Real-Time Information System for Risk Management on Motorways

Tullio Tanzi[(1,2)], Sylvie Servigne[(1)], Régis Guiol[(3)]

[(1)]Laboratoire d'Ingénierie des Systèmes d'Information, INSA de Lyon,
20 Avenue Einstein, Villeurbanne Cedex F-69621
servigne@if.insa-lyon.fr
[(2)]Etablissements Jean GRANIOU, ZI des Trois Moulins, BP 717 Antibes Cedex 1 F-06633
[(3)]Direction Recherche & Développement ESCOTA, BP41, Mandelieu Cedex F-06211

Abstract. Every day more and more people and goods have to be transported rapidly, safely and at a lower cost. Continuous economic growth brings a traffic volume increase and implies a gradual saturation of road and motorway networks. Managing motorways is today a complex task, especially during a time of crisis (traffic jam, accident). Our aim is to design a system for risk management on motorways. Risk management is a very important endeavour today and many people work on this subject [Adams 95], [Beek 92]. In our system, risk management provides tools to help managers to anticipate potential accidents so as to avoid them or, otherwise to reduce accident consequences. In addition, the system must be able to give fit information to initiate preventive actions and then to follow them in real-time.

Such a system requires much information in real-time. Information must be acquired and then sent to the various motorway departments to be processed. It is necessary to have a complex real-time architecture based on sensors and communication technology to link motorways with the management stations. The proposed global system for risk management on motorways is presented in this paper. Real-time information composition and use particulars are presented. Details on processing can be found in [Tanzi 97b]. An industrial prototype has been realised and for the motorway network of the south of France.

1 Introduction

In managing toll motorways a complex chain of decisions has to be taken by operators when an accident occurs in order to rapidly restore to a normal traffic. Indeed, even a minor incident (the fall of luggage from a car, a small collision) can have consequences that hold up the traffic during several hours after the end of the incident [Boulmakoul 93]. The number of cars caught in the resulting traffic jam depends on the time needed to repair the carriageway. The delay between the incident and the arrival of intervention vehicles implies increasing difficulties in accessing to the incident location because of the traffic jam [Tanzi 97a]. As lanes are one-way lanes, it is very difficult to use lanes in the opposite direction, even for vehicles authorised to do so.

To come back to a normal situation, it is then necessary to evacuate the cars caught in the traffic jam, which may last a long time. Various studies on traffic control show that a reduction of 30% of the total intervention duration implies a reduction of 55% of the lost time of the drivers [HCM 95].

To obtain a realistic overview of the situation on the motorway, motorway managers receive traffic data from measuring sites at their disposal. Measuring equipment are numerous and set along the motorway at frequent intervals. To make an optimal use of traffic data, it is necessary to send them rapidly from an acquisition station to the processing station and to assemble these data from several acquisition stations to produce a global overview of motorway areas. Improving the speed of data transmission allows operators to react rapidly to incidents. It is so vital to have a real-time system.

Depending on the type of incident and existing information concerning it, it could be possible to anticipate the potential accident so as to avoid it by initiating preventive measures. Nevertheless, if it is not possible to avoid accident, preventive actions could still reduce or ameliorate consequences.

Our aim is to build a system for risk management on motorways. A sine qua non condition for a system able to be successful in preventing motorway risk is to obtain immediately information which characterise traffic and environmental conditions. The aim of the paper is to present our proposed architecture for a real-time system. First, information characterising traffic will be described. Then the real-time system will be presented. After a general presentation of the system context, information flow and processing will be described, going from the acquisition process to their use in the decision phase. The prototype has been realised on the Escota's motorway network. The Escota company is in charge of a part of the motorways of the south-east of France.

2 Traffic Data

Traffic is characterised by a flow (distribution of vehicles in time), an business index of a given road segment (concentration) and the vehicle speed. Different sensors are used by traffic managers for traffic data acquisition. The most common procedure for traffic data supervision consists in using magnetic loops buried in the road surface, which detect the passage of metallic masses (vehicles). Two loops situated successively in the same lane (Figure 1) allow acquisition of vehicle speed.

