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RISK MANAGEMENT: A NEW APPROACH TO IMPROVING SAFETY

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ABSTRACT:

The Spanish Government has stated that one of its priority aims is to improve road safety, taking on board the EU commitment of cutting down the number of traffic accident fatalities by the 2010 horizon to 50 per cent of the 2002 figures and to 25 per cent of this by 2020. This calls for energetic action on all the factors affecting motoring safety and specifically road infrastructure. This report covers some of the most innovative and efficient initiatives to have been implemented in Spain over the past three years for improving the National Road Network. Efficient road operation is firmly linked to road safety improvement and particularly in respect of the operation of long tunnels involving heavy traffic densities. It was consequently decided to report on the latest advances in ventilation and fire extinction systems installed in the Madrid Calle 30 and Monrepós Tunnels, permitting rapid response to any emergency occurring inside these major tunnels.

1. INVESTING IN ROAD INFRASTRUCTURE IN ORDER TO ENHANCE ROAD SAFETY

The accident rate on Spain's State-run National Road Network has recorded a positive trend in recent years. 1990 saw the start of a decline in casualty rates with a steady drop in the risk of accidents occurring involving personal injury on the State-run roads as from 1989 and accident risk rates decreasing from 40.3 that year to 13.99 in 2004. There has also been a gradual decline in the number of fatal casualties, from 2,939 in 1991 to 1,463 in 2004, representing a 50.2% drop in absolute terms and 72.1% in fatality risk as the fatality rate (number of fatal casualties for every 100 million kilometres travelled) has fallen from 4.3 to 1.1. It should be recalled that Spain uses accident risk and fatality rates, corresponding respectively to the number of accidents involving personal injury and fatalities recorded per 100 million kilometres travelled, thereby measuring the risk of suffering an accident or loss of life when travelling on a road network. The intensification of the policy of improving all facets of road safety meant that the falling trend in accident risk and fatality rates on the State-run Road Network was accentuated in 2004 and 2005, as shown by the following graphs.

