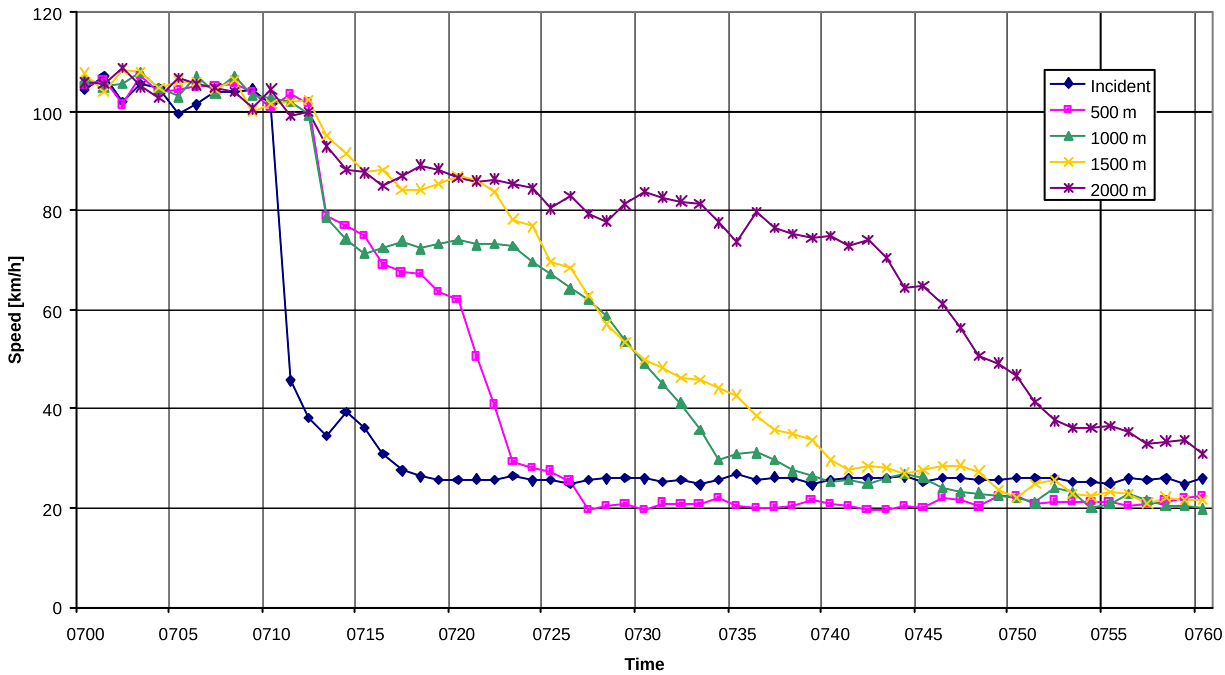

Fig. 13 Evolution of the speed of traffic measured at five different places in the scenario 3 (120-100-80)

Although the shape of the speed curves is obviously different in the two cases, the time at which the congestion situation is reached (the end of the drop in speed) is practically identical for each sensor. This indicates that the rate of growth of the queue is the same in both cases.

To analyse the queue growth more precisely, it is more profitable to compare the different speed curves measured at the same point for each scenario, as shown in Fig. 14. The drop in speed shown for scenario 1 is solely due to the progressive arrival of the jam at the sensor location, since no new limitation is applied. In the three other cases, however, the drop in speed occurs in two phases. The first, resulting only from the new speed limit, is very quick and is followed by a period during which the speed is stable (at about 10 km/h below the limit). The length of this period varies with the scenario. The second drop in speed is caused solely by the development of the jam. For scenarios 2 and 3, the speed curves join that of the reference scenario in this second phase, again indicating that these scenarios in no way affect the formation of the jam. As in the case of the 500 m sensor, the curve for the fourth scenario does not join the other curves during the slowing-down. The jam occurs earlier in this case, which suggests the conclusion that scenario 4 "worsens" the situation as compared with the reference case.