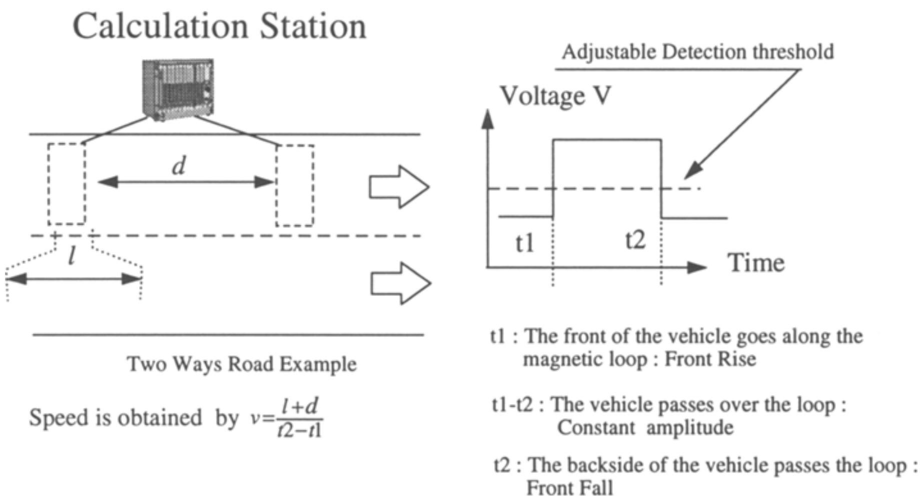

Fig. 1. Calculation station

The processing of the data produced by various pieces of equipment that already exist on the motorway network gives an image of the real situation. The Figure 2 shows an example of traffic properties of a given motorway lane.

Station		Weight	Time Date	Flow		Speed		Oc rate		Truck Flow		District
23	1	0	20/04/97 00:30:00	800	1	115	1	1	1	0	1	11
23	1	0	20/04/97 00:36:00	800	1	112	1	1	1	5	1	11
23	1	0	20/04/97 00:42:00	720	1	113	1	1	1	3	1	11
23	1	0	20/04/97 00:48:00	740	1	112	1	2	1	5	1	11
23	1	0	20/04/97 00:54:00	700	1	108	1	1	1	0	1	11
23	1	0	20/04/97 01:00:00	590	1	114	1	1	1	1	1	11
23	1	0	20/04/97 01:06:00	620	1	111	1	1	1	0	1	11
23	1	0	20/04/97 01:12:00	630	1	108	1	1	1	13	1	11

Fig. 2. Example of real traffic data of a lane

The processing of such data into a display form allows the preparation of three curves (speed, flow, and concentration) as seen in Figure 3. In this example, a first accident occurred at 10h40 am, and a second one occurred one hour after. Nevertheless, an inspection of these curves suggests that the risk of the first accident can be detected as early as 10h00 a.m.

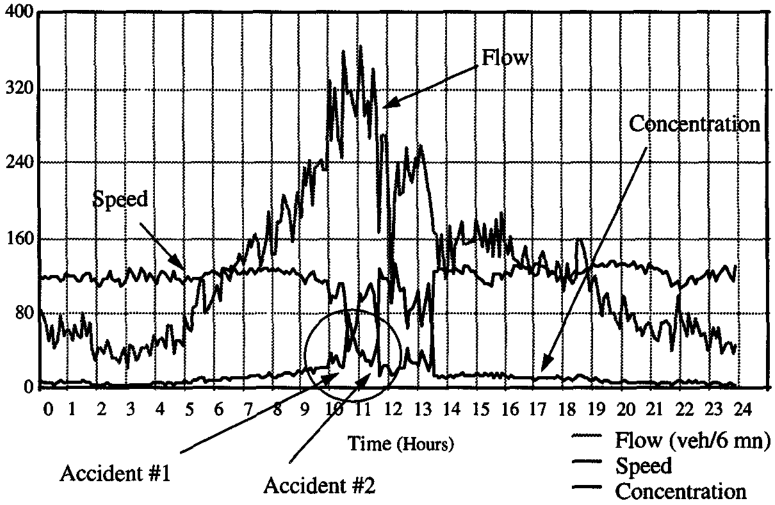

Fig. 3. Display of traffic data

Our aim is to use the delay between the risk detection and the potential accident to avoid this accident by implementation of a preventive action. For example, the vehicle speed may be reduced by displaying messages on dynamic roadsigns along the motorway. The most important action is to alert the motorway so that they can anticipate the potential crisis situation. More details concerning risk rate estimation may be found in [Tanzi 97b] and [Oppe 90].