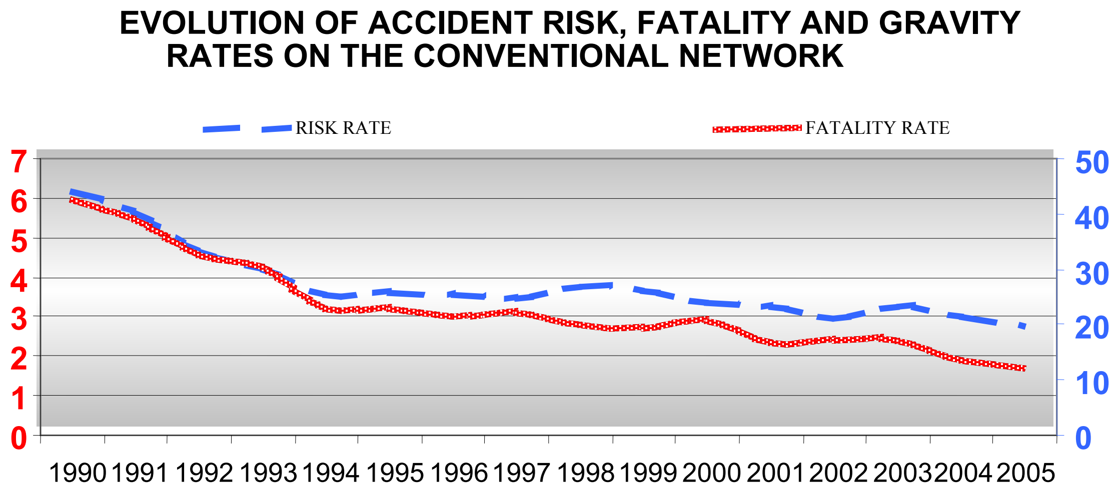

Figure 1 - Evolution of accidents on two-lane roads

EVOLUTION OF FATALITY RATES ON THE HIGH CAPACITY NETWORK

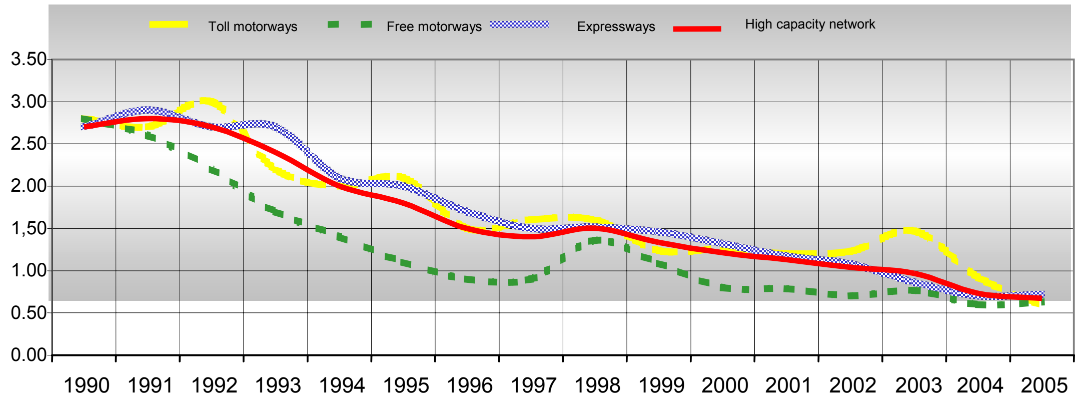

Figure 2 - Evolution of accidents on roads with four or more lanes

1.1. An Integrated Investment Strategy in Safety Improvements for the Spanish Road Network

The essential aim of all the actions implemented by the Directorate General of Roads belonging to the Spanish Ministry for Development when it took on the Government's commitment to cutting traffic accidents to half the 2002 rate by the 2010 horizon and to one quarter by 2020, and in line with the Strategic Infrastructure and Transport Plan (known by its Spanish acronym PEIT) currently being applied, is to improve driving safety on the road network it manages. To help to achieve this aim, a series of procedures are being adopted specifically designed to take safety into account from the actual conception of a road right through its service life, covering all stages from planning, design, construction, start of service operation and maintenance. This integrated strategy attempts to meet all the conditioning factors derived from the human factor, handling road design in such a way that the interactions between environment, roadway and user take place with the lowest possible level of risk. A road safety auditing system is being implemented during the planning and design stages constituting a separate section of the design process. This system involves an independent team of road engineering and road safety experts examining the configuration of the physical elements of a road and their interrelations with a view to detecting potential risks to user safety and making recommendations to the planning or design team concerning adequate measures for avoiding any such risks prior to the construction stage. In addition to this, an audit is being carried out on the State-run roads currently in service concerning the state of road safety in order to guarantee that the safety features of each section are compatible with the road's functional classification and in order to detect any situation that could eventually become a safety problem. To this end, in 2006 nine teams of experts examined the road infrastructure and the way it relates to the environment, drawing up the corresponding proposals for improvement.

Finally, the annual safety improvements campaigns for roads in service first begun in 1986 continue to be carried out every year in Spain. These programmes include a set of actions designed to solve accident concentration sections (as subsequently defined) and to make preventive improvements to road safety conditions by rectifying the functional shortcomings detected in order to cut down potential accident rate risk on the network as a whole.

1.2. Low-cost, Preventive Road Safety Programme Actions

The most relevant factors in cutting down the accident rate on the State-run Road Network in Spain over the past ten years have probably been the commissioning of new expressways and bypasses and implementation of the abovementioned annual road safety programme, the aims of which are as follows.

1. to deal with accident concentration sections;
2. to make preventive reductions in potential areas of conflict, chiefly located at intersections and junctions, on cross-town links, in periurban areas and other sections involving animal underpassages, level crossings and sections where overtaking is difficult, etc.;
3. to carry out systematic Road Safety Audits (RSAs) on the network as a whole, providing a basis on which to define the preventive measures for safety enhancement.

The treatment for accident concentration sections covers a set of highly effective actions affecting approximately 5% of the network in which 20% of accidents involving personal injury and 15% of fatal accidents occur. On an annual basis, the Ministry for Development identifies these accident concentration sections, taking into account other variables such as Annual Daily Traffic rates (ADT), road type and surroundings (urban, interurban or semiurban), in addition to the accident rate recorded over a five-year period. Having identified these sections, they are then subjected to detailed studies by engineers specialising in road safety analysis who inspect each section individually, carrying out a safety analysis and diagnosis on which the actions required to treat and improve them are based. In spite of the high effectiveness of the actions on accident concentration sections, it should not be forgotten that the other 80% of the accidents and 85% of the fatal casualties are produced on the remainder of the network. It is on these sections that preventive actions are being carried out, designed to eliminate potentially dangerous infrastructure elements and to equalise the characteristics of the network, improving it before accidents take place. The study on the reduction of accident rates achieved subsequent to implementation of 3,800 road safety works carried out under the road safety programmes meant that the average reduction in accident risk rate after this action proved to be 38% with a 34% reduction in the fatality rate.

With these results, the average recovery period for the investment cost made through the reduction in the social costs of the accidents was 2.5 years, without quantifying other aspects such as enhanced capacity, mobility, fuel savings and travelling time, etc.

