REPORT

Urban rail, climate change and resilience

A joint report by the Metro Committee, the Light Rail Committee and the Regional and Suburban Railways Committee
Climate change and urban rail

Report - December 2016

1. Introduction

An efficient and reliable rail transport system is essential for the cities, society, employment and leisure. Climate change is predicted to increase the frequency and severity of such harsh weather events and the scope of gradual “slow” changes. The conjunction of mobility growth and increased climate change hazard can potentially lead to severe disruption of no less than most human activities.

Currently, transport systems across the globe struggle to cope with extreme weather events that affect operation and in most cases damage assets.

In addition, unlike extreme weather events, gradual climate changes can go unnoticed but still have effect on the durability and functioning of rail infrastructure, like steady increases in temperature, sunshine (UV exposure), seawater-level and changing groundwater-levels.

Despite all efforts made on climate change mitigation through the adoption of low carbon technologies, urban rail infrastructure will be significantly impacted, affecting the way that the industry/sector plan, design, construct, operate and maintain its assets in the future. This report aims to determine how rail infrastructure shall adapt to the inevitable changes.

The goal of the working group is to identify the vulnerability spots of urban rail systems and to develop a check list of areas to look at and defense measures to be recommended on:

- **Immediate term**: define preparation and preparedness strategies and measures related to People, Processes and Products
- **Short term**: restore operation after damage have been made, disruption minimization
- **Medium-term**: protect / retrofit existing assets against weather damages

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1 Climate change was substituted to previous title “harsh weather events” because gradual change can go unnoticed and have effect on the durability and functioning of infrastructure.
In 2011, UIC commissioned IZT-Institute of future studies and technology assessment, Berlin to prepare a report on “adaption of railway infrastructure to climate change”. The report can be summarized in block diagram shown in the figure below. It suggests managing data bases for current weather related warnings, past extreme weather events, weather forecast reports and railway assets with their respective conditions. These data bases help in identifying future extreme weather events due to climate change and railway infrastructure vulnerable to these weather events. Hence operator can make plan for risk management and priority list for infrastructure to take adaption measures.
Rather than a long theoretical dissertation on the subject, the purpose of this report is to focus on concrete measures (last block of the block diagram mentioned in the above paragraph) that have been implemented among rail companies affiliated to UITP, many of which have been confronted with major climate change related disruption and damages in the last 10-15 years. A survey was designed to gather information about potential impacts on different subsystems of rail infrastructure, possible measures to avoid disastrous effect in future and measures to restore systems to normal quickly in case of damage. Following companies responded to our survey by pointing out potential hazards and measures based on their experience of handling such situations and common practices.

- Wiener Linien (Austria)
- Metro Rio (Brazil)
- Santiago Metro (Chilli)
- RATP (France)
- Hamburger Hochbahn (Germany)
- Stuttgarter Straßenbahnen AG (Germany)
- Stadtwerke Verkehrsgesellschaft Frankfurt (Germany)
- MTR (Hong Kong)
- Budapesti Közlekedési Vállalat; Budapest (Hungary)
- Agenzia del trasporto autoferrotranviario del Comune di Roma (Italy)
- Mexico Metro
- Metro de Porto (Portugal)
- Moscow Metro (Russia)
- Ferrocarrils de la Generalitat de Catalunya (Spain)
- Network Rail (United Kingdom)

The report consists of:

- Section 2: General preparation and preparedness recommendations prior to any event
- Section 3: list of restoration and protective measures broken down by railway sub-systems:
✓ Power supply
✓ Stabling and maintenance facilities
✓ Stations and interchanges
✓ Tunnels, structures and tracks
✓ Control-command / signaling
✓ Rolling stock
✓ Level crossings

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2. Generic preparation and preparedness recommendations

This section covers general preparation and preparedness recommendations prior to any event. The measures are listed according to the type of stakeholders’ involvement and cooperation required:

  a) Operator internal measures
  b) Actions with weather agencies
  c) Actions requiring cooperation with emergency services