3 Real-time system for traffic control

More and more sophisticated equipment constituting a global information acquisition system are available on motorways. It is necessary to adapt data exploitation tools to this context. This can be done taking real-time data acquired by sensors of the traffic management system into account. Then data are used for various purposes at various levels of the hierarchical motorway organisation (Technical Office, District, Control Station) in order to produce a synthesis to help managers to make a decision. Between the acquisition of data and its use for a decision, it is necessary to implement a data processing sequence.

3.1 Information use

The various informations acquired along the motorway may be used for different purposes and by different departments (Figure 4). First, information is used by departments in charge of the viability of the network in order to maintain the *quality* of level of services. Information is also used during a crisis situation when an incident occurs, to verify if the proposed solution is *appropriate* to the incident. This is possible using people knowledge about conditions about the accident site. *Strategy definition* for the management and intervention by operators is easier using these information. After the crisis, the chronological account of computing events is used for *training*, enriching the management organisation experience using the details of the stored information. In future, these data could be analysed and taken into account into the development of long-range action plans so as to avoid accidents and to manage accident situation better.

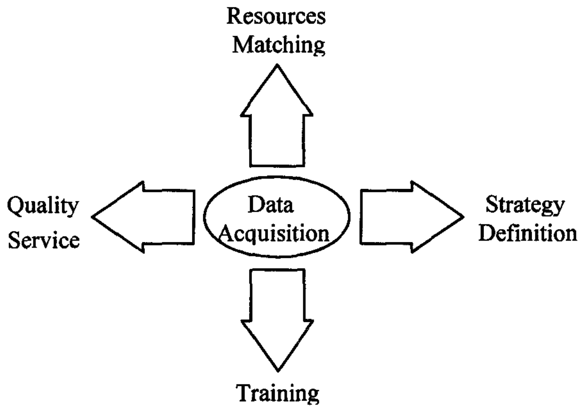

Fig. 4. Use of acquired information

To understand and simulate traffic variations, numerous parameters must be taken into account at the same time because of data and context variety, but also due to mechanism complexity. It was necessary to design a hierarchical method so as to enhance the impact of parameters on the global process. The resulting method allows information filtering. All non significant-information (low impact on the phenomenon) is rejected. The information kept depends on a threshold value which has to be determined according to a desired precision.

3.2 Risk management

At the beginning, an accident is often slight and controllable by the appropriate person, at the right time and at the right place. Concerning a motorway incident, the fit persons are the staff in charge of motorway. Telecommunications and computers allow decisions at a distance by means of a virtual visit to the right place. But what about the right time ? In the risk domain, a little problem may generate a lot of trouble bearing in mind that time operates against humans. We define the right time as the closest time to the event occurence, and, if possible, the best fit time would be the time just before the event.

When an accident analysis is done a posteriori, we can realise how important event anticipation is, that is to say, to be at the right place, at the right time with the appropriate intervention measures. We chose to work on event prevention. We define prevention as the technical measures already located on the site when the incident occurs. The aim of prevention is to prevent from common risk and to limit the accident and its consequences.

3.3 Real-time decision process

When an incident occurs, real-time information allows verification of how appropriate resources are for the problem. Real-time data simulation tools gives a projection of the incident evolution and so allows identification the gravity of the incident. Action plan implementation and strategy definition are also based on the real-time data. Figure 5 shows the event management in real-time.

Recording information also facilitates building the incident memory and enriching the organisation experience. In the future, modifying generic intervention plans by this experimental data will improve an operators ability to confront an accident.