In these economic studies on the investment return period, the social costs of the accident rate were valued at 150,000 € per fatal casualty, 20,000 € per serious casualty and 360 € per slight casualty. Among the road safety works included in the abovementioned study, the signing improvements proved to be the most cost effective as they cut down the fatality risk by some 39% and are amortised in less than 2.5 months (6.5 cost-benefit ratio). Verge treatments cut down the fatality risk by some 84%. Lighting, cross-town link treatments, local layout improvements and carriageway pavement road safety treatments reduce the accident risk and fatality rates by over 50% and 62%, respectively. Finally, ditch treatments have cut the fatality risk by some 31%. On the other hand, replacing intersections by junctions on conventional roads, in spite of having reduced accident risk by some 41% (c95 = 99%) in general terms, is not economically justifiable purely on the grounds of road safety criteria as the high cost of these actions, rated at approximately 1,200,000 €, makes their amortisation period much longer.

Figure 3 - Example of low-cost action improving traffic guidance equipment in Murcia

Road Safety Audits (RSAs) are intensified in potentially hazardous areas which, as stated earlier, exist at intersections and junctions, cross-town links, road narrowing spots, animal underpassages, level crossings and sections where overtaking is difficult, etc. In these areas, the route characteristics are analysed and the necessary actions proposed.

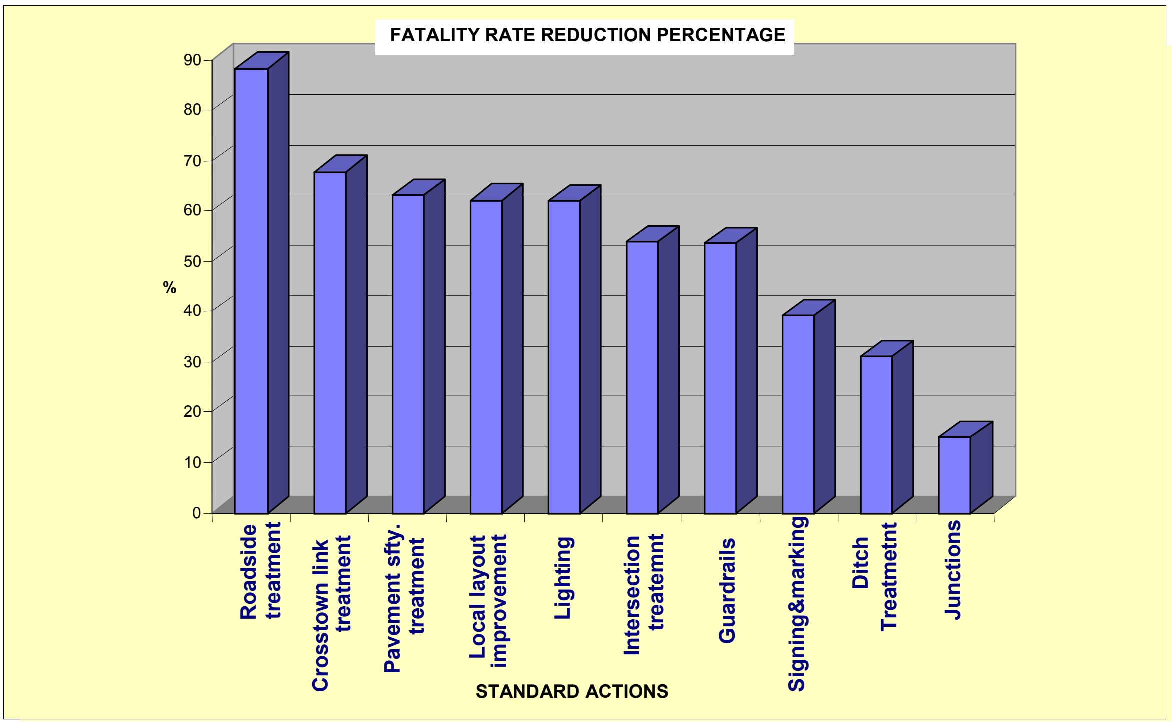

Figure 4 - Effectiveness of safety actions

The following aspects are studied in detail in the Road Safety Audits.

