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ROAD MANAGEMENT SYSTEM IN ADVERSE WEATHER CONDITIONS: FOG AND WIND

XXVII ROAD WORLD CONGRES

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ABSTRACT

The A-8 Cantabrian motorway (hereinafter A-8) in the area of Alto del Fiouco, between km 545+500 and 549+500, presents particular weather conditions with episodes of dense fog combined with strong winds which make driving difficult, because of this, sometimes, it is necessary to close the motorway and divert vehicles to the N-634 road, as it is not possible to guarantee the minimum safety conditions for its use.

For this reason, the Directorate General of Traffic (hereinafter DGT) has established protocols for managing the road when there are adverse weather conditions of fog and wind, and has installed a series of ITS equipment that has made it possible to manage the restrictions more efficiently and safely, also increasing the number of hours that the motorway is operational.

The system installed allows the automatic closure and detour of vehicles by using the following ITS devices: weather stations to detect visibility values and wind speed and direction, Variable Message Signs, red light cameras to control compliance with restrictions and traffic lights and beacons to inform the user. In addition, presence detector beacons have been installed, which allow greater safety in foggy conditions, warning of the presence of vehicles on the road.

This article describes the protocols applied, the equipment systems installed to comply with these protocols and the effect these systems have had on the operability and safety of this affected section of the A-8.

1 DESCRIPTION

The A-8 is a two-lane road running almost parallel to the coast of the Cantabrian Sea, connecting the Autonomous Communities of the Basque Country, Cantabria, Asturias and Galicia. The A-8, with a total length of approximately 486 km, begins in Bilbao, at the junction of the AP-8 with the AP-68, and ends in Baamonde (Province of Lugo) where it joins the A-6 motorway.

Figure 1 – Route of the Cantabrian motorway (A-8). Source: Wikimedia maps

In February 2014, the Mondoñedo-Lindín and Lindín-Careira sections of the A-8 were inaugurated, which pass through the municipalities of Lourenzá, Mondoñedo, Abadín and Pastoriza. Both sections are 15.9 km long and run southeast of the old national road N-634. The infrastructure has two carriageways, each with two 3.5 m wide lanes, outer verges of 2.5 m and inner verges of 1.0 m, separated by a median between 2.0 and 6.0 m wide, depending on the section.

These sections of motorway have required important and complex engineering works, as they run through uneven and geotechnically very complicated terrain. As a result, major cuttings, surface and deep drainage works, retaining walls on the mid-slope sections and a large number of structures of various types have been carried out. Among these, the O Fiouco viaduct stands out.

The section of the A-8 under study corresponds to the Alto de O Fiouco, which is between KP 545+500 and 549+500, runs at an altitude of 700 m and has two main problems: wind and lack of visibility due to fog.

Since it was put into service in February 2014, there have been numerous episodes of intense fog which have caused significant multiple collisions. On 26 July 2014, the most serious multiple collision occurred, involving a total of 39 cars and lorries, resulting in 1 fatality and more than 40 injuries of varying severity. Since then, specific measures have been implemented to mitigate the effects of fog on this section of the A-8, which are described in this article.

2 OBJECTIVES

The main objectives of the initiative are listed below:

- To provide a coordinated framework for action in the event of a traffic situation due to adverse weather conditions.
- To inform road users about weather conditions on the road and the necessary adjustment of speed or detour to an alternative route.

- Contribute to road safety in adverse weather situations associated with fog and high winds.
- Contribute to optimal traffic management: information on adverse weather episodes on the roads allows Traffic Management Centres to make decisions quickly and efficiently.

3 TECHNICAL CHALENGES

3.1 PROTOCOL DEFINITION

Based on the meteorological records of the visibility distance in the presence of fog and the intensity and direction of the wind in the area, action protocols were defined on this stretch of motorway to adapt the speed of vehicles according to the weather conditions at the time.

