Guidebook for Enhancing Resilience of European Rail Transport in Extreme Weather Events
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The MOWE-IT project: The goal of the MOWE-IT project is to identify existing best practices and to develop methodologies to assist transport operators, authorities and transport system users to mitigate the impact of natural disasters and extreme weather phenomena on transport system performance. The project is funded by the European Commission’s 7th RTD framework programme between October 2012 and September 2014. MOWE-IT is co-ordinated by the Technical Research Centre Finland (VTT) and involves 12 European research institutes and companies. For more details please consult our website www.mowe-it.eu.

This document contains guidelines and recommendations for the improvement of resilience of rail operations in extreme weather conditions developed by the project team and reviewed by rail sector experts at the MOWE-IT rail workshop. Following an extensive review of previous projects on the impact of weather on rail operations including EWENT (www.ewent.vtt.fi) and WEATHER (www.weather-project.eu), case studies were identified in three broad weather categories; Heavy rain, wind and snow/winter conditions. Brief summaries of the case studies are given here (Section 1).

A number of recommendations and guidelines for the reduction of weather impacts on rail operations were synthesised from the experiences reported in the case studies. These are split into long-term planning and resilience building measures and actions which can be implemented before, during and after a given event. These include a range of actions including improving the resilience of physical infrastructure to specific weather conditions, learning from past events and dealing with affected passengers. Section 2 highlights recommendations that are specific to the three weather event types. Section 3 introduces broad recommendations that are applicable to most weather-related events.

Intended audience

This document addresses governments and the management and board of railway companies (infrastructure and transportation). It does not directly address working and operative staff of railways. The authors recognize that these individuals are doing a good job in case of extreme weather conditions and do their best on the basis of information and equipment they have in case of hazards. Looking at the recommendations in this guidebook three aspects have to be mentioned:

- Most of them are very well known by experienced people in the rail industry, especially operative staff on the track, the control centres and the workshops.
- Gaps, shortcomings and difficulties are often a result of bad preparation, lack of buffers, resources for preventive maintenance and the number of skilled staff among others. These deficiencies result from political and/or management decisions.
- Without skilled and motivated staff we still have in railway companies, impacts of hazards can become even worse, staff-balance short comings mentioned above and in the guidebook. Unfortunately the number and motivation of local working and operative staff is shrinking in most railway companies.

The recommendations and findings are results of the case studies and the experiences in extreme weather conditions the authors identified from desk research or having been involved is as railway passengers. They should be taken into account for strategic decisions and adopting the rail system for extreme weather events. Indeed, some of the guidelines and recommendations have already been established previously but have been forgotten, neglected or disestablished in the only economical design of railways.
Case studies

Heavy Rain

Saxony flooding 2002

This event saw widespread flooding across the region of Saxony. Dresden’s central railway station flooded and 20% of the rail network across Saxony was destroyed. Damage was estimated at €0.8 billion.

Alpine flooding 2005

Flooding across a number of countries including Switzerland, Austria, Romania and Germany. Many railway services had to be suspended as lines were undermined or destroyed by landslides and bridges were washed away. Total damage was estimated to cost around €2.7 billion in Austria and CHF 3 billion in Switzerland.

UK summer flooding 2007

This event saw widespread flooding across the UK during July 2007 as a result of heavy rain. Many passengers were stranded and there was widespread disruption across the rail network. The economic costs are estimated to have been around £36 million.

Intense convective storms, June 2012

An intense convective storm of the 28th of June 2012 caused flash flooding and infrastructure damage, closing sections of both the East and West Coast Mainlines, temporarily severing rail transport between England and Scotland.

