LIGHT RAIL
Safety and Standards Board

Weather and Climate Resilience Guidance

CALL
0121 214 7107

EMAIL
info@lrssb.co.uk

WEB
www.lrssb.org

TWITTER
@LightRailSSB

LINKEDIN
@lightrailssb

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DESCRIPTION:

THIS DOCUMENT PROVIDES GUIDANCE ON PREPARING FOR SEASONAL WEATHER TO REDUCE IMPACTS TO THE OPERATION OF LIGHT RAIL SYSTEMS AND CLIMATE RESILIENCE

EXPLANATORY NOTE:

LRSSB is not a regulatory body and compliance with this guidance document is not mandatory. This document reflects good practice and is advisory only. Users are recommended to evaluate this guidance against their own arrangements in a structured and systematic way, noting that parts of this guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not adopt) elements of this guidance should be documented. Compliance with any or all of the contents herein, is entirely at an organisation's own discretion.

SOURCE / RELATED DOCUMENTS:

LRG 1.0 Tramway Principles and Guidance (TPG) (LRSSB)
LRG 8.0 Guidance in the Management of Vulnerable Persons (LRSSB)

RELATED TRAINING COURSES:	**RELATED LEGISLATION:**
N/A	Health and Safety at Work Act etc. 1974 Management of Health and Safety at Work Regulations 1999 Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) (as amended)

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WEATHER AND CLIMATE RESILIENCE GUIDANCE

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TERMS AND ABBREVIATIONS

Table A – Terms

Term	Definition
Emergency Speed Restriction	A change from the permanent speed restriction for a very temporary period that is shorter than the reasonable time required to put out additional temporary speed signage.
Extreme Weather	Weather conditions that have unusual or unexpected consequences.
Ghost Tram	Trams operating along the tracks that are not providing a passenger service, used for ice build-up prevention.
Seasonal Weather	Weather experienced as typical to UK climate, whether to an expected or unexpected degree.

Table B – Abbreviations

Abbreviation	Definition
ARISCC	Adaption of Railway Infrastructure to Climate Change
°C	Degrees Celsius
ESR	Emergency Speed Restriction
EWMP	Extreme Weather Management Plan
EWRG	Extreme Weather Response Group
HVAC	Heating, Ventilation and Air Conditioning
Km	Kilometres
LRSSB	Light Rail Safety and Standards Board
NSWWS	National Severe Weather Warning Service (UK Met Office)
OCC	Operations Control Centre
OLE	Overhead Line Electrification
PID	Passenger Information Display(s)
RAIB	Rail Accident Investigation Branch
ROGS	Railways and Other Guided Systems 2006 (as amended)
RTC	Road Traffic Collision
SPAS	Signal Passed at Stop
TPG	Tramway Principles and Guidance
UK	United Kingdom

1. Introduction

1.1. This guidance supports the high level principles set out in LRG 1.0 Tramway Principles and Guidance (TPG) published by the Light Rail Safety and Standards Board (LRSSB).

1.2. This document provides high level weather and climate resilience guidance for those delegated this responsibility in relation to UK Light Rail systems (tramways) based on 'line-of-sight' operations only. As with all guidance, this document is not prescriptive and is intended to give advice, not to set a mandatory industry standard, and it is based upon goal setting principles as best practice.

1.3. Much of this guidance is based on the experience gained from existing UK Light Rail systems and from published documents. It does not prescribe particular arrangements adopted by any existing UK Light Rail system and is intended to give guidance and advice to those involved in the management of the impacts of weather.

1.4. This guidance is not intended to be applied retrospectively to existing Light Rail systems. However, owners and operators should consider and assess any implementation of this guidance and / or any subsequent revision, to ensure continual improvement in reducing risks related to the impacts of weather and climate, so far as is reasonably practicable.

1.5. Other guidance and information regarding weather and its affects is available from other sources, for example, the UK Met Office[1].

1.6. In addition, the Highway Code also contains mandatary rules for driving in particular weather conditions[2].

1 https://www.metoffice.gov.uk/
2 Driving in adverse weather conditions (226 to 237) - https://www.gov.uk/guidance/the-highway-code/driving-in-adverse-weather-conditions-226-to-237

2. Scope

2.1. The guidance in this document relates to weather and climate resilience and includes both expected and unexpected extreme weather events.