2.1 Operator internal measures

- Hire an adequate insurance coverage for hazard events.
- Emergency chain of command and communication process. Establishment of an alert/crisis committee in order to plan the actions to be implemented, assigning responsibilities and duties, and ensure that all internal and external resources are located in the appropriate places with the scheduled personnel brigade, vehicles, and equipment ready for action.
- Establish criteria for declaration of emergency state (suggested by RGI webinar as well). Format a process and defined conditions to declare emergency. (Hong Kong has defined signals for different weather conditions http://www.hko.gov.hk/publica/gen_pub/tcws.pdf).
- Link/combine/synergy between regular maintenance work with additional factors and measures to increase climate change resilience
- Avoid over-prescriptive set of measure / SOP in order not to stifle innovation
- Organization of effective and quick response services, procurement of devices needed for quick damage elimination.
- In case of extreme events, adopt “Fix & Fortify” approach
- Put in additional maintenance efforts and operational measures by deploying more skilled staff and equipment to prevent railway service interruptions in a proactive manner (such as increased inspection and application of temporary speed restriction, special time tables)
- Implement a communication plan for times of transport disruption for passengers and stakeholders, a tailored plan using the same channels customers use, social media and operator’s website/apps, with provision of real-time, true and realistic info, suitable to each moment during the different phases of the event. Keep staff informed so updates can be relayed to customers.
- Follow the Deming’s wheel approach. (plan, do, check, act) to learn and constantly improve from rehearsal and past incidents
- Check the availability of equipment and spare parts and plan storage.
- Procure pumping equipments in sufficient quantity.
- Stockpile sand bags in sufficient quantity, concrete blocks, wooden beams and aluminum thick boards for endangered areas.
- Explore new and cost-effective technologies that address our concerns about adverse weather impacting railway service
- Keeping abreast of latest design standards and evaluate whether short-to-medium measures need to be applied to improve asset conditions. Similarly, check such design standards of asset especially those related to asset resilience against extreme weather (e.g. surge and lighting protection) and adopt the latest standards as long as practical. Take opportunities of asset replacement to adopt more stringent design in anticipation of extreme weather conditions.
- Operation and maintenance staff should follow procedures and be well trained to cope with common extreme weather conditions (e.g. typhoons and heavy rain)
- Availability of extra staff on standby to help in case of an event, no matter if predicted or not.
- Training of operational staff for damage prevention and damage elimination

**Worth remembering, and studying deeper...**

A specific and very critical aspects of management of harsh weather situation for public transport companies is the **Human Resource factors**. While medium and long term actions listed in this report are (more) easily planned and procured, immediate and short term actions linked to crisis management mode of operation are critical and need to be tackled and prepare properly, including with workers representative organisations:

- Access to or egress from job sites
- Preparation and training of crisis procedures
- Longer working hours
-...
When rail systems are partly or fully disrupted or even out-of-service, the issue of minimal **substitution services** arises. Multimodal transport companies are better off than rail only operators; indeed, they have a fleet of road vehicles that can be used and dispatched to serve the main areas along the disrupted line. In such crisis situations, planned preventive maintenance schedule are postponed in order to free the largest possible fleet. Even school or museum buses can be exceptionally reverted to in order to maximize the substitution transport capacity and relieved stranded customers. Mono-modal rail companies face the lack of internal substitution transport and depend of the availability of third party resource. This should be planned and contractually agreed in advance.

### 2.2 Actions with weather agencies

- Vulnerable spot mapping by cooperating with weather forecast providers or by purchasing detailed weather reports. Need to have clearly agreed channels for receiving weather forecast and alerts, monitored in real-time during periods when extreme weather is expected.
- Use past weather trends and forward looking information for making policies.
- New development and planning must include climate dynamics
- Holistic review existing contingency and risk management plans to enhancing resilience of railway operations under adverse weather conditions by assessing weather-related vulnerabilities observed during previous events, developing hazard, vulnerability and risk mapping in cooperation with weather services. Ensure policy compliance in risk governance issues: forecasting, planning, operation, prevention (vulnerability and impact assessments, performance procedures, and frequent drills), response and recovery, and adaptation actions. (Hong Kong has set up a division level working group to monitor and review status of these measures).
2.3 **Actions with emergency services.**

- Organize (via UITP?) a fast response rescuing inventory to provide equipment, expertise and staff to companies affected.
- Implement joined-up contingency plan, cooperating with local emergency services, keep good communication to share information and to ensure that actions are according to agreed plan.
- Lay urban rain water drainage and sewage maps over public transport infrastructure maps to identify vulnerable spots.

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**Transport for London Report** *(Providing Transport Services Resilient to Extreme Weather and Climate Change, 2015)*

In 2012, TfL carried out UK’s first climate change risk assessment which gives details of 100 potential impacts of climate change. A brief summary of potential climate risks and its potential effect on specific part of the system is given on the left side of figure below. On the right side, figure shows a matrix in which risk is mapped with respect to its likelihood of happening and severity of its impact. The risks mapped on the top right corner (orange and red boxes) are more critical and need to be corrected immediately. Whereas risks mapped in bottom left corner are (yellow and green boxes) less critical and can be adapted in long term.