a) Layout (groundplan and elevation): suitability of the design parameters to traffic characteristics and to the real driving speeds involved and to visibility distances at real driving speeds. Layout consistency: variations in specific velocity between consecutive elements. Sufficiency of overtaking opportunities (on two-lane roads). Adequate treatment of transitional areas between consecutive sections.
b) Cross section: covering the adaptation to traffic and local characteristics, consideration of the variations along the section and the transitional areas between consecutive sections.
c) Pavement and drainage: suitability to local traffic characteristics and geographical location (climatology).
d) Equipment: analysing the clarity, opportuneness and uniformity of the road signs and markings, continuity of the orientation signs; suitability of the traffic guidance equipment along the road and at junctions and lighting.
e) Treatment of special elements: specifically analysing interchanges, cross-town links, tunnels and underpassage works, taking into account legibility, visibility, cross angles and the channelling of movements of all users.
f) Prevention of the effects of fatigue: analysing attention alerting elements and rest areas.
g) Access location and suitability.
h) Verges: treatment of the obstacles and retaining systems existing on verges including those corresponding to roadway elements: ditches, drainage works, structure supports, gantry and signing supports, lampposts and slopes, etc.
i) Flow study: pedestrians and cyclists.
l) HCV safety both on slopes and at interchanges.
m) Queue formation analysis on entry and exit sliproads and at intersections and suitability of the measures provided
n) Vehicle parking: location and layout of stops for public transport vehicles and access routes for emergency vehicles.

1.3. Specific Actions for Improving Road Safety for Motorcyclists

Vehicle retaining devices are installed in places where the gravity of crashes into a protected obstacle would be far greater than the consequences of a crash into the guardrail. The Spanish legislation and technical codes relative to retaining systems designed to increase vehicle safety were embodied in Circular Order 321/95 T&P “Recommendations on distance retaining systems for vehicles”. According to the accident rate study on these systems carried out by Spain's Directorate General of Roads, accident gravity is greater on sections not provided with guardrails, reaching approximately double the gravity in motorways and expressways. And this is the case in spite of the fact that these distance retaining systems are precisely installed in the potentially most dangerous places. Similarly, studies carried out on the effectiveness of these devices revealed that their installation successfully lowers the gravity of crashes (fatal accidents for every 100 accidents involving casualties) by values close to 30%. However, whereas guardrails have proved to be capable in many cases of steering vehicles away from veering off the road or from invading lanes and leading them back to the carriageway, they have proved to be particularly aggressive for riders on two-wheel vehicles.

This has led to the gradual attempt to improve the design of these retaining systems with a view to minimising harm to motorcyclists. Accidents involving motorcycles over the 1999-2003 period amounted to 12% of the accidents with casualties occurring on the Spanish State-run Road Network, and accidents as a result of motorcycles veering off the road amounted to 2.4% of the total of fatal accidents. Spanish legislation, adapted to the directives issued by the European Commission's Standardisation Organisation, provides the supply of C-shaped guardrails on expressways and tubular posts on conventional roads, designed to prevent cuts to motorcyclists crashing into the guardrail and thereby constituting an improvement over the previous “I-shaped” guardrails. Notwithstanding, although installation of new metal guardrails and the repair of any accident-damaged rails is always done using the new C-shaped or tubular post designs, very many of the old design I-shaped guardrails still exist and they are being protected by special fenders to buffer the possible impact on motorcyclists.

Figure 5 - Protection made of recycled rubber N344. New guardrail design.

However, the most important advance in guardrail improvement to protect motorcyclists has involved the installation of a new design, defined in Circular Order 18/2004 on “Criteria for the Use of Motorcyclist Protection Systems” which, after numerous trials, came into force on January 10, 2005 and consists of incorporating a second metal guardrail under the existing one in the conventional guardrail design, as illustrated in the following figures.

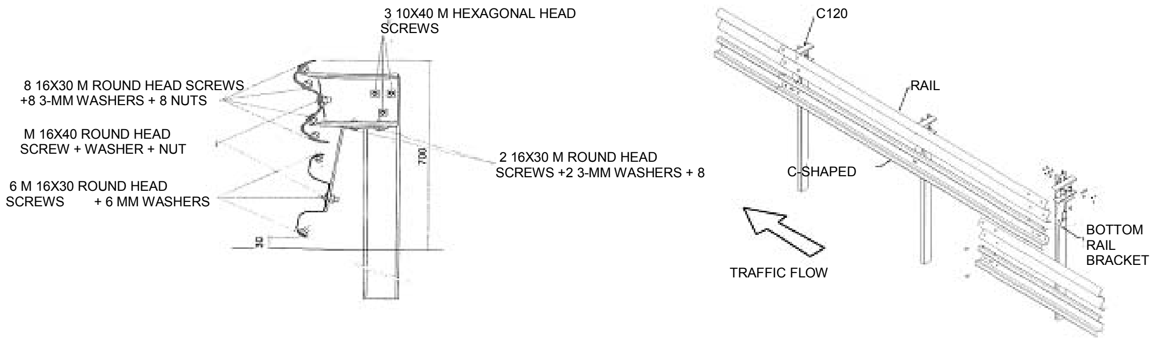

Figure 6 - Detail of the guardrail to protect motorcyclists

This system prevents motorcyclists from passing under the guardrail and possibly colliding with the posts yet does not harm the other vehicles in the event of being involved in an accident.

