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CEDR Technical Report 2021-02

Wet Weather Driving Risks

CEDR Working Group Road Safety

March 2021

CEDR Working Group Road Safety: Wet Weather Driving Risks

CEDR Technical Report 2021-02 is an output from CEDR's Working Group Road Safety. The Working Group's main task is to provide NRAs with relevant input after analysing any new developments and policies on road safety with significant implications for road networks.

The Working Group consists of technical experts from Austria, Belgium (Flanders and Wallonia), Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland and UK (England, Northern Ireland and Scotland).

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1. Introduction

In January 2021, CEDR launched a survey on the different measures NRAs take to reduce wet weather driving risks. In more detail, NRAs were asked why these measures (if any) were chosen and whether there is evidence of how effective the measures have been. The exact questions of the survey were the following:

1.What specific measures are taken at a national level to reduce wet weather driving risks?
This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

2.Why was each specific measure chosen?

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.),
b. a lead performance indicator e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

Seventeen different NRAs participated in the survey and their answers can be found in the pages below. A summary of the findings was also developed and can be found below as well.

2. Country feedback

2.1 Austria

In general, and first it is the obligation to the drivers to choose the appropriate speed regarding the weather conditions by the Austrian Road Act. Within our road standards wet conditions are often the defining threshold (gradient, roughness, drainage, sight and stopping distance). Based on incident and accident statistic of existing roads there is a permanent assessment of wet related hotspots. In case of a hotspot, road authority and road operator are obliged to find improvements in a hierarchy-based methodology. The first one is to reduce the accident risk by roadworks and warning signs if there is a deficit and a short time solution (repairing of drainage, grinding, grooving of road surface, cleaning of the road…). Second, we take care on roadside to minimise the accident consequences or strengthen speed enforcement. If there is no short time possibility, a temporary reduction of the speed limit is necessary and long-term changes in the road design and drainage system is started (changing the drainage system, gradients of sections). The effect of measures is measured in the numbers of incidents and accidents related to the weather conditions, speed measurements before and after.

2.2 Belgium (Flanders and Wallonia)

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

- A prohibition on truck overtaking during wet weather on highways. For the moment we are developing a system to fine this with cameras
- Dynamic speed limits on some parts of our highways
- We put on the lights on our highways when there is bad weather at night to improve visibility
- Maintenance procedures aimed at improving the conditions of rainwater runoff from the road surface and increasing the roughness and porosity of the road surface

2.Why was each specific measure chosen?

Lowering risks, improving visibility etc.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.),
b. a lead performance indicator e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

No research

2.3 Cyprus

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

In Cyprus, no automated wet weather or icing conditions detection system is yet in place. However, there are a number of general measures, such as:

- Specifications for increased skid resistance in pavements
- Tackling locations where rainwater concentrations are increased, particularly in areas of superelevation transitions at longitudinal sag sections, through surveying of all national motorway networks
- Special signage for slippery surfaces
- In regards to the limited occurrence of snowy conditions (not on motorways but rather some mountainous roads), signage is changed manually to denote the use of snow chains as mandatory
- General provisions in the traffic code for reduction of speed under rainy conditions

New Project currently underway for the installation of VMS systems to warn drivers accordingly during wet weather.

2.Why was each specific measure chosen?

Cost of installation and maintenance, effectiveness and severity of risks.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.),
b. a lead performance indicator e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

There are no kpis in place.

2.4 Finland

1.The measures:

Already when planning and constructing a road the drainage as well in summer conditions as in wintertime snow and slush conditions is considered. Road maintenance measures include surface water drainage with ditches and piping.

One example of measures to minimize the wet surface is typically carried out in the spring by cutting down the snow slopes along the road, so that the water from smelting snow is not streaming to the carriageway.

Road paving every now and then (if not all the surface, at least the worst parts of driving tracks that gather water) helps to prevent to some extent aquaplaning. The pavement materials are developed further to give good friction but not more noise. For some weeks after the pavement measure the speed limits are lower due to the characteristics of the new material.

Finnish Road Traffic Act raises the importance of every road user to anticipate in traffic possible risks and behave him/herself so that the traffic flows fluently and safely: the speed and distance to other road users in relation to the road and weather conditions, visibility, load and quality of load and other circumstances. The driver has to be able to stop the vehicle within the visible part of the road in all predictable cases.

If there appear new slippery sites, warning sign will be used and if needed, also the speed limit will be changed lower.

A small part of the busy traffic roads is equipped with variable speed limits. They are operated by the road traffic centre personnel with the help of systems gathering information of road traffic and weather systems.