![Risk Matrix](image)

1. Extreme Hot Weather - Key track, signals, & communications assets and staff & passengers.
2. Rain & Flooding - Track & signal drainage
3. Cold & Freeze - Impact on track integrity
4. Rain & Flooding - Key infrastructure drainage
5. Drought - Vegetation impact
6. Snow - track, signalling and depot operations
7. Cold & Freeze - Train system components
8. Cold & Freeze - Slips/trips for staff and customers.
9. Rain, Flooding and snow - Damage to inside of carriages
10. Wind - Damage to infrastructure, track and vegetation.
11. Drought - Ground stability impacts
- Raise awareness of adaptation to climate change.
- Organize joint training exercises with local emergency services i.e. EU Sequana Exercise 2016 Paris. (see )
- If an operator does not have enough resources itself, make a contract with external company to provide heavy machinery in case of extreme weather event. (Hochbahn made a contract with THW. A national unit with heavy equipment for technical support in case of every kind of disaster. They have cranes, heavy tools and high-performance pumps, e.g.. So we are more independent of local fire brigade, which is very often overloaded, of course, during heavy weather conditions.)

**EU Sequana Exercise 2016 Paris (07 March 2016 – 16 March 2016)**

The police department of France organized a flood simulation exercises named as “EU Sequana 2016” which was co-financed by EU. The aim of the exercises was to check coordination of different actors involved in crises management and effectiveness of chain of commands on every level of decision making. The exercises were attended by over 800 experts coming out of around 90 partners (communities, major operators, private companies, emergency services) and 36 full scale exercises were conducted.
3. Analysis by sub-systems

3.1 Power supply

3.1.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain / floods</td>
<td></td>
<td>• Substation drowned leading to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o power outage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Flashover of trackside circuit breaker</td>
</tr>
<tr>
<td>Excessive Heat, drought and increased UV exposure</td>
<td></td>
<td>• OHL loosening (serious sagging cause crashing of pantograph)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Closing of 3rd rail dilatation (risk of buckling)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• De-rated power equipment</td>
</tr>
<tr>
<td>Wind / storms</td>
<td></td>
<td>• OHL damage due to tree falls</td>
</tr>
<tr>
<td>Sand storm</td>
<td></td>
<td>• OHL damage</td>
</tr>
<tr>
<td>Thunderstorms and lightnings</td>
<td></td>
<td>• Overvoltage damages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Flashover of insulator and sub-station equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Breakdown of lightning arrester</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nuisance tripping of circuit breakers</td>
</tr>
<tr>
<td>Snow / Ice</td>
<td></td>
<td>• OHL damage by ice build-up causing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o electrical arcing and power surges due to poor electrical contact</td>
</tr>
<tr>
<td>Sea and ground water level increase</td>
<td></td>
<td>• Problems of negative return current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased corrosion on power equipment</td>
</tr>
<tr>
<td>Blackout</td>
<td></td>
<td>• System down</td>
</tr>
</tbody>
</table>
3.1.2 – **Short-term: Damage control, reduce disruption, restore service**

- Additional inspection of equipment under extreme temperature to protect threshold.
- Applying de-icer to the overhead power lines in order to prevent ice formation whenever freezing rain or fog is expected.
- Assess damaged caused by lightening and arrange repair equipment accordingly. Priority shall be given to safety and rapid resumption of traffic/power for network section.
- Use of redundant installation to withstand basic performance and minimum services.
- Own mobile power supply substations that can be use in case of power failure. (Metro do Porto use it also for other temporary needs)

3.1.3 – **Medium-term: Protection of existing assets**

- Keep a regular check to trim tree branches near the power lines.
- Enforce the cleaning of insulator at high polluted area.
- Review existing power system arrangement to enhance supply reliability (add redundancy) to essential power trains and signaling for safe operation.
- Identify equipment at low lying area, add flood proof features if it is possible and install sump pit and pumping system as well. Relocate the equipment present in an area with high flood potential.
- Maintain catenaries properly ensuring that the wire maintains its working tension. Need to foresee its capacity to collect the length variations, contraction in winter and expansion in summer, as well as the capacity of the brackets to rotate enough.
- Modernization of protection equipment which can bear more intense weather. i.e surge protection facilities.
- Development of maintenance vehicles for the case of operational failures (e.g. use of vehicles with distinguishing sign)
- Use of rigid catenaries, less subject to fall in case of harsh weather.
3.1.4 – Long-term: Design of more resilient assets

- Review existing power system arrangement (redundancy) to enhance supply reliability (N-1 criteria) to essential power trains and signaling for safe operation.

- Design internal grid to allow system to continue operation with loss of one or two sub-stations.

- Feeding configuration should be so arranged that power of healthy zone(s) can be resumed.

- Design “fail safe systems” with reliable and selective protection schemes to quickly isolate electrical equipment in distress to avoid proliferation of failure.