In order to install these guardrails, the Spanish Ministry for Development drew up an Adaptation Plan for guardrails providing for the continuous installation of equipment along

1,505 km in areas of the State-run Network with adverse geometry. This requires an investment of 43 M€ to be carried out over six years.

1.4. IITS. Variable Message Panels

In the early 1980s the Ministry of the Interior's Directorate General for Traffic (DGT) tackled traffic management and control as a possibility of improving the service provided for road users. To this end, it proceeded to install a set of high-tech devices with great powers of attracting motorist attention, providing drivers with timely awareness of and information on traffic incidents such as accidents, road works, traffic retention causes, weather-related incidents and recommendations on itineraries and alternative routes. This information must be provided in an accurate, continual and real-time manner and this is achieved by use of variable message panels (VMPs). At the present time over 1800 VMPs are installed on the 23,842 km oh High Capacity Roads on the State-run Network, concentrated on the accesses to major cities involving significantly higher traffic rates. Given that traffic density on the roads provided with VMPs is normally greater than 50,000 vehicles/day, it can be stated that three quarters of Spanish motorists receive information via this type of equipment during their daily travel. Based on LED technology, unitary and versatile chromatised light body, VMP features have undergone considerable evolution, from a two-coloured or multicoloured pixel-configured structure to a monocolour LED unitary control, as a function of the need to provide the physical and operational features necessary. The DGT contributed to this by drafting, drawing up and issuing nationwide definitions and by its active European-level participation in the EN 12966 Standard which, from the time it was passed in February, 2005, constitutes the basic element for defining the features of the new VMPs. The first three units of this type of panel were installed at the end of 2005, in Corunna; on the Murcia Bypass on the occasion of the II National Road Safety Conference, and in Malaga, coinciding with the V National and I Latin American Conference on Intelligent Transport Systems. It should be stressed that the latest generation VMPs installed in Spain possess exceptional distinguishing features among which it is worth mentioning the integration concept, the possibility of extending the alphanumerical writing in the graphics area, the power range at maximum-charge of these panels in the event of 1-hour power failures and the monitoring process of the operating hours of the visualisation plates as a means of measuring the stage of use and wear of the panels. A further 110 similar VMPs will be installed over 2006, complying with European Standard EN12966, at locations such as the access routes to the city of Palma de Majorca, the Salamanca-Tordesillas section of the A-62 Motorway, the expressways in Cantabria and the access routes to Malaga and Murcia, thereby comprising one of the largest networks of this type of VMP design currently existing in Europe.

1.5. Weather Stations

The first scheme for installing weather stations for roads (SEVAC) began to be developed in Spain from 1998 onwards. Since then, a total of 113 stations have been set up, covering the most important highways and motorways in the central area of Spain (with an installation rate of one station every 10-15 kilometres). These stations house adequate sensors to help to detect the atmospheric phenomena having the most effect on motoring safety such as fog, ice on carriageway pavements, snow, strong wind and rain. The good results obtained from the start of the plan created the favourable conditions for extending the programme to three new areas as from 2000, namely Galicia (where rain, snow and fog are the most important factors), the access routes to the Pyrenees (snow, ice and rain) and eastern Spain - Albacete, Alicante and Valencia (affected by fog, frost and sporadic yet significant snow storms). At the preset time, over 350 SEVAC roadside weather stations have been set up, covering over 10,000 km of high capacity roads on which there is a significant risk of adverse weather conditions. Complementing the SEVAC stations, spiral detectors have been installed on carriageway pavements designed to pick up traffic data such as density, speed and percentage of HCVs, etc. and allowing the real-time transmission of messages such as: “DENSE FOG OVER XX KM, SNOW FROM KM XX TO KM YY” to be done sufficiently ahead in time to enable motorists to make the most appropriate decisions. In addition to these weather stations, essentially aimed at providing information for motorists, there exists another network comprised of 97 permanent stations and 19 mobile stations, which are used to manage winter serviceability operations and which, in addition to atmospheric data, pick up other data required for winter maintenance such as asphalt temperature, salinity, estimated freezing temperature and dew points, etc. by means of sensors installed in the road pavement. Data is transmitted via GPRS, in real time, to the integrated road maintenance centres where, after duly consulting the Maintenance Service Chiefs at the Directorate General of Roads, the appropriate de-icer spreading preventive or curative treatments are set in motion as from the time the ambient temperature drops below 2 ºC and the ambient humidity levels rise over 75%.

Thanks to this, success is being achieved in respect of anticipating actions on the carriageway to the time when motoring conditions on it are bad, and are especially successful in preventing the appearance of icy patches on the State-run road network that can have such negative effects on road safety.