2.These measures are to provide a safer and fluent traffic. Variable speed limits are so expensive to use and maintain that their expansion will take time.

3.The measures needed are planned based on the information of pavement measurements, accident data and road user feedback. We are not aware of any new research findings to be given from Finland. We follow the research elsewhere, too.

2.5 Germany

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

In Germany, the “Guidelines for the design of Motorways” contain planning principles (methods, design elements, and equipment characteristics) for the construction of new motorways and for the reconstruction and improvement of existing motorways (e.g., the widening of the cross-section, re-alignment, redesign of junctions).

Included there is an own chapter about planning principles for the drainage of roads. In this chapter it is shown that Motorways should, where possible, be drained by means of surface drainage. This means that the surface water is shed towards the outside edge of the carriageway

over the verge and into shallow surface channels or the soil. In many cases, sub-surface drainage may be necessary, e.g., in situations where

- there is no permeable soil
- the motorway runs through a protected drinking water area that requires such drainage or
- the crossfall of a carriageway in curves leans to the central reserve

In such cases, the surface water at the edge of the paved width is shed into gutters and kerbs and then channelled into rain reservoirs via pipelines or drainage channels. Once in the rain reservoir, the water is filtered using oil separators and sediment traps and is emitted gradually to the discharge system. Alternatively, the water can be allowed to infiltrate the soil.

The “Guidelines for the Design of Motorways” give furthermore recommendations, how to avoid zones with insufficient drainage. These are solutions that could be realized by road design, construction or traffic rules including:

- increase of the longitudinal gradient
- open-pored layer (porous asphalt)
- constructional measures (gutter box)
- avoidance of a superelevation transition by applying a negative cross slope (constant cross slope of -2,5%) with large radii
- special form of a transition (rolling crown)
- speed limit at wet conditions

HERMANN (2008) determined that milling longitudinal grooves can also reduce water film thicknesses in zones with insufficient drainage. This method will be taken into account when updating the „Guidelines for the Design of Motorways“.

Also the „Guidelines for the Design of Rural Roads“ contain planning principles for the drainage of roads. In general all relevant measures to avoid zones with insufficient drainage that are integrated in the „Guidelines for the Design of Rural Roads“ are already listed above.

2.Why was each specific measure chosen?

The measures named above are selected to avoid zones with insufficient drainage. Speed limits at wet conditions are considered as a traffic law measure if no other technical solution is possible or as a short-term and time-limited measure. In the relevant areas the speed is limited to avoid aquaplaning. The traffic authorities determine the maximum permitted speed in wet conditions, often limiting it to 80 km/h.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.),
b. a lead performance indicator e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

a. LIPPOLD/RESSEL et al (2011) analysed among others the effectiveness of the special form of a transition, the “rolling crown“, and the negative cross slope.

For the measure “rolling crown” it can be stated that this measure shows a comparatively lower accident occurrence in wet conditions, whereas the standard transition have a noticeably high proportion of accidents on wet roads due to insufficient drainage in this area. When looking at the accident rates of accidents with personal injuries, the “rolling crown” proved to be safer compared to the standard transition that would lead to insufficient drainage.

The evaluation of accidents has shown that the road safety of radii with negative cross slope decreases with increasing speed. In general, however, such radii are just as safe over all speed ranges as the corresponding neighbouring sections, namely the same size curves in the opposite direction with positive cross slope. In curves with negative cross slopes, no noticeably higher accident occurrence can be detected compared to other road sections and other drainage solutions (via the road surface design). The existing accident occurrence is of the same order of magnitude as the basic accident occurrence on motorways. Compared to a standard transition in areas with insufficient drainage, road safety is higher when a negative cross slope is implemented.

LIPPOLD/RESSEL et al (2010) investigated the connection between the longitudinal gradient and the occurrence of accidents in transition areas of motorways. For this purpose, a total of 124 transitions were examined, which were divided into different transition classes. The accident rate and accident cost rate show that the highest accident cost rates occur at longitudinal gradients 1.0 % ≤ $|s|$ < 3.0 %. Thus, the expected high accident occurrence in the area of low longitudinal gradients 0.0 % ≤ $|s|$ < 1.0 % is not confirmed. They explain this with the longer flow paths that occur despite a faster discharge of the water at greater longitudinal slopes. This leads to an increase in water film thickness.

LIPPOLD/RESSEL et al (2010) were unable to establish a connection between the occurrence of accidents and the longitudinal gradient.

b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or

HARTZ/LÖHE (2008) investigated the connection between rain intensity and the speed of freely moving vehicles on motorways. For this purpose, the authors evaluated the speeds at nine cross-sections at different rain intensity levels.