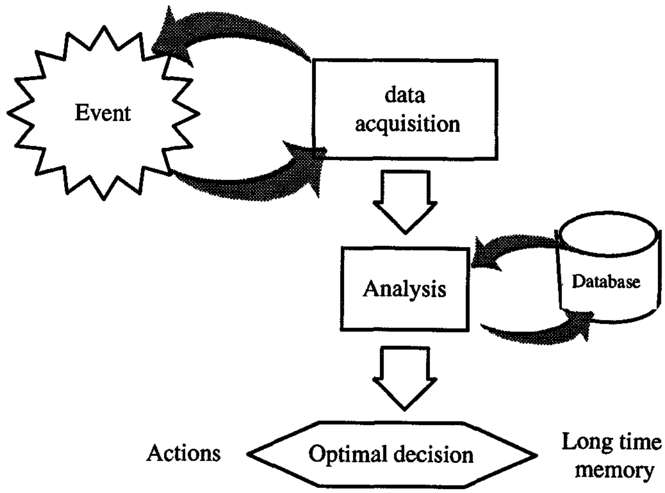

Fig. 5. Event management in real-time

The decision process is composed of steps (Figure 6) which are not always sequential. Sometimes, backtracking is necessary. The first step is the relevant data acquisition. The aim is to collect as much information as possible concerning the problematical event that occurred. Next, the conception phase consists in developing one or more a priori possible solutions and scenarios. At this step, additional information can be required which implies a second acquisition process (backtracking). The third step consists in choosing the best solution among the list of alternatives previously built. The final step, the evaluation process, consists in evaluating the previous choices and decisions. The aim of the final step is to correct if necessary the entire reasoning.

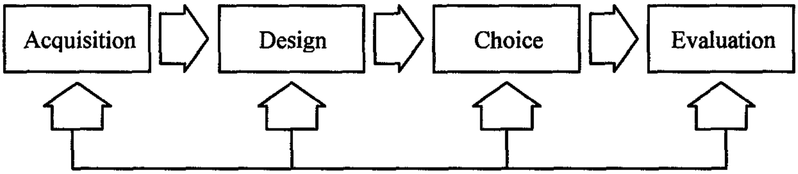

Fig. 6. Decision process

To validate the proposed architecture, a prototype has been made on Escota's motorway. The prototype is devoted to help the operator follow the evolution of conditions which can imply an accident occurrence and so to detect automatically geographic areas where the risk of accident is high. All information and calculated data are displayed in real-time and continuously.

Data are issued from acquisition stations (Figure 7) and meteorological stations. Other information, for example concerning road works maintenance, is acquired through communicating with an existing information system.

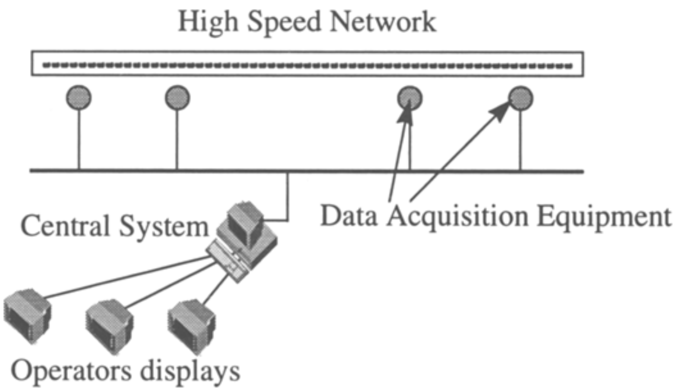

Fig. 7. Data acquisition stations

4 Architecture of the real-time system

In analysing traffic data, the automated system may detect conditions which are going to favour the increase of the risk level of every motorway segment. When a threshold of the risk is passed, the system is setting into a state of pre-alert. Information (motorway synopsis, flow, vehicle speed, concentration (Figure 14)) are displayed automatically and continuously on a specific screen. The risk index is computed and displayed in real-time. The operator is able to follow in real-time the evolution of the conditions and so to decide what to do to prevent or reduce consequences of a potential incident. To realise these operations, a specific architecture is needed.