Figure 7- Weather station at Lorca for winter maintenance management purposes

2. VENTILATION AND FIRE EXTINGUISHING SYSTEMS IN TUNNELS

Safety in tunnels depends to a great extent on the ventilation and fire extinguishing systems installed. The two cases reported are very different but considered of interest in the field of tunnel operation. The first one involves a system of urban tunnels of considerable length and handling extremely high traffic densities. The second case is a successful adaptation of an existing tunnel to make it comply with the new safety regulations.

2.1. The Madrid Calle 30 Urban Tunnels

'Madrid Calle 30' is a major scheme transforming the old M-30 express ringroad into an urban motorway, a large part of the layout of which runs below ground, eliminating the existing barrier between the centre of Madrid and the other districts comprising the capital. The design of this urban motorway allows the road network to function better by cutting down trip times and creating new green spaces, particularly including recuperation of the River Manzanares that is scarcely accessible to Madrid residents at the present time.

Figure 8 - Recuperation of the River Manzanares

The solution chosen to meet these targets involves tunnelling several sections of the motorway and constructing several kilometres of new tunnels. The total length of the tunnel sections, including junctions, amounts to 50 km and the longest, continuous underground section will be 11.5 km. The majority of the works are using diaphragm walls but two new 3.8-km long parallel tunnels will be built using a tunnelling machine with a diameter of almost 16 metres. Average Daily Traffic predictions for the new Madrid Calle 30 urban motorway go as high as 300,000 vehicles/day and are expected to exceed 100,000 vehicles per day on the tunnel sections. The agents responsible for managing the tunnels consider it is an essential aim to cut down the number of incidents and to be able to respond as efficiently as possible to any that do occur, prioritising safety but preventing congestion on the roadway to the greatest extent possible. This meant it was necessary to carry out a thorough examination of the safety systems involved and to make considerable improvements to the design parameters regularly used.

2.2. Some Figures

A 60 MW power supply is required for the set of tunnels as a whole, supplied by five electric substations, and a redundant ring has been designed with a 15-kV medium voltage. In addition, multiple subsystems have been designed to guarantee safety in the tunnels. These will be remotely controlled from a tunnel control centre incorporating a second, additional backup centre ready to take over control in the event of any malfunction in the main centre. These two control centres will be physically connected to the Madrid City Council's mobility centres and municipal police and to the firefighters and emergency medical services (Samur), as also to the management centre at the Directorate General for Traffic.

The following subsystems are most important owing to their effect on safety in the event of fire breaking out:

- ventilation system
- air filtering system
- high-pressure water mist fire extinction system.

2.3. Ventilation System

The layout of the tunnels, incorporating multiple junctions, meant that the planned ventilation system had to be a transverse design in the Southern Bypass tunnels and longitudinal in the river area, based on wells and accelerators incorporating reinforcement in the event of a fire and with evenly spaced extractions. The aerodynamic behaviour of the tunnels is therefore uniform in the event of a fire.

University experts and the best manufacturers of ventilators, control and filtering devices collaborated in the system design in order to create characteristic safe, heavy duty and reliable systems for each tunnel.

The ventilators used are as follows:

- 155 axial ventilators comprising the basic core of the ventilation system, capable of functioning by impulsion and/or extraction and with a total capacity of 43.340 MW;
- 451 longitudinal or jet fan ventilators to be distributed throughout certain tunnel segments in order to set up longitudinal movement of the air inside the tunnel and having a total capacity of 11.747 MW;
- 258 mass extraction ventilators distributed at specific points throughout the tunnel and with a total capacity in the order of 5 MW.

2.4. Air Filtering System

In order to reduce the pollution produced by extraction of the air in the tunnel, a total of 30 particle filtration stations will be installed applying electrostatic precipitation technology and four NO2 filtration stations.

These filtration stations are designed to achieve adequate air quality levels and eliminate noxious pollutants without expelling them to the exterior or affecting the environment as the same air taken out of the tunnel is recycled after being subjected to a filtering and cleansing process.