It was examined that a mean speed of 156 km/h could be measured on a dry road at the left-hand lane. With light rain (0 mm/h to 5 mm/h) this was reduced by approx. 10 %, with medium rain (5 mm/h to 10 mm/h) by approx. 20 %. In the case of heavy rain with more than 10 mm/h, the drivers chose an average of 25 % lower speed than on dry roads.

For the same cross-sections, HARTZ/ LÖHE (2008) simulated the aquaplaning speeds as a function of the alignment, surface condition, tyre tread depth and rain intensity.

For four of the nine cross sections, the real measured speeds of the left-hand lane were higher than the calculated aquaplaning speeds of the left-hand lane, i.e. there is a risk of flotation in wet conditions. These four areas have cross-slope changes. The areas without floating risk were, except for one, outside of areas, where the crossfall passes through zero.

c. specific research into the use of the measures described in question (1).

LIPPOLD/RESSEL et al (2016) investigated and evaluated the different measures to avoid insufficient drainage regarding durability, dimension, construction and costs. The main aspects on the effectiveness of the measures are noticed below.

- increase of the longitudinal gradient: By significantly increasing the longitudinal gradient drainage is improved in most cases. In certain cases, a greater longitudinal gradient can have the opposite effect (e.g. in the case of very wide roads or if the longitudinal gradient is to high).

- avoidance of a superelevation transition by applying a negative cross slope with large radii: With sufficiently large radii (R ≥ 5,500 m) the negative cross slope is an effective measure to improve drainage. With a cross slope of - 2,5 % to the outside of the road, a cross slope of 2.5 % within a superelevation transition can be completely avoided. This ensures adequate drainage of the of the pavement for new and reconstructed/improved roads.

- special form of a transition (rolling crown): the rolling crown is an effective measure to reduce insufficient drainage, because in all areas there is a cross slope of ≥ 2,5 %. The disadvantage is the complex installation. Completely mechanized paving by machine is not possible, so that areas remain that have to be paved by hand. All in all, the rolling crown is an economical measure to improve drainage, both in new constructed as well as reconstructed/improved roads despite the complex installation, which is associated with higher installation costs.

- constructional measures (gutter box): Gutter boxes are an effective measure to increase drainage. Depending on the width of the road and the existing longitudinal gradient, several gutters may be necessary that have higher operational expenses, because they must be cleaned quarterly. In the case of two and three lane directional carriageways the installation of the gutters in asphalt and concrete construction is always economical for new and reconstructed/improved roads despite the high costs for the implementation and higher operational expenses.

- open-pored layer (porous asphalt): The drainage performance and the reduction of spray for the rear traffic are very good with open-pored asphalts. If the geometry of the roadway is unfavourable, water may leak onto the road surface (e.g. in troughs) as a result of water accumulating. Open-pored asphalt is economical despite the high costs for the pavement and higher operational expenses.

- Grooving: milling longitudinal grooves can also reduce water film thicknesses in zones with insufficient drainage. The process is comparatively cheap and thus an economical measure for improving drainage on existing roads.

- speed limit at wet conditions: If the restriction of the maximum permissible speed in wet conditions is respected by vehicle drivers, it is an effective measure for eliminating accident blackspots in areas with poor drainage. It can only be considered as a traffic law measure if no other technical solution is possible or as a short-term and time-limited measure. In the relevant areas the speed is limited to avoid aquaplaning. The traffic authorities determine the maximum permitted speed in wet conditions, often limiting it to 80 km/h.

2.6 Hungary

1.Specific measures are:

- additional marking with the sign A-30 (caution, danger)
- activating „speed limit" or „warning sign" on VMS (mostly on motorways)
- speed limit sign with additional sign „in wet weather conditions"
- additional protections with protective barriers on dangerous sections of the roads
- repair works on roadsides and embankments to improve drainage
- maintenance procedures aimed at improving the conditions of rainwater runoff from the road surface and increasing the roughness and porosity of the road surface
- wet weather traction improvement grooves" to reduce hydroplaning and skidding
- replacement of the surface on a dangerous section of the road
- bend correction with reconstruction

2.Which solutions we choose?

It depends on safety situation, road type, road conditions, traffic volume.

3.Is there evidence of how effective the measure has been?

We monitor the change in the accident situation and new interventions take place depending on it.