The protocols for fog and wind, described below, establish four levels which, following the colour code of the traffic lights, increase the restrictions as road conditions worsen.

3.1.1 *Protocol in windy conditions*

In the process of drawing up the protocol for action in the event of wind, the analysis of meteorological records in the area was complemented with exhaustive benchmarking to determine the thresholds to be implemented based on success cases. [2-6]

The wind protocol has a first level (green level) of recommendation of moderation of traffic speed when wind speed exceeds 30km/h, and two levels of reducing speed limit to 80km/h (yellow level), if wind speed exceeds 50km/h, and to 60km/h (red level), if wind speed exceeds 80km/h. The fourth level corresponds to the closure of the motorway when the wind speed exceeds 130km/h.

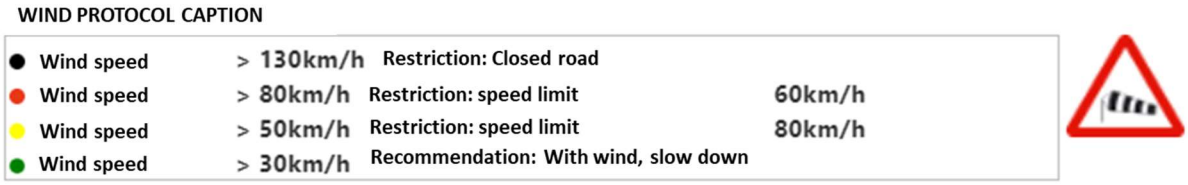

Figure 2 – protocol in windy conditions

3.1.2 *Protocol in the presence of fog*

In order to define the protocol for action in the event of fog, initially, in addition to analysing the visibility in the area, the provisions of Regulation 3.1-IC Layout of the Highway Instruction ("BOE" of 2 February 2000)[1] were taken into account in relation to visibility and braking distance, thus obtaining the visibility value of 40 metres for the closure of the motorway.

Subsequently, with the installation of the presence-detecting beacons described in section 3.3, and the consequent improvement in traffic conditions, the threshold for closing the motorway was adjusted to a visibility of less than 30 metres.

Therefore, the current fog protocol, like the wind protocol, has four levels: one of recommendation and three of restriction. The first level (green) is applicable when the visibility distance is between 150 and 250 metres, where it is recommended to moderate the speed and the use of dipped headlights is mandatory in conditions of reduced visibility. In the second level (yellow), with a visibility between 75 and 150 metres, the speed limit is restricted to 80 km/h. At the third level (red), with visibility between 30 and 75 metres, the speed limit is 60 km/h and, finally, when visibility is less than 30 metres (black), the motorway is closed and the automated detour of vehicles to an alternative route is activated.

Figure 3 – Protocol in the presence of fog

3.2 AUTOMATED DETOUR AND PROTOCOL IN FOG AND WINDY CONDITIONS

Initially, the detour due to the presence of fog/wind was carried out manually, so that each activation of the detour was notified to the Piedrafita Tunnel Control Centre, which in turn notified the Integral Maintenance of the Mondoñedo area (Lugo) under the Ministry of Transport, Mobility and Urban Agenda, which was responsible for signalling and making the detour effective. This procedure, in addition to entailing considerable time between communications and coordination of personnel, also increased risk situations, by having agents on the road in charge of signalling and allowing vehicles to pass in foggy conditions while the detour was being made effective.

Figure 4 - Manual detour by means of physical lane markings on A-8.

Figure 5 - Manual detour by means of physical signalling on access to A-8

The characteristics of the fog concentrated in this environment, which is capable of reducing the visibility distance very quickly, covering the entire stretch of motorway in less than a minute, make it necessary to have an agile system that allows the closure of the motorway to be applied when necessary.

The automated detour, therefore, is designed to facilitate the existing methodology, eliminating the need for agents on the road, with the consequent reduction of occupational risks and reducing the time required for coordination between the different entity involved.