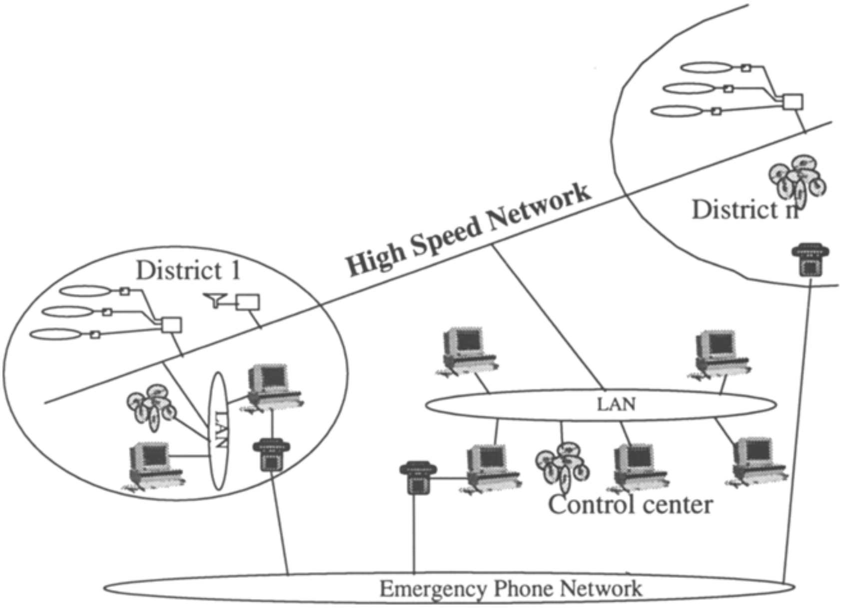

Fig. 8. System architecture along the motorway

Figure 8 gives an example of a potential global system architecture for a motorway. This architecture requires use of information issued from traffic data instruments at various levels of the hierarchical motorway organisation (Technical Office, District, Control Station). Information flow and according processing offices are graphed in the Figure 9. The foundation consists of Acquisition Stations in charge of data *acquisition*. Then, Technical Offices have to *concentrate* these data. A *local analysis* is undertaken at the district level. Finally, *data consolidation* is made by the Control Station.

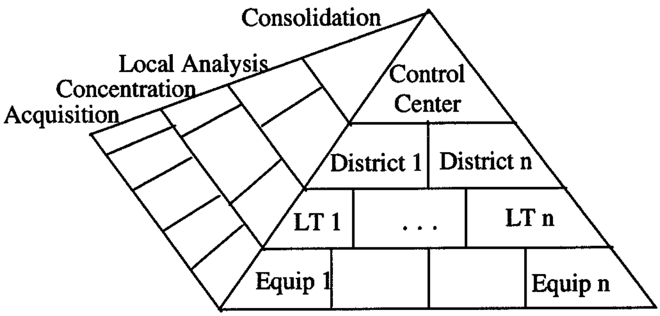

Fig. 9. Information flow of motorway organisation

4.1 Data acquisition

Data acquisition is realised in real-time by sensors (as previously described in the first part) and characterises each passing vehicle. Acquisition Stations are in charge of real-time acquisition and then data transmission to the Technical Offices upon which they depend.

4.2 Data concentration

Concentration of acquired data is realised by various Technical Offices. Each station corresponds to a specific geographical area of the motorway. First, data are stored locally and sent every night to a the control station by batch processing. The chaining processing is described in Figure 10. Upon arrived at the Technical Office, data are analysed to produce a synthesis of every Acquisition Station situation. Meteorological data are integrated here into the analysis process. As previously said, processing depends on climatic conditions, for example, a safe distance between vehicles depends on road-grip characteristics. Meteorological data may be furnished by a local station or acquired from a distant meteorological data server.