2.7 Iceland

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

First, it should be underlined that a huge emphasis is put on drainage in road design and when roads are maintained. Apart from that, until recently, the main measure was to put a sign to indicate that the friction was limited for some reason. However, it should be underlined that this sign is not used when friction is limited because of snow or ice on the surface.

Last summer (2020) a fatal accident occurred on a section of road no. 1 which had been resurfaced (with asphalt). In addition to the new asphalt, there had been rain showers. A head-on collision occurred between a motorcycle and a recreational vehicle. Two people, the driver of the motorcycle and his passenger, were killed. In this case something was wrong with the asphalt in question and it turned out to be necessary to exchange it. Following this tragic accident all working procedures regarding resurfacing with asphalt have been revised. In addition, new traffic signs will be introduced:

The orange-coloured sign indicates that the road surface has been renewed and that the friction is limited, especially under wet conditions. The blue speed sign shows the advisory speed. This orange-coloured sign will always be put up on road sections with new asphalt and the sign will not be taken down until the measured friction is in accordance with

requirements. The regulatory speed limit will only be lowered if something indicates that the circumstances are worse than in general on a new asphalt.

2.Why was each specific measure chosen?

Because of problems with friction on new asphalt, especially in wet weather. Following the tragic accident mentioned in 1 there are a lot of new requirements to contractors and surveillance bodies, such as accreditation. Also the requirements to the asphalt itself will be changed.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

a. No kpi have been defined yet.

b. As mentioned above, the use of advisory speed limit will be prevailing and the regulatory speed limit will only be lowered if the circumstances are worse than in general on a new asphalt.

c. No research yet.

2.8 Ireland

1.What specific measures are taken at a national level to reduce wet weather driving risks?
This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

- Retrofits: 120 sites were analysed for flat spots on the Motorways Network, of these sites 21 rolling crowns were installed. There have been few to no recorded wet weather collisions at any of the 21 sites since the retrofit programme. A cluster analysis revealed approximately six wet skid incidents per annum before intervention, and this reduced to zero over 3 years after intervention
- New Design Standard: A revised design standard was prepared to assist Designers in removing water off the carriageway, based on water depth, flow path lengths and minimum gradients. See chapter 11 in https://www.tiipublications.ie/library/DN-GEO-03031-11.pdf
- Speed Surveys: Recent research (using speed from traffic counters on the network) showed that, at a macro level, a consistent 8-10% of traffic on Motorways travelled at excessive speeds no matter what the weather conditions
- Warning: We have since then put-up VMS signs in areas susceptible to hail showers and have been working with the Weather Forecasters to determine methods to predict hail
- Adverts: The Road Safety Authority runs regular commercials reminding people to slow down in hail/snow weather during winter months
- Ave Speed Cameras: We are also looking at installing average speed cameras in sections where high speeds in rain have resulted in collisions
- Variable Speed Limits: We are also currently putting in place variable speed limits on the busier motorways to reduce speed limits in bad weather

2.Why was each specific measure chosen?

Answers above

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

- Retrofits: See Q1
- Speed Surveys: On going
- Warning: On-going
- Adverts: On-going
- Ave Speed Cameras: On-going
- Variable Speed Limits: On-going

2.9 Italy

1.What specific measures are taken at a national level to reduce wet weather driving risks?
This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

The main measures adopted are:

- VMS with warning messages and indication of speed limit (mainly on motorways);
- additional panels placed below the vertical warning sign to indicate a dangerous stretch of road in case of wet weather. This type of sign advises road users to reduce speed and increase their safety distance in the event of rain
- Speed limit sign with additional sign "in wet weather conditions", which reduces the speed limit of a specific section only in those particular weather conditions. To be consider that if it rains, the maximum speed limit mandatorily drops to 110 km/h on motorways and to 90 km/h on main extra-urban roads
- Regular maintenance of roadside verges and ditches to maintain efficient road drainage
- Use of draining pavement. Assessment of weather conditions and altitude are very important, as in areas with heavy snowfall and/or risk of ice, this type of pavement is not used

2.Why was each specific measure chosen?

Reduction in hydroplaning and skidding, interference with following vehicles and speed, thus reducing the risk of accidents.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

At the moment no specific KPI or studies are available to evaluate the effectiveness of these measures.

2.10 Luxembourg

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

On the highways, in general under rain conditions or other precipitations the maximal speed limitation is by law reduced to 110 km/h and visualised by text messages on the VMS. When there are very nasty weather conditions (storm, wind, snow, aquaplaning,) the Traffic Center may reduce the general speed limit to 90 km/h for safety reasons.