Furthermore, this automated system aims to reduce the time from the moment the detour or opening of the road is necessary until it becomes effective, guaranteeing the safety of road users and improving the management of the road's operation.

The current detour methodology proposes to apply new technologies to send/receive information on road conditions, infringing vehicles and alternative routes in real time. For this purpose, various ITS equipment such as Variable Message Signs, beacons, surveillance cameras (CCTV) and illuminated signs are installed in the area.

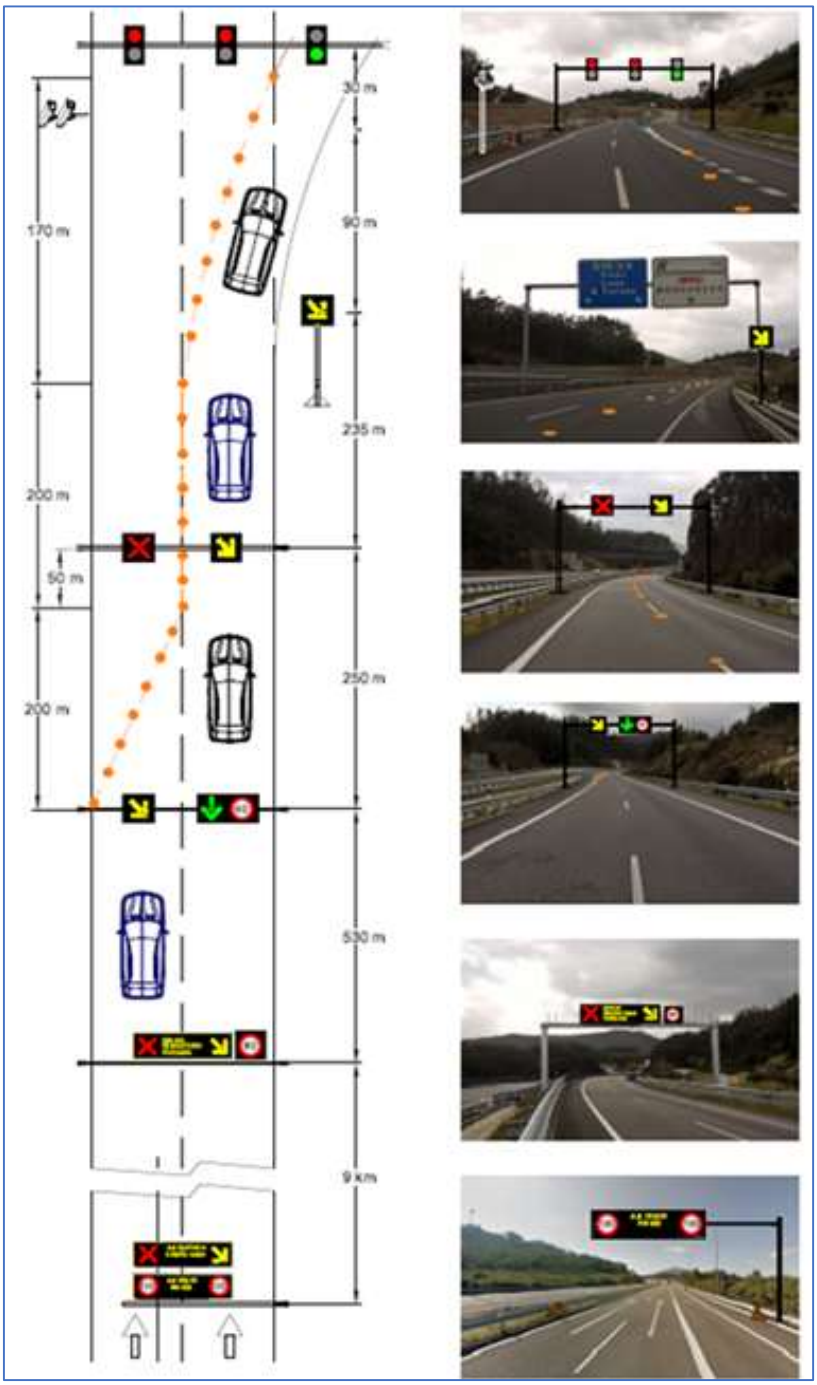

Figure 6 – Detail of the diagram of the equipment installed on the affected section of the A-8 and its operation.