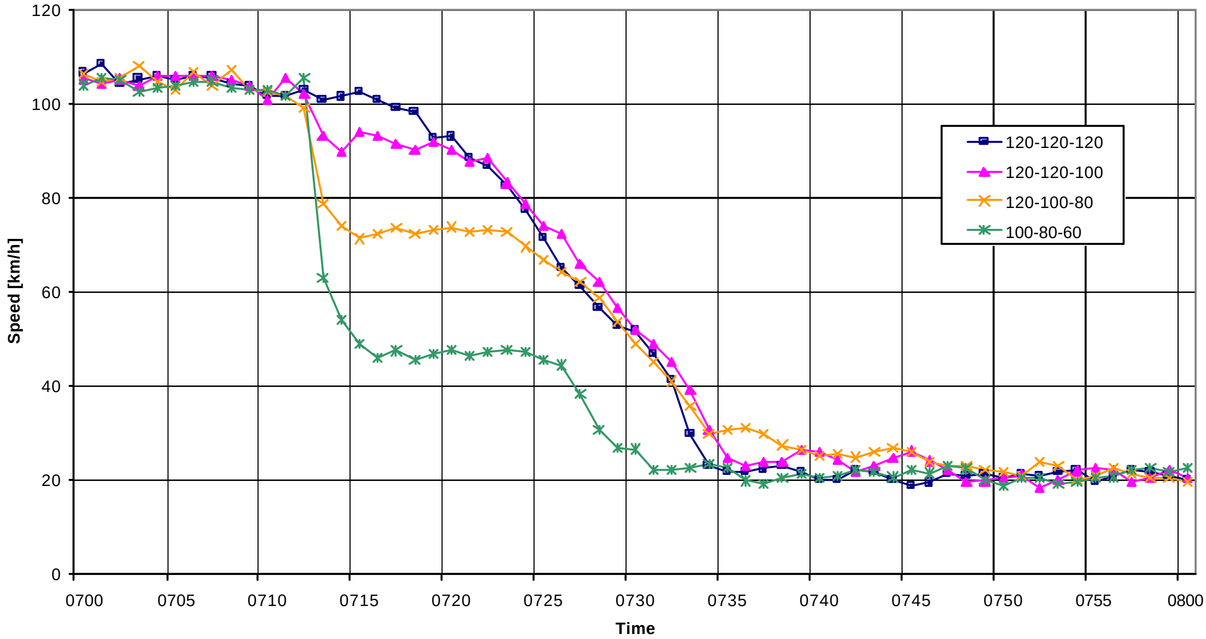

Fig. 14 Evolution of the speed of traffic measured 1000 m in front of the incident for the four scenarios

From the safety standpoint, it is difficult to know whether the step-wise drop in speed (scenarios 2 to 4) is better than a drop, which decreases constantly (reference scenario). Although the step-wise drop has the advantage of interspersing patches of constant speed when the traffic is stable, it also has the disadvantage of a greater gradient in the first phase.

From these graphs, it is clear that none of the scenarios decrease the rate growth of the queue. This was predictable since the incident is similar to a bottleneck that limited capacity. In the case studied here, measurements show that this rate is about 3000 vehicles per hour. As the demand at this point of the network is at all times superior than this flow, the difference accumulates at the back of the jam. Since the demand was the same for the four scenarios, the queue should grow at the same rate, as confirmed above. Table 2 shows the very small difference in performance between the four scenarios.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Number of vehicles	2933	2922	2920	2868

Tab. 2 Number of vehicles passing the sensor at the incident point between 7h00 and 8h00

In summary, the use of variable speed signs as modelled in these scenarios does not improve the performance of the network. For certain instances (scenario 4) it even diminishes performance.

This study was not able to demonstrate the improvements in user security expected from the use of variable speed signs. However it helped to understand incident effects on safety.

The step-wise drop in speed, caused by the lowering of the speed limit, has the advantage of interspersing periods of constant speed when the traffic is stable but it also has the disadvantage of a greater speed gradient during deceleration.

The question of the utility or otherwise of variable speed signs should not be judged solely from the conclusions of simulated measurements since the simulation neglects some important parameters. For example, the sight of an unusual speed limit attracts the attention of the driver who, realising that something has happened on the road ahead of him, pays more attention. This type of behavior is not currently simulated by MITSIM.

6. General conclusions

This first phase of PAPABILES produced many insights, not only into the results of the simulations, but also about the way they were obtained.

This work justifies the use of a tool such as MITSIM for the purpose of traffic flow analysis. The determination of vehicle movements based solely on driver behavior models produced results, which are not influenced by pre-established traffic laws. However, analysis of the results exposed some significant differences between the simulated behavior and actual observation. Some refinements of the behavioral parameters were performed but further work on this subject would be desirable.

The analysis of the effects of using variable speed signs in traffic gave the following indications.

This study did not demonstrate any significant modification in the performance of a motorway network with a normal speed limit of 120 km/h when the speed limit was lowered during heavy traffic. For limits below 100 km/h, performance was reduced. While, some graphs showed a slight improvement in performance at speeds of about 105 km/h, these improvements are too small to serve as sole justification for the setting-up of such equipment. This confirms the conclusions from a study of variable speed limits made in the context of the DIATS project and supported by the VII Commission of the European Union, which stated that "No evidence was found to suggest that the introduction of VSL (Variable Speed Limits) would reduce average journey times or increase the throughput of a motorway".

Concerning user safety, this study showed that the lowering of the speed limit in heavy traffic and especially in the case of a traffic jam developing near a junction, presents certain advantages. The simulations showed that, in some cases, cars travel more slowly so that if they have to brake suddenly, the gravity of incidents caused by collision from behind will be lessened.

In the presence of an incident which significantly reduces the capacity of a motorway, the simulations performed to date have shown that the application of different speed limits does not improve the performance of the network, nor was it possible to find clear evidence for an improvement in user safety.

In order to test convincingly the utility of installing a system of variable message signs, this study should be extended to a larger network with several values of the demand (OD matrix). Some interesting results given by these simulations did not enter into the framework of this study, particularly concerning user safety. However, other studies (for example DIATS) have shown that reducing the speed limit has the effect of homogenizing the speeds in the different lanes, thus diminishing the number of lane-changes and hence the risk of incidents. From the results obtained, it can only be recommended that an extension of the field of study should allow further simulations and that the parameterisation of the model be continued.

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