Heavy flooding, Central Europe, June 2013

In June 2013 heavy rainfall in Austria, Czech Republic and Germany (Saxony, Saxony-Anhalt, Bavaria) led to flooding of rivers in the affected regions, particularly true the Elbe. The team used the event to follow in real time the developments in passenger transport, especially the performance of newly introduced real time passenger information systems.
Wind/Storm

**Storms Lothar and Martin, December 1999**

On 26 December 1999 wave interference from the area of sea south of Ireland developed under a very strong frontal zone into a cyclone. This cyclone was called Lothar. Maximum wind velocities of around 250 km/h were measured in Germany. In the Swiss lowlands maximum gusts of wind were measured with a speed of 140 km/h. The second storm, which was called Martin, hit the Western coast of France one day later. The wind speeds of Martin were not as fast as the wind speeds of Lothar but damage arose from rain and subsequent flooding and also from heavy snow fall.

**Windstorm Gudrun in Sweden, January 2005**

The windstorm Gudrun hit Sweden's west coast on January 8th having been intensified to hurricane levels - winds of 31 metres per second were noted. Southern and western Sweden suffered the most from the storm.

**Winter storm Kyrill over Western Europe, January 2007**

Winter storm Kyrill hit the United Kingdom, the Netherlands, Belgium, France, Germany, Poland and in minor intensity Austria, the Czech Republic, Denmark, Switzerland and Slovenia over the 18th and 19th of January 2007. The overall losses were estimated at EUR 7.7 billion. Because of the heavy wind velocities up to 212 km/h in Poland large sections of forests were heavily affected and hundreds of thousands of households suffered power cuts.

**Hurricane Sandy in North America, October 2012**

The storm developed in the Caribbean Sea and then travelled northwards, developed into a hurricane over the Atlantic Ocean and then moved in a westerly direction towards the United States and southern parts of Canada. Winds up to 130 km/h were measured during this event in some areas.

**Snow/winter conditions**

**Heavy winter conditions in Stockholm 2001–2002**

The weather conditions at the turn of the year 2001/2002 were exceptional in the Stockholm metropolitan area. According to the Swedish Meteorological and Hydrological Institute similar weather conditions occur about once every 15 years. Depending on the area the snow depth increased by 66-109 cm. Temperature stayed below zero during the whole period between December 19th and January 3rd and light powdery snow caused many problems.
Exceptionally hard winter conditions in Sweden 2009–2010

The winter of 2009–2010 was exceptionally cold in Sweden as well as in the other Nordic countries. The average temperature in southern Sweden was six degrees lower than the average of the previous 30–40 years. The average snowfall was not exceptionally high but due to the coldness the snow did not melt away.

Impact on winter conditions on Eurostar services, December 2009

Heavy snowfall in the Calais area on the evening of December 18th caused the closure of the Eurotunnel which lasted for four days. During the first evening of the heavy snowfall five trains failed inside the tunnel. This event caused direct disruption to the traffic between the cities of London, Paris and Brussels.

Exceptionally hard winter in Southern Finland, 2009–2010

The winter of 2009–2010 was exceptionally hard in Southern Finland. The continuous period of freezing weather began on December 30th and lasted for 60 days. Because of low temperatures and light powdery snow the ground frost lasted until June in many parts of the country.

Winter 2009–2010 in Europe

All parts of Europe were affected by the bad weather conditions during the winter of 2009–2010. The first incidents began in mid-December, but impacts of this extraordinarily strong winter (heavy snowfalls and very cold temperatures) occurred until April in some locations.
Weather-specific guidelines and recommendations

Heavy Rain

Before - Preparations for a heavy rain event tend to vary by location. In Saxony, few preparations were made ahead of the 2002 event, and as a result there were few strategies in place to deal with the effects of rainfall as the event went on. However, in New York for example the effects of Hurricane Sandy were pre-empted and as a result, the appropriate measures were put in place to minimise the damage caused to the rail network. Although the subway system was flooded, all traffic was interrupted before the storm and trains remained in depots for the duration meaning that no wagons were damaged and no injuries were incurred on the subway system.