On secondary road sections with a speed limit of 110km/h (several 2+1 sections), by law the general speed limit is automatically reduced to 90 km/h under rain conditions or other precipitations. Normal signs indicate this measure on the road.

2.Why was each specific measure chosen?

In general to reduce accidents during bad weather conditions.

3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

There are no KPI's or any other assessment for these measures.

2.11 Lithuania

1.What specific measures are taken at a national level to reduce wet weather driving risks?

There are no special separate measures applied specifically for wet weather driving apart variable message signs system which will be introduced on the main two highways sections until 2022 and will cover 160 km of these roads.

2.Why was each specific measure chosen?

Variable message signs system has interoperability with road metrological stations network, in case of an appropriate weather and (or) road surface conditions metrological system will trigger VMS to reduce limited speed and (or) switch on the sign of a slippery road risk.

3.Is there evidence of how effective the measure has been?

System will be implemented as one of measures planed in the National Road Safety Plan (Vision Zero).

2.12 Netherlands

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

The most important measure that has been taken is by replacing the asphalt of the highways. The asphalt (zeer open asfalt beton (ZOAB)) that is in use now, can take up water and transport it underground to reduce amount of water that stays on the asphalt.

Now, double (2 layers) ZOAB is being introduced. That is a version of ZOAB that can take up even more water.

When the conditions are so bad that ZOAB is not enough to reduce the risks significantly, warnings of slippery road surfaces and reduced speed limits are used.

2.Why was each specific measure chosen?

The advantage of ZOAB is that it not only reduces the amount of water on the surface but it also reduces the amount of noise of the road.

3.Is there evidence of how effective the measure has been?

No recent research has been performed on the effects of ZOAB on traffic safety in wet driving conditions.

The reduced (perceived) risk thanks to ZOAB also leads to behavioural adaptation which can negate the effects of ZOAB.

2.13 Poland

1.What specific measures are taken at a national level to reduce wet weather driving risks?

General Directorate for National Roads and Motorways (GDDKiA) conducts activities consisting of monitoring the places on the roads where water stagnation occurs. The places of possible water stagnation on the roads supervised by the Directorate are monitored as a part of a current detours, as well as a part of a dedicated actions. In 2020, an analysis of dangerous places on the motorways and expressways was carried out, including the analysis of number of accidents on wet surfaces.

Moreover, in the winter conditions, current conditions on the road surface are also monitored by using a camera system and the so-called weather stations, which gives the road administrator information about the condition of the surface.

2.Why was each specific measure chosen?

Poland is a country located in the zone of humid continental climate, where, according to the measurements, there are about 150 rainy days per year. Due to the presence of wet surfaces, there is an increased risk of a car skidding. Therefore, it is necessary for the Directorate to conduct ongoing monitoring and take actions described in point 3.

3.Is there evidence of how effective the measure has been?

As a result of the analysis carried out in 2020, it was found that most of the motorways and expressways (supervised by the Directorate) do not suffer the problem of water stagnation, however, in a few cases remedial actions were introduced as a result of the observed increased accident rate on a wet surface. These were activities involved:

- replacement of the surface on a dangerous section of the road
- additional marking with the sign A-30 (caution, danger)
- repair works on roadsides and embankments to improve drainage
- additional protections with protective barriers on dangerous sections of the roads
- lowering the speed limit
- maintenance procedures aimed at improving the conditions of rainwater runoff from the road surface and increasing the roughness and porosity of the road surface

After performing the above-mentioned procedures, the number of road incidents in dangerous places is monitored on an ongoing basis.

2.14 Spain

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

At national level, no specific measures are taken, because Spain is not a particularly rainy country. However, in Spanish wetter areas, draining pavements are used.

On the other hand, it is not compulsory to reduce speed when it rains (there is no legal limitation). Speed reduction is only recommended using variable message signs. This usually happens on motorways/highways because there are not many rural road stretches with variable message signs.

2.Why was each specific measure chosen?

The selection of this kind of pavement is due to its main advantages:

- Reduced aquaplaning
- Less splashing, which improves the handling of vehicles behind.
- Less noise
- etc.

However, this kind of pavement requires maintenance actions in drier seasons to avoid clogging of the pores, such as cleaning with specific trucks with pressurized water equipment.

3.Is there evidence of how effective the measure has been? This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather; compliance with tyre safety rules achieving targets for drainage maintenance etc.) or
c. specific research into the use of the measures described in question (1).

No evidence or measure have been developed to define the effectiveness of these measures.