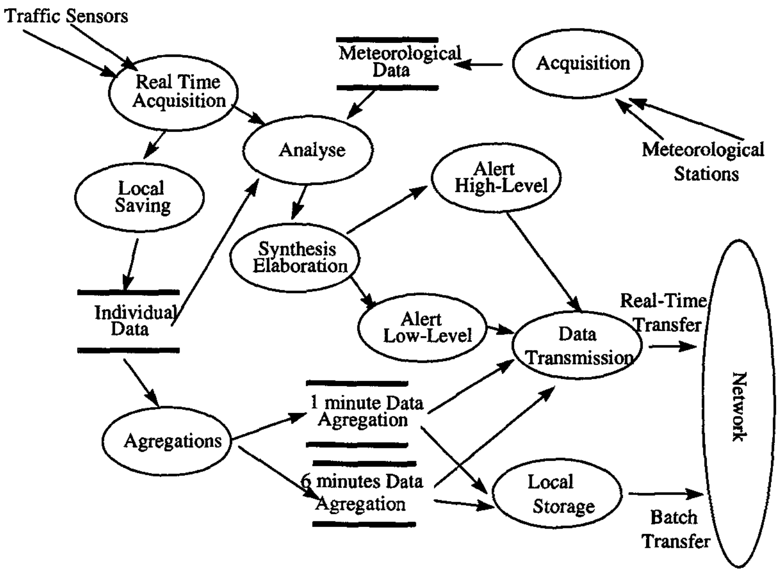

Fig. 10. Data acquisition : processing sequence

Depending on the type of acquired data, a pre-alert (low-level) or alert (high level) situation may be generated for every acquisition station federated by a Technical Office. When a pre-alert or alert situation is detected, the data transmission process is realised. It consists in transferring data issued from every Acquisition Station to the corresponding district. Transferred data are raw data (acquired data) or aggregated data (for example, for a period of one or six minutes). The choice of the most adequate data is done according to the alert level of every Technical Office.

Generally, data are transferred every six minutes during a pre-alert phase and every minute during an alert phase. It can be changed by intervention by a district operator.

4.3 Data local analysis

The local analysis is made by Districts. A District is an administrative entity representing about 40 kilometres of motorway. Every District receives a data synthesis from the Technical Offices. A cyclical observation of the traffic is made for every station. The frequency of data scanning depends on the alert level of every station. Figure 11 presents the processing sequences for the traffic observation.

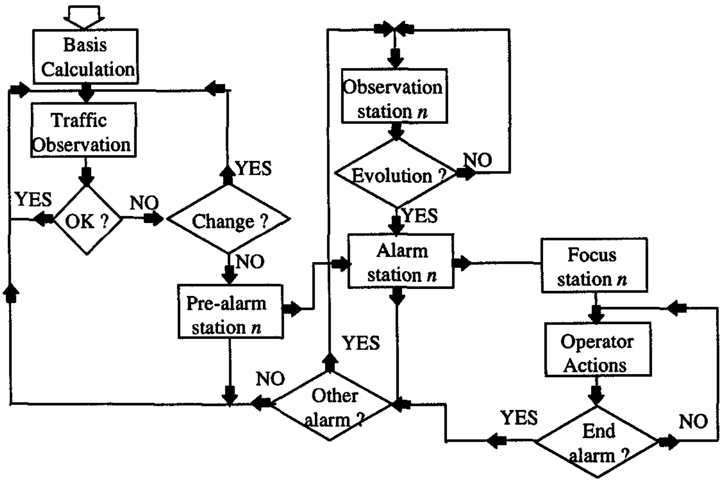

Fig. 11. Traffic observation processes

The traffic observations allows in real-time verification of the evolution of the traffic conditions. The display given as figure 12 shows an interface of our prototype during supervision time.

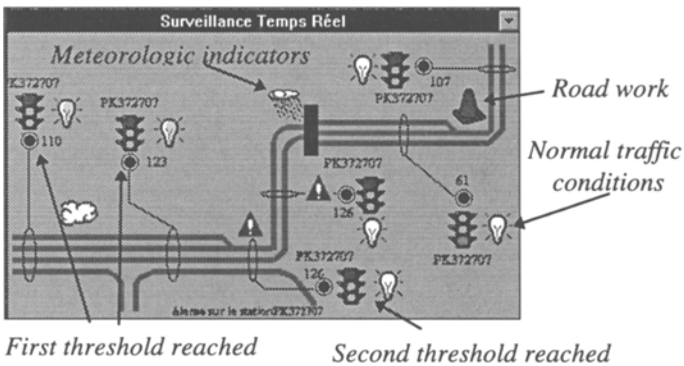

Fig. 12. Supervision Time interface

When index values reach a defined threshold, the system moves into a *pre-alert* phase and automatically switches the information onto a specific screen. This operation is devoted to attract attention of employees. When a second threshold value (more important than the first one) is reached, an *alert* phase is initiated. Data acquisition and calculation (risk index) are real-time and continuous processes so information are always displayed. The value of the alert threshold has been defined by various surveys of motorway companies, and estimated at 90% of the maximal capacity of the traffic. To keep enough time for the pre-alert phase, it is important for the first threshold value to be lower than the alert threshold (usually between 10% to 15% less).