- Installation of flooding detection alarms to facilitate power system controller’s judgment on whether a controlled manual shutdown would be required.

- Incorporate flood gates and flood pumps in new designs to counter the risk of flooding.

- Design systems with better weather-resistance, developing protection against atmospheric overvoltage, improved protection for electric devices, protected location of buildings and equipment, etc.

- Implement water level gauges for underground sub-stations in tunnel installations, plus aligned strategies for supplying power to gauges.

- The installation of post-tensioned overhead lines, instead of simple contact lines.

- Refrain from use of underground substations in lower points of the local topology.

- Construction reinforcement of operational buildings in order to protect the electric equipment (against rain/water leaks) and installation of air conditioning system in technical rooms in order to avoid negative effects of ambient heat and high humidity on devices such as electronic relays for power system protection and control.

- Adopt “Mechanical sectioning” & “Electrical sectioning” for OHL design to minimize damage in the case of dewirement or wire breakage and design to facilitate detection of faults and to restrict the disruption of the system by isolating the faulty sections.
• Use of rigid and latest design catenary in order to avoid fall in case of harsh weather events.

• Review the dimensioning of foundations to counteract the wind forces. Geometry depending on type of track formation. On flat grounds, trench and parallelepiped concrete foundation. On embankments, trapezoidal concrete foundation.

**Key Words (Wikipedia)**

- **De-Icing** is defined as removal of snow, ice or frost from a surface by heating or using some chemical.
- **Redundancy** is a system design in which a component is duplicated so if it fails there will be a backup.
- **Surge** is defined as an oversupply of voltage from the power company that can last up to 50 microseconds.
- **Catenary** is an overhead wire is used to transmit electrical energy to trams, trolley busses, or trains.
- **Fail Safe System** is the system’s design that prevents or mitigates unsafe consequences of the system’s failure. That is, if and when a “fail-safe” system “fails”, it is “safe” or at least no less safe than when it was operating correctly.
- **Break Down** is a long reduction in the resistance of an electrical insulator when the voltage applied across it exceeds the breakdown voltage. This result is the insulator becoming electrically conductive.
### 3.2 Stabling and maintenance facilities

#### 3.2.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Stabling and maintenance facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain / floods</td>
<td></td>
<td>• Damage to fleet and equipment</td>
</tr>
<tr>
<td>Excessive Heat, drought and increased UV exposure</td>
<td></td>
<td>• Damaged to fleet and equipment&lt;br&gt;• Damage to Tar insulation used in tunnels&lt;br&gt;• Damage to electrical and electronic equipment</td>
</tr>
<tr>
<td>Wind / storms</td>
<td></td>
<td>• Damage to roofs and canopies</td>
</tr>
<tr>
<td>Sand storm</td>
<td></td>
<td>• Drainage Clogging</td>
</tr>
<tr>
<td>Thunderstorms and lightnings</td>
<td></td>
<td>• Damage to electrical and electronic equipment</td>
</tr>
<tr>
<td>Snow / Ice</td>
<td></td>
<td>• Operation stops due to jammed switches</td>
</tr>
<tr>
<td>Sea and ground water level increase</td>
<td></td>
<td>• Flooding in low lying facilities</td>
</tr>
<tr>
<td>Blackout</td>
<td></td>
<td>• Electrical maintenance machines stopped</td>
</tr>
</tbody>
</table>

#### 3.2.2 – Short-term: Damage control, reduce disruption, restore service

- Distribute the functions and assignments to other facilities
- Building up emergency points at central locations, with all potential devices needed for damage elimination and rescue (and re-start of traffic)
- Ordering emergency preparation units based on weather forecast
- Keep snowploughs and drivers available as a rapid response team
- Extension of closed storage facilities, updating of maintenance plan
3.2.3 – Medium-term: Protection of existing assets

- Need to revise the condition of roofs and canopies and renew them if necessary to remove high wind-related risk.
- In case of stables, maintenance facilities controlled by men, at least surveillance by cam
- Carrying out trials to explore new technologies for improving ventilation and cooling of equipment and buildings

3.2.4 – Long-term: Design of more resilient assets

- Select a location on an upper site of the local topology to allow dry storage of equipment and rolling stock
- Better lightning protection design of new depots, equipment rooms and buildings
- Assess the impact under more severe weather conditions (e.g. more serious flood) and review design standards to cater for increasing trend of extreme weather anticipated such as flooding in light of global warming.