2.15 Sweden

To our knowledge, we have no specific measures taken. We have had some sections with variable speed limits trigged by weather. But we have not seen any real evaluation of this.

During winter, wet roads are rather the normal situation. We quickly looked at some statistics on fatal accidents during the last ten years. The distribution was like this on our roads (urban roads excluded)

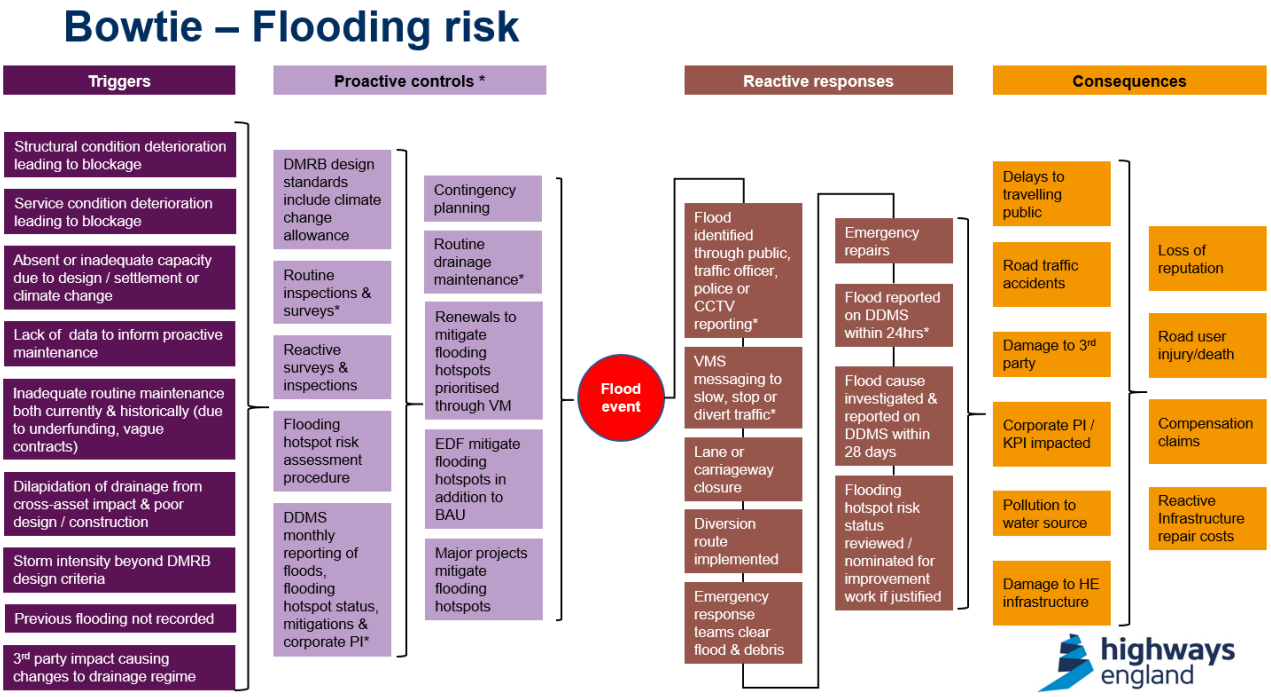
Snow	Wet	Dry	Unknown
15%	23%	59%	4%

2.16 United Kingdom

1.What specific measures are taken at a national level to reduce wet weather driving risks? This may be any measure and not just relating to highway infrastructure (e.g. reduced speed limits in wet weather).

Measures include those undertaken to manage the asset in wet weather conditions and those designed to influence driver behaviour both before and during wet weather.

Asset management interventions are described below:



Behavioural measures include:

- Wet weather driving awareness campaigns covering higher risk behaviours relating to choice of speed; use of cruise control; misuse of fog lights; close following/tailgating
- Enforcement campaigns targeting compliance with tyre regulations
- Use of our commercial vehicle, at-work drivers, and company networks to promote safer behaviours and improved tyre safety standards