A key determining factor in the level of preparedness appears to be the history of past experience of relevant conditions. For example, it was observed during the Alpine flooding of 2005 that Southern Bavaria was more prepared than other regions because of prior experience with the Whitsun flooding incidents of 1999. This included technical measures put in place for flood protection in the intervening period.

(Long-term preparation)

- Have flood response plans in place - prioritise use of limited resources during flood events
- Use improved flood prediction models incorporating better weather forecasts and much more detailed information on topography, infrastructure, geology and hydrology
- Enhance flood resilience of infrastructure where necessary or provide movable flooding walls. Work together with local authorities to have general local flood defence. Use inflatable dams
- Improve and maintain drainage network along the rail network
- Clean drainage especially after autumn (in Essen there was flooding on the roads in November 2010 after some days normal rain due to clogged drainage by leaves)
- Incorporate climate change projections into the design of drainage to cope with predicted future flooding frequency and magnitude
- Consider infrastructure interdependencies. This especially applies to ensuring energy supply
- Explore relocation of important infrastructure to higher elevations and areas of lower flood risk
- Develop tailored plans for flash flooding and seasonal flooding

(Immediately before event)

- Flood warnings should be given in plenty of time
- Monitor drainage and solve problems quickly
- Deploy trouble shooting teams (drainage, bank repair teams)
- Install flood protection walls or inflatable walls
- Prepare water pumps for affected areas
- Interrupt operations before events occur

During - A number of responses to heavy rain and flooding are implemented during an event, often the response implemented depends on the nature and extent of flooding, as well as the measures which may or may not have been put in place prior to the rainfall. As would be expected, a common response is to remove any accumulating debris from tracks to enable trains to run once flood water across the track has subsided.
Where there is little preparation for a wide scale event, such as the floods in Saxony in 2002, more extreme responses are needed, particularly where an emergency is declared. The German Army provided 40 000 soldiers to assist following the floods - these were soldiers who had previous experience of dealing with the effects of adverse weather phenomena and could therefore help immediately. The use of inflatable dams to contain flood water is a new response being used by Network Rail. It was used for the first time in south west England in December 2012 to contain flooding at Cowley Bridge near Tiverton. The dams were successful in holding back water and preventing even more damage to the railway tracks following extensive damage to both tracks and the ballast beneath which had been washed away by floodwater.

When travellers’ journeys are disrupted due to closure of railway lines during heavy rain events, alternative transport has to be found for passengers, be it replacement bus services or taxis. Of course, where there is also disruption on the road network then it is not possible to arrange alternative transport and passengers may be stranded as a result.

- Quick responses are essential to limit further damage – having flood response plans in place helps to facilitate this
- Reduce speed limits or stop trains in flooded areas where appropriate
- Clear tracks of any accumulated debris
- Personnel – having extra personnel on standby to help with additional duties during a flood event or to replace crews displaced by delayed/cancelled trains

After - Following heavy rainfall events, practices are often implemented to ensure that infrastructure is able to withstand a similar event in future. Infrastructure is often repaired to the same specification as before the event or modified to meet a higher specification. Track drainage is often surveyed following a flooding event to ensure there are no blockages which may impede drainage during future rainfall events. Where lines have to be reconstructed, priority tends to be given to long-distance railways first and then to local networks with repairs to stations and remaining infrastructure being of the lowest priority.

Repair work can take months and even years. For example, following the Alpine flooding in 2005, access to Engelberg was only restored once a new railway bridge had been built 5 months after the initial flooding occurred. A common response following a heavy rainfall event is to carry out further asset assessment. This identifies any damage to assets, repairs which need to be carried out and also where improvements may be needed to ensure that the infrastructure can withstand any future heavy rain events. Europe wide, there are a number of responses to flooding events which not only allow the network to begin operating again following a flooding event but also seek to reduce the risk of flooding during future events.