2.2. Different forms of seasonal weather and climate affect the operation and safety of Light Rail systems in varying ways and to different degrees depending on the location of the Light Rail system and its attributes and environment. Space weather is also increasingly being considered due to its impact on communication systems[3].

2.3. The impacts of the following forms of weather considered by this guidance include the following:

- Precipitation (rain, snow, ice, frost, fog, mist, dew, etc.);
- Extreme cold;
- Thunder and lightning;
- High winds; and
- Extreme heat.

2.4. The purpose of this document is to assist Light Rail systems to adequately, appropriately and sufficiently prepare and pre-plan to respond to seasonal weather events. This includes items to be considered in the design and construction of Light Rail systems, that may later assist when the system is in operation.

2.5. Types of weather not considered by this document include specific references to coastal weather and extreme weather events that are very rare in the UK, such as tornadoes.

2.6. This document does not provide guidance in relation to seasonal events that may have an impact on passenger and other people's behaviour, for example, Christmas.

2.7. For guidance in relation to behaviour of vulnerable passengers and others in and around the Light Rail system, please refer to LRG 8.0 Guidance in the Management of Vulnerable Persons.

2.8. Specific detail relating to the preparedness of drivers including any training relating to driving trams in extreme weather conditions is not considered within this document, including the preparedness of tram vehicles.

2.9. For further reading, in relation to 'climate change' the Met Office provides information on their website[4] and Network Rail have information on their website regarding asset management[5].

3 https://www.metoffice.gov.uk/weather/learn-about/space-weather/impacts
4 https://www.metoffice.gov.uk/weather/climate-change/effects-of-climate-change
5 https://www.networkrail.co.uk/sustainability/climate-change/climate-change-adaptation/

3. Managing Seasonal Weather Impacts – General Guidance

3.1. Certain forms of weather and climate have the potential to affect Light Rail systems and can potentially cause problems including risks to staff, passengers and members of the public in the vicinity of the Light Rail system, as well as the actual tram infrastructure and its operation.

3.2. Weather and climatic impacts can be localised to a certain area around a Light Rail system, for example, puddles at some tramstops, or they can affect a more widespread area and therefore impact a large part of the system, for example, flooding over large sections of a Light Rail system where tracks and tramstops are under water.

3.3. Weather and climate impacts can be prolonged and persist for several days or weeks, or can be short-term lasting a few hours or a day.

3.4. Adequate forecast and warning data, communications and preparedness are all key to maintaining and maximising Light Rail services in extreme and seasonal weather as far as practicable.

3.5. An Extreme Weather Management Plan (EWMP) can assist Light Rail systems to pre-plan for seasonal and extreme weather including adequate preparation and response activities and thresholds (refer to Section 6 for further guidance).

3.6. Preplanning for seasonal weather also includes lessons learnt from previous years' experiences and adequate provision within the Light Rail system's risk management and safety management systems.

3.7. The Adaption of Railway Infrastructure to Climate Change (ARISCC) recommend the 'three Rs' in terms of guiding principles of an integrated strategy[6] as outlined below:

- Readiness: to be well prepared for extreme weather events;
- Resilience: to systematically increase the resilience of the whole system; and
- Recovery: to have contingency plans allowing for fast and full recovery.

Forecast / Warning Data

3.8. It is important that Light Rail systems have easy, quick and reliable access to accurate information on local weather conditions and forecasts, especially those who are managing a response to weather and its impacts.

3.9. Weather warnings provided by external sources, for example, local and national weather meteorological services (the UK Met Office and Met Éireann for Ireland) can be of crucial assistance in anticipating and planning for the level of expected impact of the forecast weather, and the likelihood of the impacts occurring. Local Authorities may also have a detailed weather service for the local area that can be accessed by Light Rail systems.

3.10. The UK Met Office focuses on the likelihood of impacts occurring from seasonal / extreme weather and consider a number of factors such as the time of year, time of the week, time

6 http://www.ariscc.org/index294f.html?id=105

of day, location and the environment, such as underlying ground conditions. They consider the general impacts of weather and grade impacts as 'low', 'medium', and 'high' as seen in Table 3.1 below and the Met Office website[7]. However, these are not exhaustive.