In this new methodology, the detour is established automatically from the North-West - Cantabrian Traffic Management Centre and the steps to be followed are summarised below:

- Detection: based on the values of the visibility and wind parameters received from the devices installed on the road (weather stations and CCTV), the level of visibility is evaluated at the Northwest - Cantabrian Traffic Management Centre and it is detected when the visibility on the stretch is less than 30 metres or the wind speed is higher than 130 km/h and it is therefore necessary to close the road and detour vehicles. This is continuously monitored through a computer tool that contains the signalling protocol and informs in real time of the situation on the stretch.

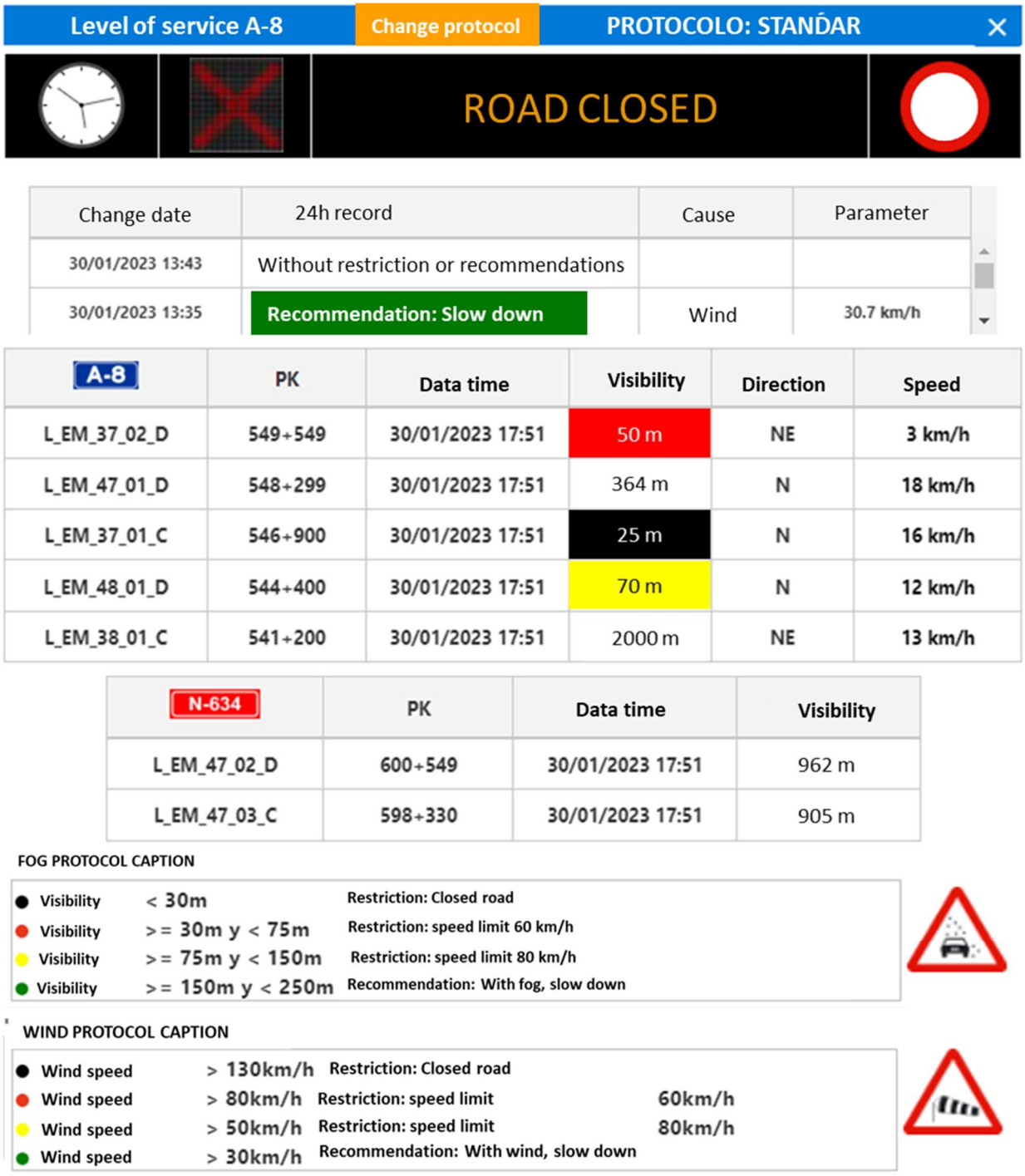

Figure 7 - Continuous monitoring system for weather conditions on the A-8. Northwest - Cantabrian Traffic Management Centre. DGT. Ministry of the Interior. Spain

- Signalling panels: Once low visibility or high wind speeds have been detected, the corresponding speed limits, or the closure of the road and detour to the N-634, are signalled from the North-West - Cantabrian Traffic Management Centre. The corresponding warnings to drivers are displayed on the Variable Messaging Signs (VMSs) installed at the beginning and end of the section. In addition, the luminous beacons installed on the pavement are lit to direct vehicles, as shown in the following figures.

Figure 8 – Variable Message Sign and pavement markings. A-8 Motorway. Alto del Fiouco (Lugo). Spain

- Control: In addition, to ensure that vehicles comply with speed restrictions, two speed cameras have been installed, as well as traffic lights equipped with red light cameras at the motorway's detour points.

Figure 9. Variable Message Sign and traffic lights with red light cameras. A-8 Motorway. Alto del Fiouco (Lugo). Spain

3.3 ADDITIONAL BEACONS TO THE AUTOMATED DETOUR