Figure 13 shows our prototype interface for an alert phase. In addition to the various indexes already represented in figure 12, numerous windows that allow to following the data evolution in detail are displayed. Every window corresponds to one data acquisition station. When a incident occurs, managerial operators of the incident can see on the screen the impact and evolution of the event on the traffic.

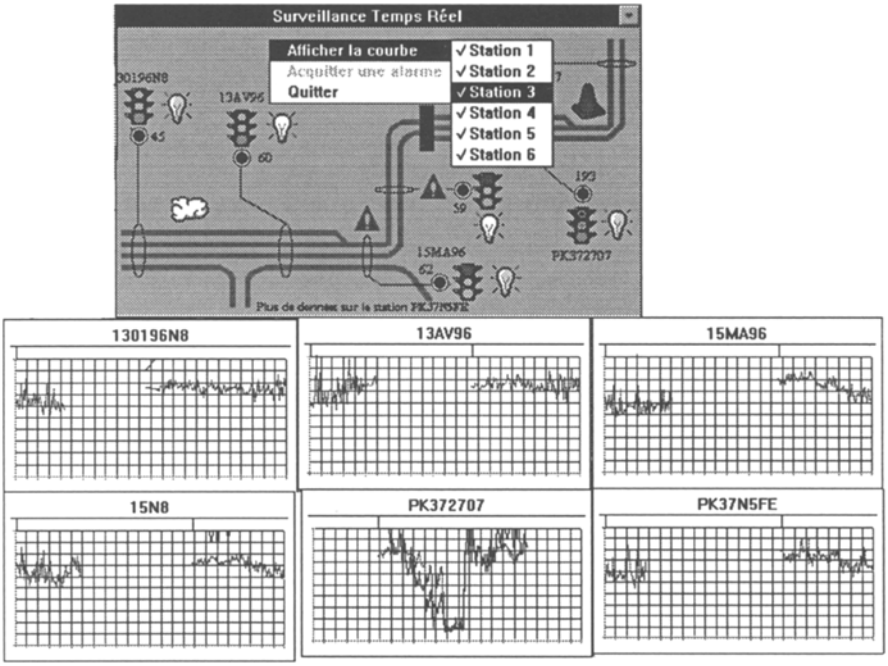

Fig. 13. Alert phase interface

4.4 Data consolidation

Data consolidation is done by the Control Station of the motorway. Information concerning road works on the motorway are taken into account by the Control Station. To do this, the system uses data issued from various external databases belonging to different departments of the motorway, like the road works planning department.

Taking into account road-works information, the Control Station is able to balance synthesis elaborated by districts. The Control Station has a unique and global vision of the entire network of the motorway at it's disposal. Nevertheless, the Control Station can have a localised display of one or more districts.

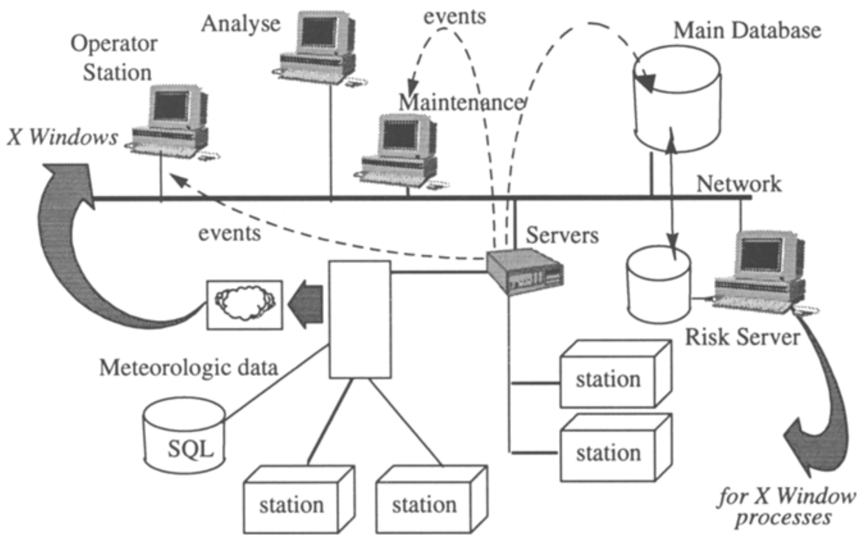

Fig. 14. Architecture of Exploitation Support System for motorways

Figure 14 represents a classical architecture of an Exploitation Support System for motorways. A "risk server" is added to complete the existing system In this case, system interoperability was realised based on classical database management systems and XWindows capacities for interface conception.