**Key Word (Wikipedia)**

**Topology** means the shape and features of the surface of the Earth.
3.3 Tunnel stations and interchange

3.3.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Tunnel, Stations and interchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain / floods</td>
<td></td>
<td>• Station / tunnel drowned</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Accessibility reduced to the stop/Interchange</td>
</tr>
<tr>
<td>Excessive Heat, drought and increased UV exposure</td>
<td></td>
<td>• Thermal inertia and cooling issues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Dilatation Problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• E&amp;M equipment damage</td>
</tr>
<tr>
<td>Wind / storms</td>
<td></td>
<td>• Foreign objects ingress to the tunnel at tunnel mouth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Damage to roof structures at over ground stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The furniture fixed on the platform could be damaged and fall off position</td>
</tr>
<tr>
<td>Sand storm</td>
<td></td>
<td>• Quicker deterioration of ventilation filter equipment</td>
</tr>
<tr>
<td>Thunderstorms and lightning</td>
<td></td>
<td>• Threat of striking lightning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• E&amp;M equipment damage</td>
</tr>
<tr>
<td>Snow / Ice</td>
<td></td>
<td>• Risk of slipping</td>
</tr>
<tr>
<td>Sea and ground water level increase</td>
<td></td>
<td>• Capability of pumping systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• “Floating” of Tunnel</td>
</tr>
<tr>
<td>Blackout</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 – Short-term: Damage control, reduce disruption, restore service

- Create an emergency point (station superintendent)
- Inspect the flooding black spots before the heavy rain and use mobile dams in order to protect the entry segments of underground stations against flood (especially the ones in underpasses).
- Check and de-slit, if necessary, water drainage systems in order to protect buildings
• Development of plan how to inform passengers in emergency cases, evacuation plan. Presence of equipped and trained staff to provide the necessary assistance to passengers at stations and interchange facilities.
• Timely, careful planning and organisation of snow and ice clearance for stops and tracks.
• Immediate interventions for traffic safety and operability if extreme weather event happens.
• Enhancing maintenance in response to more landslides / flooding / rain / storm

3.3.3 – Medium-term: Protection of existing assets
• Conducting consultancy studies to identify locations with high risk of flooding / surge storm / landslides and carry out improvement works to lower the risk.
• Prevent water from coming into tunnels and underground stops by using mobile barriers, and keeping additional pumps ready to deploy.
• Need to review the condition of roofs and canopies and renew them if necessary to remove high wind-related risk.
• Assessing the cooling capacities at station under extreme temperature conditions.
• Renew shaft lining to reduce water penetration using coating material. Try to divert water to other locations on the structure, so that water is drained effectively by drainage system.
• Fitment of snow and ice covers to protect detection and drive equipment from severe weather i.e. application of anti-icing and dry Teflon film to components sensitive to the build-up of snow and ice.
• Provision of ventilation fans to protect E&M equipment for excessive heat condition.
• Provision of plastic ties, locks, weights, etc to secure the furniture in position in extreme storm condition.

3.3.4 – Long-term: Design of more resilient assets
• Design underground stations with flooding gates e.g. mobile barriers in order to avoid water intrusion.
• Install additional storage capacity and larger pumping systems.
• Avoid the use of niches both in tunnels and underground stops, as flammable materials can collect in these.

• Need of more efficient passive and active cooling to fight too high temperatures, especially for staff.

• Enhance the drainage system capacity i.e. additional trackside catch pits, sand traps, etc.

• Raised station entrances with one extra step and floor boards for trackside equipment to prevent water ingress.

• Better lightning protection design of new over ground stations

• Provision of plastic ties, locks, weights, etc to secure the furniture in position in extreme storm condition.

**Key Words (Wikipedia)**

**Thermal inertia** is degree of slowness with which the temperature of a body approaches that of its surroundings and which is dependent upon its absorptive, its specific heat, its thermal conductivity, its dimensions, and other factors

**Black spot** is a place or area marked by a particular trouble or concern.

**De-silt** is to remove silt from a basin of water
3.4 Structures and track (formation)

3.4.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Rail sub-system</th>
<th>Structures, track (formation)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weather factor</strong></td>
<td></td>
</tr>
</tbody>
</table>
| **Rain / floods** | • Wet rail syndrome (poor adhesion)  
| | • Landslide which can cause damage to  
| | o track & embankment  
| | o track geometry  
| | • Wash out ballast and track circuit  
| | • Drainage clogged  
| | • Track sections become impassable |
| **Excessive Heat, drought and increased UV exposure** | • Points damage  
| | • Earthwork dissection  
| | • Damage in crushed stone (ballast) bed  
| | • Early damage in rail ties (timber ties/sleepers),  
| | • Damage in fastening elements  
| | • Melting of asphalt  
| | • Line-side fires |
| **Wind / storms** | • Side signs visibility reduction  
| | • Tree falls/Poor adhesion  
| | • Threat to track gauge/clearance |
| **Sand storm** | • Track & side signs visibility reduction  
| | • Unusable track and points  
| | • Occupied status of insulated joints  
| | • Threat to track gauge/clearance |
| **Thunderstorms and lightnings** | • Tree falls threaten the gauge |
| **Snow / Ice** | • Rail surface gets slippery  
| | • Unusable track and points  
| | • Barriers in gauge  
| | • Side signs visibility reduction  
| | • Avalanche hazards |
| **Sea and ground water level increase** | • Embankment and earthwork damages |
3.4.2 – Short-term: Damage control, reduce disruption, restore service