As a complementary method to the automated detour, a system of beacons has been implemented to detect the presence of vehicles in low visibility conditions. Similar to the cantonisation of railway tracks, the beacons are installed on both sides of the road, 50 metres apart, and their function is to warn drivers of the presence of other vehicles on the road in low visibility conditions, so that they can adapt their speed and keep their distance from other vehicles.

The system of beacons for the detection of vehicles in low visibility conditions has already been put into operation on the O Fiouco stretch along a length of 4.28 km. The following images show how it works. In the presence of dense fog, with visibility less than 150 metres (yellow level), the lower amber lights of all the beacons installed on the stretch are activated to alert vehicles to the situation. Then, as soon as a vehicle enters this zone, the upper red light of the beacons closest to the vehicle on both sides is switched on to warn the following vehicle that another vehicle is travelling on the stretch. As the vehicle advances along the stretch, the following beacons are lit, and those 100 metres away from the vehicle are switched off. In this way, each vehicle has two beacons lit from behind, alerting road users that, in the next 100 metres, there is another vehicle driving ahead and that they should adapt their speed and keep their distance.

Figure 10 - Diagram of the operation of detector beacons in low visibility conditions. A-8 Motorway. Alto del Fiouco (Lugo). Spain

Figure 11 - Detector beacons in low visibility conditions. A-8 motorway. Alto de O Fiouco (Lugo). Spain

In order to inform drivers of the meaning of these beacons, so that they proceed with caution instead of stopping at a red signal, vertical signs explaining the system have been installed at the beginning of the section.

Figure 12 - Vertical sign located at the beginning of the section. Alto de O Fiouco (Lugo). Spain

4 NO TECHNICAL CHALENGES

One of the main obstacles or barriers in this case was precisely the definition of an action protocol for a novel situation for which there were no precedents at national level.