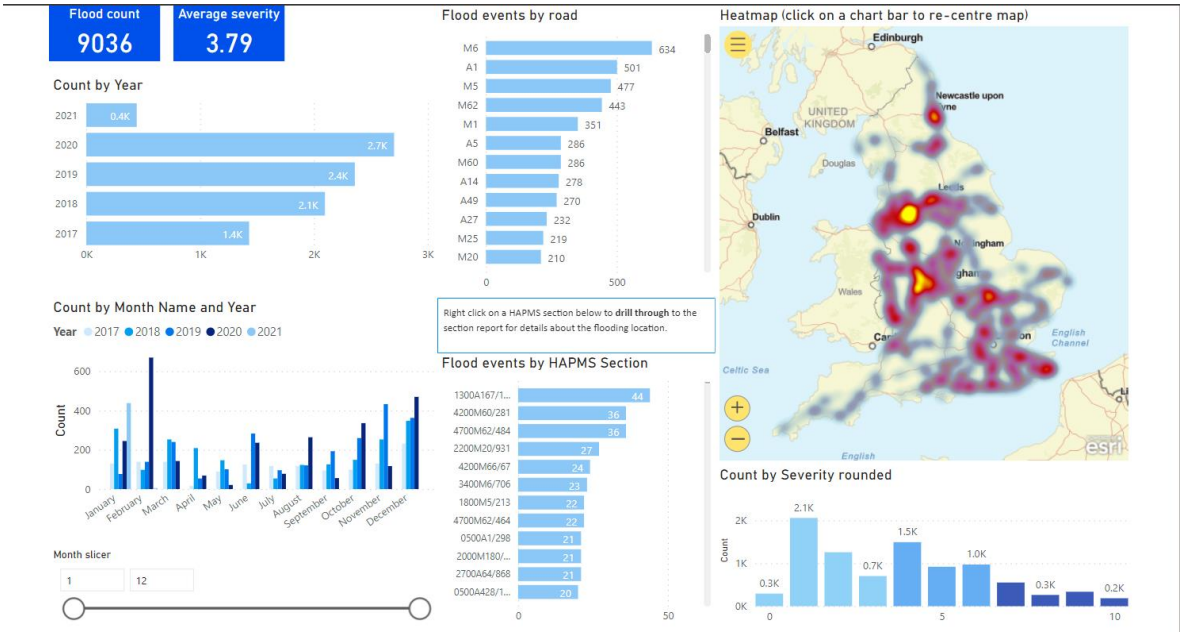
2.Why was each specific measure chosen?

Each intervention combines to reflect a Safe Systems approach, specifically the pillars of Safe Roads and Roadsides; Safe People; Safe Vehicles and Safe Speeds.

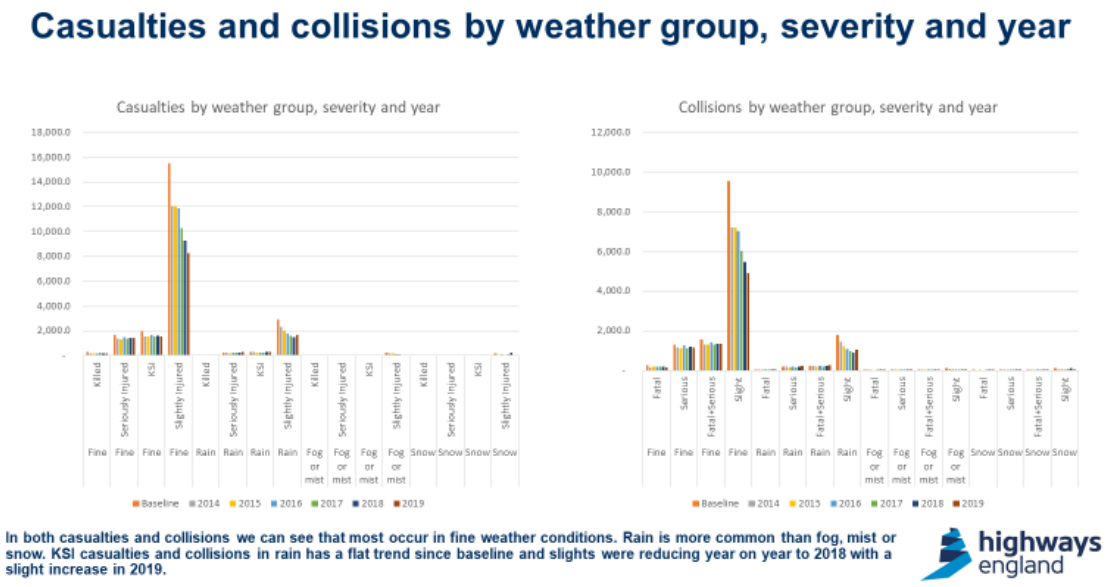
3.Is there evidence of how effective the measure has been?
This may be:
a. key performance indicator (e.g. serious or fatal injury reductions in wet weather, reductions in collisions involving slippery road surfaces etc.)
b. a lead performance indicator (e.g. compliance with reduced speed limits in wet weather;

compliance with tyre safety rules, achieving targets for drainage maintenance etc.) or c. specific research into the use of the measures described in question (1).