- Follow the procedures to prevent track buckling and make additional inspection of P-way under extreme (low or high) temperature.
- Install signs on roads and crash barriers at dangerous curves.
- Check and de-slit, if necessary, water drainage systems and minimize the drainage service interval.
- Drive during the night to keep tracks and overhead power lines free of ice and snow.
- Drivers must report any evidence of track fault they detect.
- Immediate intervene to repair damaged track section manually or by specialized machines in order to make the track safe for traffic.
- Rinse down the rail track bed and ballast to inspect its condition, clean grooved rails at level crossings especially prior to restarting service.
- Cool rail tracks down by sprinkling; carry out targeted disconnection of tracks, in particular those near to fixed points.
- Run several train sets to inspect or survey the line and ensure quick response to the critical locations before the beginning of the daily service.

3.4.3 – Medium-term: Protection of existing assets

- Plan alternative routes.
- Preparedness work for summer conditions
  - Ensuring rail stressing
  - Correction of track geometry defects,
  - Rail adjusting for jointed track and laying additional ballast where necessary to ensure stability.
- Identification of track failures with ultrasound track measuring equipment (track diagnostics).
- Track and crossing adjustment by machines in order to revoke speed limits.
- Keep tracks and areas close to tracks & catenaries free from hazardous objects and vegetation by enhancing vegetation management, preventing re-growth on embankments by setting out the responsibilities.
of both transport infrastructure owners and adjacent landowners, the consequences of failing to maintain assets, in terms of maintenance of their respective assets, including rights of access.

- Increase the rigidity of the frame (tracks and sleepers).
- Install expansion joints at especially critical points.
- Installation of warning systems that can inform the driver in advance or may stop the train in time in case of rockslides or landslides before reaching the point of collision.
- Provide redundancy and emergency capacity (switches operation on opposite lane).
- Recalculate and resize hydraulic capabilities, bridges sections and spans, ditches, etc. in order to drain flows with returning period exceeding the original calculation.
- Improve drainage network along the rail network, through renewal and refurbishing of track and off-track drainage.
- Conversion of track circuits to axle counters, which are less sensitive to water for areas at high risk of flooding.
- Review the stability of slopes and embankments, especially of those of weak rock material, and re-profile or fasten them, if needed.
- Reinforce current sea defence or install new sea defence and increase drainage capacity in coastal lines.
- Procurement of paints and lubricants which resist to extreme weather conditions.

### 3.4.4 – Long-term: Design of more resilient assets

- Avoid ballasted track in vulnerable locations and possible use of the most modern track structures made of more resistant material. i.e. use of continuous welded rail rather than that of jointed rail.
- Design new drainage and size them accordingly to cope with predicted future flooding frequency and magnitude. Need to adapt parameters according to climate change projections.
- Register any item vulnerable to strong wind (e.g. building site fences, crane equipment) along the line.
- Restrict the use of overhanging roofs and roof attachments or extensions on buildings near to the track.
• Avoid sinking of ballast and its pollution using a fabric layer on formation formed by fine materials. Use of bituminous sub-ballast layer against environmental actions, as an alternative to conventional sub-ballast granular layers. It minimizes vertical displacements, seasonal variations, improving geometric performance of the railway infrastructure, reducing track maintenance needs. Being almost completely water-resistant, it increases track bed life cycle.

• Avoid buckling, by means of increasing the rigidity and weight of the superstructure of the track, using mono block concrete sleepers, as well as bringing them from 70 cm to 60 or 50 cm distance, ensuring their fixation with systems that increase their resistance to lateral displacement.

• Avoid steep embankment slopes to minimize the risk of slips

• Lift roadbed and track to a uncritical level

• Build pump yards at lowest points.