4.5 Preventive actions

The risk rate estimation of infrastructure allows the creation of a strategy in order to reduce incident consequences or, if possible, to prevent the event. It is important to detect specific positions where the traffic is quite saturated with high speed vehicles and too short distance between vehicles to avoid a "pile-up". When such a position is detected, the target of a preventive action is to make drivers reduce their vehicle speed. This can be done using electronic boards displaying dynamic messages along the motorway. It is also possible to prevent traffic congestion by lane stop using an automatic folding arm (BRA [Guiol 94] : "Biseau de Rabattement Automatique") as already exists on the Escota's motorways.

5 Conclusion

As more and more people utilise motorways, the risk of traffic jams and accidents increases. When an accident occurs, it is very difficult to obtain information and to

intervene rapidly. The aim of our system is to help motorway managers in real-time to prevent accidents. If it is too late for prevention, then it is valuable to help them to build their intervention strategy and to follow their implementation. Today more and more electronic equipment along motorways and the substantial data produced bring out communication difficulties. It is important to organise processing as parallel processing in order to have a real-time working situation.
The aim of the architecture of the real-time information system presented was to optimise the communication network capacity. Only useful data (concerning raw data or data synthesis) are sent on the network. Only appropriate data are given to operators if a pre-alert or alert situation is detected. The data transfer depends on the motorway situation (normal : no transmission, pre-alert and alert : transmission) and the system moves automatically from one state to another according to received and calculated data. Data are permanently displayed and, for efficiency, are graphical. The real-time aspects of the system allow people to react rapidly and sometimes to anticipate a potential crisis.
A risk index has been elaborated to detect traffic conditions (normal, pre-alert, alert), it was not presented in this paper. More details can be found in [Tanzi 97b]. The experimental prototype checked the feasibility and coherence of the proposed system (including risk index). To do this, we achieved by setting up simulations using fictitious data selected with the aid of the operations staff of the Escota Company. Then we set up a control set consisting of simulated actual situations. We were thus able to estimate the accuracy of the system's reaction. Now we are working on an integration of our system into an Exploitation Support System as it is used in the motorway domain.

References

[Adams 95] Adams J., *Risk*, University College London Press, London 1995.

[Beek 92] Beek U., *Risk Society*, Ed. Sage, London 1992.

[Boulmakoul 93] Boulmakoul A., Selam S. *Intelligent Intersection : Artificial Intelligence and computer vision techniques for automatic incident detection.* Artificial Intelligence in Traffic Engineering, 1993, VSP International Sciences Publisher, Zeist, the Nerdherlands.

[Cohen 90] Cohen S. Ingénierie du trafic routier, Presse de l'ENPC, 1990.

[Guiol 94] Guiol R., *Neutralisation automatique de voies rapides et autoroutes.* Revue des Associations des Ingénieurs et Anciens Elèves de l'Ecole Nationale des Ponts et Chaussées, PCM LE PONT n°12, Décembre 1994, p. 25-27

[Oppe 90] Oppe S., Koostra M. J., A mathematical theory for related long term developments of road trafic and safety. Proceedings of the 11th International Symposium on Transportation and Traffic Theory. New-York, 1990. p.89-99

[Tanzi 97a] Tanzi T., Servigne S., *A Real-Time GIS for Accident Prevention on Toll Motorways.* Proceedings of JEC'97, Joint European Conference an Exhibition on Geographical Information, Vienna, Austria, April 16-18, 1997. p. 42-50

[Tanzi 97b] Tanzi T., Guiol R., Laurini R., Servigne S., *Risk Rate Estimation for Motorway Management.* Proceedings of TIEMEC'97, The International Emergency Management and Engineering Society, Copenhagen, Denmark, June 10-13, 1997. p. 125-134

[HCM 95] *Transportation Reseach Board.* Highway Capacit Manual, Special Report 209, US Transportation Research Board, Washington D.C.. 1995