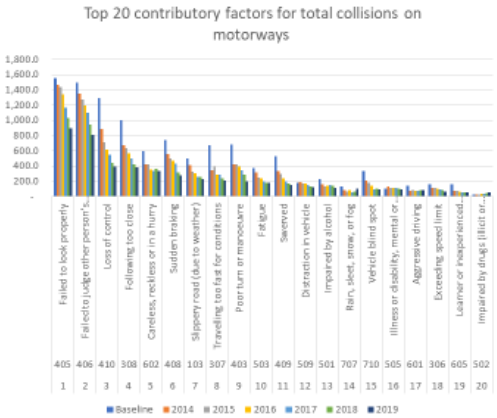
Performance and lead indicators are subject to continuous review. No specific KPIs exist for wet weather incidents but overall collision profile analysis includes tracking wet weather collisions and injuries, including identification of collision and flooding hotspots.

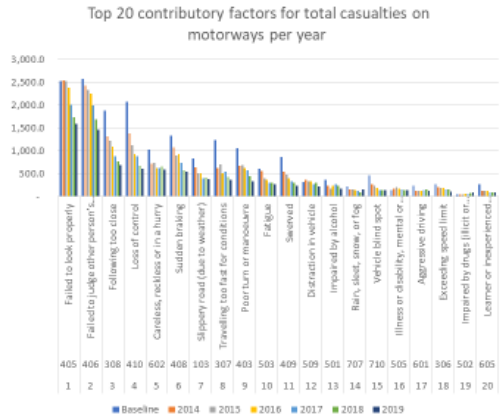


Routine collision data reviews inform the actions taken to mitigate wet weather risk.



Top 20 Contributory Factors (CF) for total collisions and casualties on motorways





In both casualties and collisions, slippery road (due to weather) was the number 7 contributory factor in 2019. The Police in completing the form don't confirm this was wet weather, it may have been ice or snow as this field covers all inclement weather events. This field has been consistently falling as a Contributory Factor (CF) since the baseline year. The number in the axis is the CF code and the lower number is the order of in the ranking from 1 to 20.

3. Summary of findings

The survey highlights the breadth of responses taken by NRAs when dealing with wet weather road risk. Responses range from no specific action through to carriageway re-design, pavement material improvements, restraint systems to mitigate collisions and warning and enforcement systems that support appropriate and expected changes in road user behaviour in wet conditions.

There is a clear link made between wet weather and the need for speed management, with wet weather interventions that range from passive signing to support expected changes in speed choice as mandated in national road codes; variable speed limits supported by VMS and enforcement; temporary speed restrictions and signing at high risk locations or scaled speed limits dependent on the severity of the circumstances and the type of highway.

Unsurprisingly there is also an emphasis on improved drainage – whether through improved and evidenced-based design or through proactive and reactive maintenance regimes. For some NRAs this includes introducing more efficient pavement materials to remove water from the carriageway.

Collision analysis is perhaps the most common evidence base for deciding if and what measures are required, with additional evidence for some NRAs provided by, for example, topographical surveys to identify flood risk areas. Primary research into the effectiveness of materials, design and wet weather collisions is also used in some cases though this may not be evident everywhere.

Reactive measures include ‘quick time’ responses to situations as they develop and ‘slow time’ through actions that are based on historical collision data. Proactive interventions range from removal of high-risk factors such as snow build up and drainage clearance, or linking VMS to advanced weather warning systems or weather stations.

Performance is most commonly tracked through collision data but there are few examples of performance indicators to track the effectiveness of interventions across whole networks. Further, whilst it is clear that in several cases multiple interventions are used to reduce wet weather risk there is limited evidence of research into what combinations of measures are most effective or cost efficient.

Where NRAs have noted their future ambitions to manage wet weather risk these have included the use of average speed camera systems for higher risk areas; additional rollout of VMS; linking VMS to advance weather warnings or road sensors; using camera technology to enforce wet weather violations and predicting specific high-risk weather events such as hail.

The emphasis on the connection between speed and wet weather risk is an example of where NRAs also acknowledge the responsibility of the road user in adapting their behaviour to wet weather conditions. In some cases, this is supported by communications, educational and enforcement initiatives to inform and encourage safer and more responsible behaviours in wet weather.

This brief survey illustrates the breadth of measures undertaken by NRAs, but additional and more detailed research would be needed to determine which measures – and importantly which combinations of measures – might be considered most effective and in which circumstances.

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