**Key Words (TDWorld.com)**

**Vegetation management** Vegetation management is a broad term that includes tree pruning; brush removal through the use of power saws and mowers; the judicious use of herbicides and tree growth regulators; hazard tree identification and removal; the implementation of strategies to minimize the establishment of incompatible species under and near power lines; and the control of weeds.
3.5 Train control-command / signaling

3.5.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Train control-command</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Track-circuit and equipment damage</td>
<td></td>
</tr>
<tr>
<td>Rain / floods</td>
<td>Damage to surface building of traffic control centre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety route cannot be set</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Signal cannot clear</td>
<td></td>
</tr>
<tr>
<td>Excessive Heat, drought and increased UV exposure</td>
<td>Track-circuit and equipment damage</td>
<td></td>
</tr>
<tr>
<td>Wind / storms</td>
<td>Damage to surface building of traffic control centre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage to communication system</td>
<td></td>
</tr>
<tr>
<td>Sand storm</td>
<td>Damage to signaling/safety equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deterioration of filters</td>
<td></td>
</tr>
<tr>
<td>Thunderstorms and lightnings</td>
<td>Overvoltage damages</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interference</td>
<td></td>
</tr>
<tr>
<td>Snow / Ice</td>
<td>Break down of LED optics</td>
<td></td>
</tr>
<tr>
<td>Sea and ground water level increase</td>
<td>Short circuit due water ingress</td>
<td></td>
</tr>
<tr>
<td>Blackout</td>
<td>System down</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2 – Short-term: Damage control, reduce disruption, restore service

- Deploy staff trained in different ways to regulate traffic, in case the most advanced systems failed.
- Applying temporary speed restrictions when adhesion conditions require.
- Improve ventilation and dust-proofing of technical rooms.
3.5.3 – Medium-term: Protection of existing assets

- Develop emergency plans
- Proactive replacement and overhaul of vulnerable and aging components
- Protection of central units and external equipment (e.g. insulation)
- Introduction of alternative routes for energy supply to train control equipment. Procure accumulators/generators.
- Need of redundant traffic control and communication systems. It will depend on the blocking technology available. Primitive systems (telephone block, local electronic block, etc.) should be kept as a backup of CTC (Centralized Traffic Control) and, therefore, the staff should be trained in different ways to regulate traffic, in case the most advanced systems failed.
- Review the design of signaling system to minimize the influence of EMC by OHL and grounding systems.
- Enhancement of grounding arrangement and surge protection at locations with high vulnerabilities against lightning strikes (especially at open sections with few structures around)
- Fitment of snow and ice covers to protect detection equipment from severe weather.
- Stock up spares in extra quantity in addition to existing level which is considered for predicted rate of failures only.

3.5.4 – Long-term: Design of more resilient assets

- Signalling system control facility should be redundant. Hence, in case of main control facility failure, other facility can be used. (Metro de Porto have such configuration)
- New signalling control centres should be equipped with back-up power supplies and stand-by generator capability.
- Make sealed technical room, cabinets and equipment on upper floors of buildings
- Set up automatic reporting mechanisms on water levels in tunnel installations to the control centre.
- Adopting more stringent surge protection measures for new signaling facilities (e.g following recommendations from EN62305 part 4)
### 3.6 Rolling stock

#### 3.6.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Rolling stock</th>
</tr>
</thead>
</table>
| **Rain / floods** | | • Train Damages  
• Failures in electric parts |
| **Excessive Heat, drought and increased UV exposure** | | • DC motor loses  
• Reliability losses of on-board electronics  
• Comfort conditions on-board  
• More intensive work of air condition equipment  
• Pantograph deformation due to overhead wires deformation |
| **Wind / storms** | | • Risk of collision to “flying objects”  
• Damage to rolling stock due to tree falls  
• Broken glasses |
| **Sand storm** | | • Failures in traction engines due to sand getting into the ventilation system  
• Quick deterioration of filters |
| **Thunderstorms and lightnings** | | • Overvoltage damages  
• May blow protection fuses leading to loss of traction |
| **Snow / Ice** | | • Risk of gliding due to the snow volume  
• Traction voltage disturbances due to freezing consequently vehicle gets immobile.  
• Engine short circuit due to powdery snow  
• Reliability of pneumatic components being affected |
| **Sea and ground water level increase** | | • Failures in electric parts, vehicle gets immobile.  
• Track gets muddied. |
| **Blackout** | | • System down |
3.6.2 – Short-term: Damage control, reduce disruption, restore service

- Regularly clean components vulnerable to temperature changes (e.g. transformers, air compressors or circuit boards) in order to improve the cooling mechanism.
- Prevent drifting snow getting into ventilated, direct current, traction motors by storing trains under roofs.
- Heat/cool vehicles to ensure they are in operational condition.
- Check vehicles for overnight weather-related issues, such as frozen couplings, bogies and doors.
- Try to isolate the fault to maintain the services if it cannot be cleared at that time.
- Fit vehicles with extra equipment appropriate for weather track works.
- Use high floor vehicles, if available, in case of a flood, or 24 hours operation in case of lot of snow.