Table 3.1 General Impacts of Weather

	Impact			
Activity	**Very Low**	**Low**	**Medium**	**High**
General 'Day to Day' Activities	Generally not affected; a few places may experience small scale impacts	Some short lived disruption to routines in affected areas	Injuries with danger to life. Disruption to routines and activities	Danger to life. Prolonged disruption to routines and activities
Emergency Services		Any incidents dealt with under 'business as usual' for emergency services	Short-term pressure on emergency services.	Prolonged pressure on emergency services
Transport	A few transport routes affected	A few transport routes affected	Transport routes and travel services affected with longer journey times and vehicles and passengers stranded	Transport routes and travel services affected for a prolonged period and long travel delays with vehicles and passengers stranded for long periods
Utilities	Not applicable	Not applicable	Disruption to utilities and services	Prolonged period of disruption to utilities and services
Property and Buildings	Not applicable	Not applicable	Damage to property and buildings	Extensive damage to property and buildings

3.11. Table 3.2 below shows some of the main impacts of extreme weather on a Light Rail system. Further information may be sought from ARISCC[8].

Table 3.2 General Impacts of Extreme Weather on Light Rail Systems

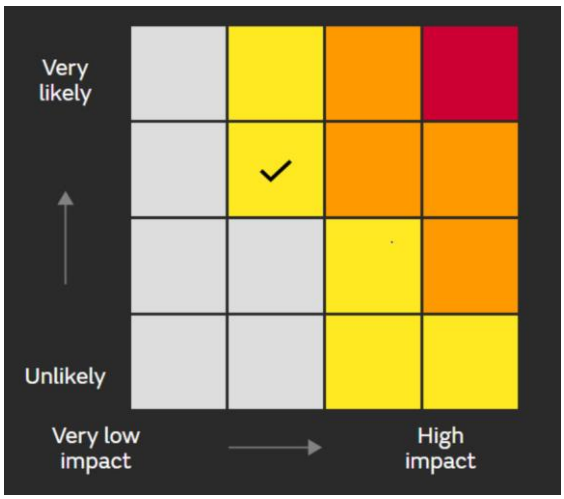
7 https://www.metoffice.gov.uk/weather/guides/severe-weather-advice
8 ARISCC Scope - http://ariscc.org/index1e35.html?id=39

Weather Condition	Effect	Main Impacts
Temperature		
High / heat waves	Overheating	Infrastructure equipment (for example, OLE sagging, impact on equipment rooms / cases, etc.), rolling stock requirements, staff and / or passenger issues (including staff outside working), fire, etc.
Sudden changes	Tension, overheating and freezing, etc.	Track buckling, fires, signalling problems, temporary loss of visibility, tram cab temperatures, loss of tension on OLE, etc.
Intense sunshine	Tension and overheating, etc.	Track buckling, fires, signalling problems, temporary loss of visibility, tram cab temperatures, loss of tension on OLE, etc.
Low temperatures	Black ice / ice OLE icing	Increased RTC risk including slips, trips and falls, possibility of icicles in tunnels, etc. Damage to pantographs and overhead wire, etc.
Precipitation		
Heavy intense rain	Soil erosion, landslides, flooding, etc.	Damage to embankments, electrical issues, etc.
Extended duration	Drainage slower, soil erosion, landslides, flooding, etc.	Infrastructure assets, operations, drainage systems, tunnels, bridges, ballast, etc.
Flooding	Drainage slower, soil erosion, landslides, flooding, etc.	Infrastructure assets, operations, drainage systems, tunnels, bridges, ballast, etc.
Snow	Low adhesion, visibility of tracks, etc.	Compacting inside points equipment, compacted in groove rail', drifts cause barriers, etc.
Fog / Mist	Low visibility	Visibility, low adhesion, etc.
Drought	Desiccation	Earthworks, fires, subsidence, slower drainage, soil erosion, etc.
High Wind	High wind, uprooting of trees, flying debris, etc.	Damage to installations, catenary, restrictions / disruption of tram services, risks to those working at height, third party structure fails (for example, scaffolding, etc.), etc.
Thunder and Lightning	Overvoltage	Catenary and signalling, fires, breakdown in communication systems, etc.
Vegetation	Faster plant growth, shedding of leaves (including unseasonal), etc.	Reduce sightlines, wheel-rail adhesion, damage to assets, contact with OLE, etc.