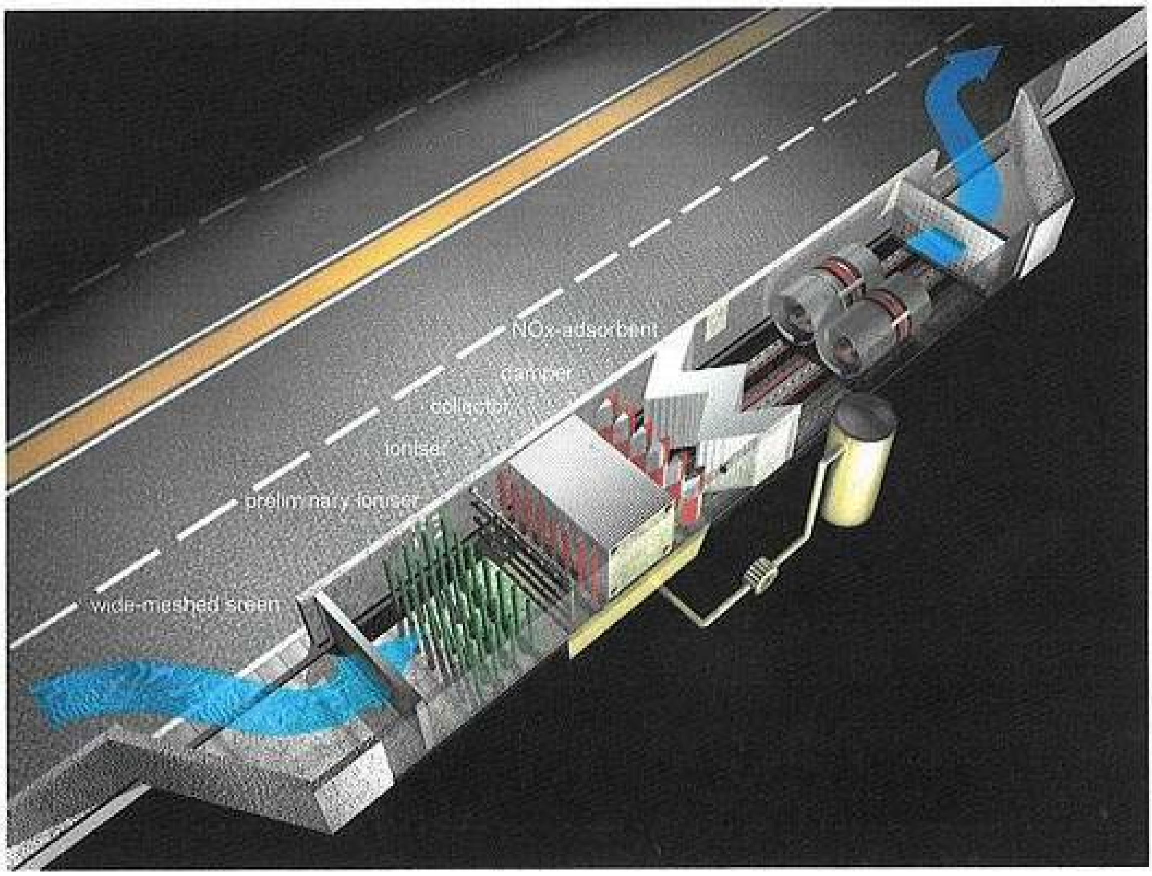

Figure 9 - Filtration system

2.5. Water Mist Fire Extinction

Water mist as an active protection system is becoming one of the most developed and utilised in the field of tunnel protection thanks to its capacity for controlling heat in the fire zone and for reducing propagation of the fire. The efficient extinguishing powers of water mist are based on the high degree of nebulisation of the water used, optimising the effects of cooling, radiant heat attenuation and oxygen displacement in the base of the fire. The high velocity of the water drops offsets their small mass when it comes to evaluating their volume of movement, the parameter characterising the capacity of the drops to penetrate the plume of hot gases produced by the flames, and guarantees that the water will not be displaced from the fire environment. The particles suspended in the environment of the fire create a dense, moist mist enveloping the fire and firstly preventing it from expanding by reducing the size of the flames and subsequently extinguishing it. In turn, the darkening effect produced by the mist in the environment of the fire lessens the amount of heat radiated.

The extinction and fire suppression principle of water mist is consequently based on three different actions:

- cooling through heat absorption as the water vaporises
- displacement of the oxygen in the source of the fire through vaporisation
- attenuation of heat transmission through radiation.

Figure 10 – Discharge of water mist. Nozzle examples.

The water mist system consists of centralised pressurising and pumping equipment feeding the water nebulising nozzles at high pressure through a network of pipes. In collaboration with the Fire Extinction Department of the Madrid Firefighting Corps, the CEMIM and manufacturing firms, real trials were carried out in the San Pedro de Ares testing tunnel facility to study the strategy for using the water mist system, which corroborated the efficiency of the system, although the optimum moment for triggering the nebulising nozzles has yet to be determined.

2.6. Monrepós Tunnel

This is a project for upgrading a non-urban, two-way and 1500-m tunnel on an extremely important road linking the North East of Spain to France and comprising an unavoidable route for crossborder traffic also utilising another tunnel on the same route – the Somport Tunnel.