- Where repairs and reconstruction are carried out, damaged infrastructure should be upgraded to improve resilience to future flood events.
- Survey track drainage - identify and remove any blockages which may impede drainage in future.
- Implement flood control measures to protect tracks.
- Reinforce embankments which are particularly susceptible to landslides (construction of hillside fixing)
- Consider line relocations where tracks are particularly susceptible to flooding
- Construction of further sub surface drains in areas where flooding is a persistent problem.
Wind / Storm

Before – Prior to such events collaboration should be made with weather services in order to assess the weather situation and to initiate the proper operations beforehand. This is confirmed by the fact that the storm Kyrill was predicted a few days in advance. This led to the result that citizens prepared by using trains beforehand or by cancelling their travel plans. This was a good measure to prevent further disruption. Since predictions for extreme weather events like Kyrill are very important, the Austrian Federal Railways implemented a meteorological information and warning system. The requirements for such a system differ from existing official and private forecasts and meteorological information systems. In Sweden severe weather scenarios were already rehearsed beforehand so that the crisis management activities could be realised effectively. In Germany on the other hand there were only a few actions of management beforehand and during Kyrill. In most of the cases the affected companies were waiting until the storm set in and reacted during the event. Some literature indicates that during previous events the clearance of the tracks of hazardous trees and shrubbery was wider and thus more effective. The reason for the wider clearance was the higher risk of fire coming from steam engines. This reduced timber fall on rail tracks and catenary. Either way, it is important to keep the areas along the tracks clear from hazardous vegetation.

(Long-term preparation)

- Have wind response strategy in place - resources should be put in place before the events occur
- Use improved wind prediction models - wind warnings should be given as soon as possible
- Keep the areas close to tracks clear of vegetation and dangerous objects that may be blown around
- Improve the resilience of catenary masts, the tracks and station buildings
- Strategies for cutting departures and reducing passenger capacity should be put in place (special timetables, rerouting models)
- Train personnel (and subcontractors) to understand the specifics of clean-up and repair-works after heavy wind-events (during the clean-up works following the windstorm Kyrill there were several fatalities)
- Design a risk-based approach for speed restrictions and line closures

(Immediately before event)

- Interrupt operations before events occur and be prepared for this interruption
- Check the affected areas close to tracks and keep them clear of vegetation and dangerous objects that may be blown around
- Advance preparations for dealing with predicted impacts of wind event should be discussed (identification of persons/groups to coordinate the work, identification of critical locations, deployment of subcontractors, ensure the availability necessary resources like cranes, chain saws etc.)
- Deploy diesel engines in the areas likely to be most affected in the case of disruption to electrical equipment

During- One of the strategies used during storm Kyrill was the imposition of speed reductions to 160 km/h for long-distance trains and to 140 km/h for short-distance trains. Furthermore there were several railway sections closed due to timber fall and damaged catenaries. Later on nearly all railway traffic was cancelled. The decision was made after an intercity train was struck by an uprooted tree. Only a few corridors of the Deutsche Bahn-network were served. These decisions were all individual. Additionally some private companies still operated. In the Netherlands there also was a complete halt to operations at 20:00.
Immediately after storm Gudrun had reached Sweden in 2005, regional special crisis management and executive groups were activated both in the south and west. These groups consisted of chiefs responsible for different sectors (material service, production, information) at the Swedish Rail Administration. This type of group could provide the required speed and proactive response in decision-making. The most important task for groups was to create an operating strategy and operating plan. Furthermore, groups took care of communications, creating a general view of the event as well as assigning personnel and resources. They also determined priorities for measurements in the railway network in cooperation with other operational actors.

In addition to regional crisis management and executive groups, a national leading group was set up at the head office of the Swedish Rail Administration. The national leading group decided that during the crisis, freight traffic was prioritised at the expense of passenger traffic. In general, in order to get the rail traffic to operate properly again, large repair works were implemented. All workers were primed for their duties in special conditions in order to avoid accidents. Due to power and communications disruption, some railway sections and grade crossings were guarded by special road guards. Furthermore, diesel trains were used so that the most important goods could be delivered. On some railway sections freight traffic was operated on special terms during the traffic cancellations. Because organisations had practised crisis management in advance, they could manage the event relatively well. In addition, persons belonging to crisis management and leading groups were used to working together and it didn’t take long to activate the operation of groups. Some additional resources were supplied even before the storm.