3.6.3 – Medium-term: Protection of existing assets

- Assess vulnerabilities of vehicles to specific weather types observed during previous events.
- Deploy vehicles with sealed motors/other critical power units (e.g. converters).
- Assess the cooling capacities in passenger trains under extreme temperature conditions. Switch-off the cooling mode of Air Conditioning Units and make sure the ventilation fan unit is operated during emergency. If required, open the hopper windows to maintain sufficient ventilation for saloon interior.
- Conduct hard-time replacement for aging/deteriorated rubber seal joint/gasket located in between saloon Air Conditioning Units & vehicle roof and other control cubicles or covers to eliminate water ingress from outside area.
- Use a combination of water jets and adhesion modifier gel to remove contamination from the railhead and improve adhesion between rail and wheel, which is affected by layers of damp leaves. It helps to minimize wet rail syndrome.
- Development of measurement system to measure snow and water level along the lines in case of rain, snow or sea level rise.
• Installation of headlights into the vehicles which can follow the movement of the vehicle in case of low visibility.
• Install scraping devices on special track vehicles

3.6.4 – Long-term: Design of more resilient assets

• Strengthen design standards e.g. increase the safety margin for new RS to cope with extreme weather conditions
• Development of laser measurement system with wireless data communication, to measure snow and water level along the lines in case of rain, snow and sea level rise.
• Use of anti-solar degradation paint, flame retardant and corrosion resistant materials to minimize rain and floods effects.
• Use of reinforced laminated safety-glass window panels, upgraded with sunscreen.
• Fairing to protect all underneath equipment, and bogies hidden to air to reduce aerodynamic resistance, in case of strong winds. Avoid protruding train components. Use of air deflectors at the front part of the train.
• Energy accumulators embarked to be used in case of emergency.
• Greater control of air inlets in the carriages to reduce energy losses.
• Improve comfort in case of cold weather, through the installation of radiant heating systems, such as a layer of carbon fibre heater thermally insulated from outdoors, providing uniform and comfortable heating and keeping feet warm. It also provides improved indoor air quality.
• Installation of threshold and door guide heaters to keep these elements free of ice and snow build-up, within a safe temperature zone for passengers, railway staff and equipment.
• Replace the existing split type Air Conditioning Units to packaged type in order to improve maintenance efficiency and service redundancy. For the new units, feasibility study should be carried out to adopt frequency inverter to drive the compressors for reducing the power consumption and achieving energy saving.
3.7 Level crossings

3.7.1 Risk and weather event matrix

<table>
<thead>
<tr>
<th>Weather factor</th>
<th>Rail sub-system</th>
<th>Level crossings</th>
</tr>
</thead>
</table>
| Rain / floods                                                                  |                                                                                  | • Corrosion of framework elements and superstructures  
• Flooded and invisible rail track  
• Damage to electrical and electronic components |
| Excessive Heat, drought and increased UV exposure                               |                                                                                  | • Ageing of crossings with rubber elements speed up  
• Quicker deterioration of signals (foils, lens)  
• Overheating of printed circuit boards inside equipment cabinets |
| Wind / storms                                                                   |                                                                                  | • Barriers damages  
• Signs damage |
| Sand storm                                                                      |                                                                                  | • Signs damage  
• Invisible track sections |
| Thunderstorms and lightnings                                                    |                                                                                  | • Tree falls which threaten the gauge  
• Overvoltage damages |
| Snow / Ice                                                                      |                                                                                  | • Destructive effects of water trapped in structures after freezing  
• Invisible track sections  
• Difficult breaking  
• Damage to electrical and electronic components |
| Sea and ground water level increase                                             |                                                                                  | • Invisible track sections |
| Blackout                                                                        |                                                                                  |                                                                                  |
4. Conclusions

In conclusion, most of the respondents were found aware of potential risks associated with climate change, measures to avoid adverse effects on rail infrastructure and quick restoration of system after damage. The feedback shows, some respondents are already practicing some measures and some are planning to implement measures in order to avoid climate effects. The crucial step in implementation is to prioritize the tasks according to potential risks and impact severity on overall system. A better communication between different stakeholders helps authorities doing better risk assessment and planning to handle adverse situations. In short, the overall feedback received and literature reviews helped us compile a generic list of measures that can be followed by every company according to their geographic conditions and potential risks.
5. Further Readings


This is an official Report of UITP, the International Association of Public Transport. UITP has over 1,400 members in 96 countries throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport world-wide.

This Report was prepared by Metro, Light Rail and Regional and Suburban Railways UITP Committees.