It should be noted that another of the main barriers to overcome was the change in drivers' behaviour when passing through this area. Although the number of offenders who ignore and fail to comply with the detour is very low, this stretch already has a special singularity in terms of fog and wind, and not all drivers are used to driving in these adverse conditions. This special feature refers to the fact that the fog completely covers this stretch in less than a minute, so drivers have to react quickly.

5 ASSESSMENT

5.1 EFFICIENCY AND EFFECTIVENESS ANALYSIS

5.1.1 *Analysis of the efficiency of automatic vs. manual detour*

As indicated above, the weather situation in the area is highly variable from one moment to the next (fog appears and disappears in a matter of minutes), so this factor, added to the fact that the closure of the dual carriageway was carried out manually using traditional signalling and beaconing elements, meant that the dual carriageway remained closed for a much higher percentage of hours than the visibility recorded below 40 metres, generating a low efficiency in the use of the road, around 40%.

From the implementation of the automated detour in December 2016 until the implementation of the new fog protocol on 25 January 2022, a total of 2,313 hours with visibility below 40 metres have been recorded on this section. This would have meant 5,302 hours of closure of the motorway with the manual detour methodology, while with the automated detour this figure was reduced to 3,405 hours of effective detour, which means a total of 1,897 hours of "savings" (equivalent to 79 days) in which the motorway could have been open to traffic.

5.1.2 *Analysis of the efficiency of the new protocol with presence detecting beacons*

With the implementation of the beacon system on 26 January 2022, 42 hours of visibility of less than 30 metres have been recorded up to 31 December 2022, which means 78 hours of detour, compared to the 314 hours recorded with visibility of less than 40 metres that would have led to the closure of the motorway for 462 hours according to the previous protocol. This means 384 hours (equivalent to 16 days) during which the motorway was open to traffic.

5.1.3 *Analysis of Operation and Effectiveness of Detours*

From the point of view of the operation and effectiveness of the detour, from December, 15 2016 to December 31, 2022, it has been detected that 0.8% of the total number of vehicles circulating on the section continue on the dual carriageway despite the closure, which means 99.20% compliance with the signalling.

In view of these results, the new detour methodology has had a significant effect on improving the efficiency of traffic operation and increasing the number of operational hours of the motorway. This effect is even greater thanks to the use of the new detector beacons, which have made it possible to reduce the value of the visibility limit to 30 metres, from which the detour is made.

5.2 ROAD SAFETY

From the point of view of road safety, the automated detour has avoided the physical presence of personnel on the motorway for the manual installation and removal of vertical signage and cones every time it was necessary to close the motorway, so it is a risk that has been eliminated.

It should also be noted that, since the implementation of the system in December 2016 to date, a total of two accidents have been recorded in foggy conditions: one involving a rear-end collision with two minor injuries, and another involving an animal run-over with no injuries. No accidents with fatalities or serious injuries have been recorded.

5.3 LESSONS LEARNED

The main lesson learned is the vital importance of effective detection and communication. Initially, the process of manually closing the road meant more time, cost and risk on the road. However, the installation of the appropriate equipment has enabled more direct communication with road users, reducing time and increasing efficiency and safety.

It is therefore essential in road management to have accurate information in real time to enable the right decisions to be made at the right time.

This system has also shown that, on occasions, the combination of various strategies or solutions already existing on the market is the best way to find the right solution.

5.4 COST

The cost of the installation of the automatic detour elements was part of the ITS equipment improvements in the area.

The cost of installing the detector beacons was part of the improvements to the maintenance of the area. The project for the installation of the detector beacons between KP 545+400 to KP 549+680 had a total cost of 873,127.15 euros.

6 FUTURE

The good performance of the system, and its proven effectiveness, makes it likely to be used on other roads with similar problems.

In the future, with the advance of vehicle-to-road communication technology, it will be possible to send information about road restrictions directly to the vehicles circulating in the area, as a complementary method to the communication to the user by means of the VMSs.

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