In some cases it was hard to put compensatory power stations and generators into use because it was not properly noted where these stations and generators were located. Some of the actions took too much time due to safety regulations because some of works are only allowed to be executed while there is a connection to the control centre. Because of the lack of power supply and thus communication connections were often discontinued so the repair works could not be executed. This has to be handled in a different way in future events.

In the future it should be possible to get a quick overview over the impacts of the event with the use of special software in order to issue instructions directly. Beforehand the process of “carrying together” all the damages took too much time. Additionally there were several differences concerning the quality of information. In these weather situations airplanes and helicopters should be used to get a quick overview of the impacts if it is safe to do so.

It is also necessary to establish certain criteria, when the use of a corridor should be cancelled or when certain measures should be taken into action beforehand. Additional criteria are needed when the cancellation should be revoked. It is also possible to ensure the transport of essential goods. During such an event the communication is very important and passenger information has to work. All participants should be trained beforehand and it is also possible to use the help of external coordinators.

- Ensure that the tracks are free of foreign obstacles
- Have additional personnel on standby to help with additional duties during a heavy wind event or to replace crews displaced by delayed/cancelled trains and to take care of passengers
- Reduce speed limits and cancel traffic where appropriate
- Use special timetables where traffic on lines needs to be reduced
- Keep trains inside the depot overnight

After – During the event it is necessary to get an overview of the damage. Following the overview of the extent of damage it has to be decided how the damage can be fixed and how much time these repair works require. Resources need to be classified and arranged. Additionally it might be necessary to install replacement schedules with differing departing times, delays and redirections.
and it also might be necessary to implement rail replacement services. It also is important to keep passengers informed about replacement schedules and about the schedules of rail-replacement services. Customers of rail freight also have to be informed about changes to schedules.

- Return to normal schedule as soon as possible
- Where repairs and reconstruction are carried out, damaged infrastructure should be upgraded to improve resilience to future wind events
- Regular clearing of vegetation along tracks
- Identification of critical locations
- Update of plans and strategies in light of lessons learned

**Snow/winter conditions**

**Before** - Based on the case studies the preparations for the heavy winter conditions tended to be ineffective in many ways. In Sweden (at the end of 2001) the railway organisations had raised their level of preparedness due to the received meteorological information but there was still not enough maintenance personnel, machines and equipment for snow and ice removal. In the Channel Tunnel the potential for condensation had been reduced by modifying the design and positioning of circuits and by ensuring a common bloc is warmer when entering the tunnel to reduce thermal shock. No other preparations were directly indicated in the case studies. In turn, it was mentioned in the Swedish case study (2001–2002) that preventative maintenance had been neglected during the previous years.

(\textit{Long-term preparation})

- Increased preventative maintenance (critical switches, pantographs and carbon strips, outdoor signalling equipment)
- Install snow covers of switches
- Install switch heaters
- Build of snow barriers
- Keep culverts and ditches open to keep the track areas and embankments dry to prevent damaged due to ground frost
- Train personnel and subcontractors to understand the specifics of winter operations
- Ensure the availability of spare parts, additional cables and other materials which are known to break in hard winter conditions
- Obtain snow and ice melting equipment and investigate of options to modify the rolling stock to prevent snow and ice accumulation on undercarriages
- Specify and test new infrastructure (especially switches) to resist winter conditions or avoid snow build-up.
- Focus winter-proofing/snow-proofing in key areas

(\textit{Immediately before event})