Owing to the enormous difficulty of building escape galleries to the exterior, the designers opted to introduce a number of *risk reducing* compensatory measures capable of improving the safety. These actions took into account the future plans for dualling the current road, which will involve converting the existing two-way tunnels into one-way configurations for which the most suitable ventilation system is a longitudinal design.

Consequently, among the actions carried out as part of the first phase of improvements planned for this tunnel it is worth highlighting *the reinforcement of the ventilation system and the introduction of an automatic ventilation control system for fire emergencies.*

Figure 11 - View of the entrance mouth

To this end, the capacity of the previously existing longitudinal ventilation system was increased by installing higher performance equipment. The aim of this was on the one hand to achieve sufficient velocity at the scene of fires to expel the gases through one of the tunnel mouths without their backtracking and, on the other, to allow the longitudinal current to be controlled, a critical matter to safety in the initial stages of a fire emergency.

In this respect, the control system helps to achieve reasonable safety conditions both during normal service and in the event of fire. It does so employing two methods:

- automatic actions direct on the ventilation;
- providing assistance in decisiontaking by the tunnel operating staff by proposing actions for tunnel management making it possible to reduce final response time.

The same general action approach is applied to both cases, namely to maintain the best possible evacuation conditions by conserving the stratification conditions based on controlling the longitudinal air stream.

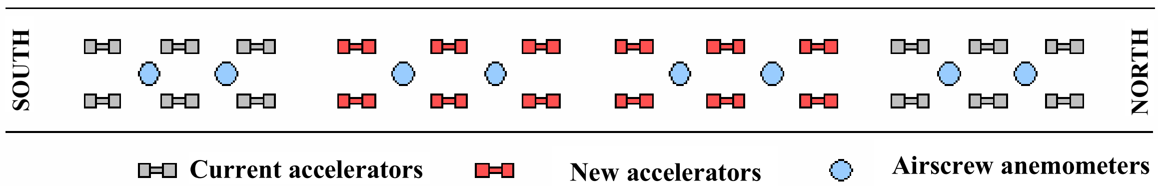

Figure 12 - Adaptation of the ventilation system

The longitudinal ventilation system installed has 24 reversible air jet accelerators, sufficient to meet the air stream demand in both normal service and fire emergency scenarios.

The ventilation stream during in-service operation is the minimum air stream guaranteeing, for each scenario, both dilution of pollutants to admissible limits and the capacity of the ventilation system to respond to a fast stream demand in every service situation.

Anemometers and pollutant detection systems (CO and opacimeter sensors) have been installed to regulate the ventilation.

For the purpose of sizing in the event of fire, designers took into account the fact that the ventilation system needs to have sufficient capacity to successfully entrain the gas cloud to any of the tunnel mouths, independently of the fact that in the initial stages of gas cloud development the ventilation strategies are aimed at cutting down the air velocity in order to successfully evacuate users in the greatest possible conditions of safety. Thus, the critical velocity considered for system sizing purposes proved to be slightly less than 3 m/s.

In this case, the ventilation strategies are based on controlling the longitudinal air stream and therefore being able to control the smoke and fumes.

The ventilation system seeks to fulfil the following aims:

- in-service scenario:
    - providing user comfort (CO and opacity levels)
- fire scenario:
    - controlling the smoke cloud
    - stopping the fire from spreading
    - supporting the rescue operation.

The Monrepós Tunnels have a control centre, manned on a 24-hour basis. In the event of fire, the system is set to operate manually or automatically, depending on the phase involved.

Phase 1: User Evacuation

The essential aim is to give users time to escape. This necessitates maintaining the stratification of the smoke cloud by maintaining a low air velocity which in any event must be less than 2m/s.

The longitudinal air stream is controlled taking into account the air velocity measurements taken in the interior of the tunnel by switching the accelerators on or off (always avoiding turning them on near to the source of the fire).

Phase 2: Smoke Expulsion

Once it is certain that the total evacuation process of persons is complete, all the ventilators will then be switched on.

In order to manage the way the ventilation develops, algorithms were drawn up to control this as a function of requirements.

The switch-on phase therefore comprises the following subphases:

- pre-alert: triggering of the linear detection system alarm or of the pollutant sensors;
- action: sequence of programmed actions: closure, reinforced lighting and ventilation control;
- adjustment: countering the imbalances produced.
- expulsion: once persons have been evacuated, all the ventilators are set off manually.

This system provides reasonable safety conditions. While some actions are automatic, others depend on the operating staff such as location of the source of the fire, as some decisions like expelling the smoke in one particular direction – on which human lives can depend – should not be taken automatically. What the system certainly does is to facilitate decisiontaking by proposing actions thereby achieving a considerable reduction in response time.

This is the way an existing tunnel has successfully been adapted to the new tunnel safety demands.