- Ensure that the track profile is free of foreign obstacles (no braches of bushes covered with snow hanging low and avoidance of ice formation at tunnel entrances)
- Increase defrosting capacity (increased depot space), and cover of the most important railway yards
- Deploy reaction teams and equipment (engines, rotary snow ploughs)
- Deliver spare parts, cables and engines to local critical areas
- Prepare rolling stock and infrastructure for snow and cold weather (e.g. heating, removal of ice and snow)
**During** - During the heavy winter conditions the focus was on snow removal to keep the tracks and switches operational (with and without machines), to keep the rolling stock in operational condition and to repair the damaged track areas (caused by ground frost) by supports. It had been identified both in Finland and in Sweden that the cooperation between the different operational actors did not work well enough. The actions were put in place too late and the snow removal took too long. It was also identified that the subcontractors’ resources for snow removal were inadequate. Several problems in gathering and sharing information to passengers, between operators, and to the general population were also identified. The passengers were either helped to reach their station of origin or destination. In some cases this was done by buses when not enough trains were available in reserve. In Finland, special timetables with fewer trains were taken into use.

- Manual cleaning of switches (brushes, spades, blowers, excavators)
- Remove snow (snow blowing machines, snow blow trains, by hand)
- Keep trains inside the depot overnight or cover sensitive parts (couplings, pantographs, switches)
- Heating of trains through the night
- In areas using third rail electrical systems keep trains moving across track overnight to reduce ice build-up
- Resistive heating of OLE to reduce ice build-up
- Take measures to keep platforms free of snow and ice

**After** - Several recommendations that were identified to ensure better preparedness of railway organisations to upcoming heavy winter conditions. Following the Channel Tunnel event the recommendations were divided into three broad categories which were (i) increasing train reliability, (ii) establishment and regular updating of evacuation and response plans and (iii) improved communication and management of the situation.

Several recommendations that resulted from the other case studies fit into these same categories. In Finland it was emphasised that the cooperation between different actors needs to be improved and the management procedures need to be made systematic and documented. Therefore, the establishment of new working groups to improve the cooperation between the different actors participating in operative traffic management was recommended. The aim was to provide speed and proactiveness in decision-making. In Sweden it was recognised that the cooperation between traffic control centres was challenging since technical systems for controlling railway traffic varies in every traffic control centre and thus improvements are needed. It was also emphasised in Sweden that practical training should be organised so that every actor knows how to carry out the work in extreme situations.

There were also several recommendations concerning the need for additional resources (personnel, machines, equipment). The need for new glycol based snow and ice melting equipment and new switch-heating systems was identified (Finland and Sweden) with special attention paid to the most critical points in the railway network. More attention should also be put to preventative maintenance (maintenance processes will be made systematic and be documented) and on the availability of additional (competent) resources for the snow removal.

- Identification of critical locations
- Update plans and strategies in light of lessons learned
- Elimination of the worst bottle necks such as single-track sections
# General recommendations and guidelines

Table 1: General recommendations and guidelines for managing the impacts of extreme weather events on rail transport

<table>
<thead>
<tr>
<th>Area</th>
<th>Long-term preparation</th>
<th>Event management</th>
</tr>
</thead>
</table>
| **Weather forecast** | • Cooperate with weather forecast providers  
• Install local weather forecasting systems where needed  
• Establish meteorological thresholds and triggers for actions and refer to asset condition databases for local adjustments | • Use weather forecasting systems to determine areas likely to be most heavily impacted and deploy equipment, staff and prepare vehicles accordingly |
| **Vehicles**  | • Assess vulnerabilities of vehicles to specific weather types observed during previous events  
• Adapt vehicles and enhance resilience | • Fit vehicles with extra equipment appropriate for weather (e.g. snow ploughs)  
• Heat/cool/clean/cover vehicles to ensure they are in operational condition  
• Check vehicles for weather-related issues (e.g. frozen couplings, bogies and doors) |
| **Infrastructure** | • Assess weather-related infrastructure problems identified during previous events  
• Maintain asset condition database and integrate with weather forecasts  
• Install redundancy and emergency capacity (pass-by trucks, switches, operation on opposite lane)  
• Keep areas close to tracks and catenaries free from hazardous objects and vegetation | • Check infrastructure for potential failures (e.g. blocked drainage, frozen switches, unsecured items)  
• Prepare infrastructure and carry out emergency maintenance (e.g. blocked drainage)  
• Deploy teams to observe vulnerable infrastructure (e.g. catenary, drainage, track)  
• Clear track of debris and other objects blocking the tracks or damaging the catenary |
| **Equipment** | • Plan which equipment is needed for local hazards (e.g. pumps, deicing machines, rotary snow ploughs, movable dams, cranes)  
• Check the availability of equipment and spare parts and plan storage  
• Provide logistic plans to deploy equipment and spare parts in case of hazards  
• Ensure the availability of diesel engines as replacement traction and provide contracts for use in emergencies | • Check the availability and functionality of equipment  
• Concentrate equipment and staff in the most affected areas  
• Deliver spare parts where needed  
• Deploy diesel engines and drivers in case of damage to electrical system |
| **Operations** | • Prepare emergency plans and general time tables (for rerouting, early turn around, reduced speeds)  
• Provide information for staff in case of emergency  
• Plan bus replacement strategies (stations, train the drivers, provide framework contracts). Replacement by bus should be well thought through as this has been a previous problem. | • Impose emergency speed restrictions  
• Establish special time tables if necessary  
• Interrupt or halt operations if necessary  
• Provide replacement services if needed |
<p>| <strong>Information</strong> | • Prepare information systems for passengers and clients (online but also locally such as displaying emergency time | • Provide real-time information to passengers (e.g. internet, mobile data and traditional formats such as |</p>
<table>
<thead>
<tr>
<th>Area</th>
<th>Long-term preparation</th>
<th>Event management</th>
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<tbody>
<tr>
<td></td>
<td>• Integration of different types of asset-monitoring databases</td>
<td>• Maintain communication with important institutions</td>
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<td></td>
<td>• Raise awareness of adaptation to climate change</td>
<td>• Keep staff informed so updates can be relayed to passengers</td>
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<td></td>
<td>• Establish greater regional and international exchange of good practice</td>
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<tr>
<td>Cooperation</td>
<td>• Plan and prepare emergencies with fire brigade and other emergency services</td>
<td>• Cooperate with local emergency services</td>
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<td></td>
<td>• Develop hazard, vulnerability and risk mapping in cooperation with weather services</td>
<td>• Install common control and steering centres including rail and emergency services</td>
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<td></td>
<td>• Foster cooperation among undertakings and institutions</td>
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<td></td>
<td>• Foster vertical and horizontal cooperation of public and private bodies</td>
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<tr>
<td>Staff</td>
<td>• Train for trouble shooting and information provision in case of events and in abnormal operation</td>
<td>• Prepare emergency teams</td>
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<td>• Build local trouble shooting teams with defined responsibilities</td>
<td>• Deploy staff to locations of the event, depending on expertise needed</td>
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<td>• Practice emergency plans for severe weather (this should involve emergency repair work)</td>
<td>• Deploy specialised staff for repair and for handling of special equipment</td>
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<td>• Organise joint training exercises with local emergency services</td>
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<td></td>
<td>• Identification of persons/groups to coordinate the work</td>
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<td>Legislation</td>
<td>• Prepare and agree with local or national governments priorities and minimum service standards which should operate as long as possible and to be reintroduced as soon as possible (freight or passenger, local or long distance, try to operate one train per hour (skip the other trains etc)</td>
<td>• Keep in contact with the authorities and agree the actions on the basis of the agreements made</td>
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<td>• Make agreements about the cost coverage of preparative actions, extra buffers and improved resilience</td>
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**Actions to be taken following event**

- Return to normal operation
- Assess damage to infrastructure, vehicles and buildings
- Assess effectiveness of response
- Adapt / enhance according to lessons learned
The MOWE-IT series of guidebooks:

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