3.12. The UK Met Office issues weather warnings through the National Severe Weather Warning Service (NSWWS) when severe weather has the potential to bring impacts to the UK. These warnings are given a colour code (yellow, amber or red) depending on a combination of the impact the weather may have and the likelihood of those impacts occurring.

3.13. Yellow and amber warnings represent a range of impact levels and likelihoods. Therefore, it is important to read each warning to know what level of impact can be expected in a chosen warning area, and how likely those impacts are to occur. The risk matrix in Figure 3.1 below illustrates the application of the warnings through a risk based matrix approach.

Figure 3.1 Risk Matrix



Yellow Warnings

3.14. Yellow warnings can be issued for a range of weather situations. Many are issued when it is likely that the weather will cause some low level impacts. Most people may be able to continue with their daily routine and travel on Light Rail systems. However, it is important for the Light Rail system to assess how they will be affected.

3.15. Other yellow warnings are issued when there is the risk of the weather bringing more severe impacts to the majority of people, but the certainty of those impacts occurring is much lower.

Amber Warnings

3.16. When there is an amber warning given, this usually means the forecast suggests an increased likelihood of impacts from severe weather, which could potentially disrupt Light Rail systems. Passengers may change their travel patterns.

Red Warnings

3.17. Red warnings indicate that dangerous weather is expected, indicating that Light Rail systems are likely to need to take action to protect infrastructure and rolling stock, assess service patterns and / or take measures to keep passengers and staff safe from the impact of the weather, etc.

3.18. The impacts of this weather may include risk to life and substantial disruption to Light Rail systems, including disruption to energy supplies and possibly widespread damage to property and infrastructure.

Flood Warnings

3.19. National environment agencies provide flood warnings and alerts of flooding for specific rivers. Light Rail systems can sign up for environment agency text messages, for example, in relation to local rivers, etc.

Light Rail Systems Data

3.20. Although weather information including forecasts and warnings are provided by external sources, Light Rail systems may choose to undertake their own weather measurements to supplement this information, for example, localised wind speeds, temperatures, etc. Alternatively, they may choose to receive data from a contracted external metrological / forecasting service provider to cover items such as the following examples:

- OLE temperatures;
- Track temperatures;
- Precipitation charts (rain, hail, snow, etc.); and
- Wind gust speeds, etc.

3.21. On site equipment can relate accurate relevant information to Light Rail systems. Such measurements can include, for example, temperature gauges, wind speed data, etc. at locations known to produce localised micro climates that may be more extreme or sensitive than other areas of the network.

3.22. There will also need to be clearly defined roles and responsibilities in relation to reviewing all weather forecasts, warnings and other information.

Communications

3.23. Clear lines of communication are key to the response to seasonal weather as well the management of the Light Rail system. These include those within the Light Rail system as well as those with external organisations, including thresholds of activation.

Internal Communication

3.24. Clear lines of communication are required, for example, in relation to the reporting of extreme weather between operations and engineering teams, and the activation of the EWMP with contacting staff, etc. (For further details on the EWMP, refer to Section 6).

3.25. Reactive communication in line with pre-planned protocols can be activated when extreme weather impacts Light Rail operations in accordance with agreed thresholds and delegations.

3.26. Undertaking briefings / notices on a regular seasonal schedule will help to keep a Light Rail system's staff informed and aware of potential impacts from extreme and / or seasonal weather ahead of it occurring. This could include advice on changes in driving styles required, or the need to report incidences to the Operations Control Centre (OCC) as and when experienced, for example, instances of low adhesion, blankets of fog or heat distorted rails, etc.

3.27. Advanced planning also needs to be undertaken, for example, for contracted services such as regular leaf clearing during leaf fall season, braking sand availability, etc.

3.28. Light Rail systems may like to consider the following examples of communication:

- Internal system for disseminating information, for example, in all depot canteen areas, etc.;
- Noticeboards;
- Specific driver briefings;
- Email alerts;
- Emails to specific staff, for example those in charge of tramstops, drivers, maintenance and cleaning staff etc.;
- Updates via website, Twitter and other social media etc.;
- Face-to-face briefings to all staff;
- Repeated radio messages via the OCC;
- Passenger information displays (PIDs); and
- On tram public address announcements.

3.29. The dissemination of information may need to include any non-maintenance / operations staff who may be called in to assist in instances of extreme weather, for example, gritting and clearing snow, etc.

3.30. Seasonal department meetings or a slot at standard staff meetings may be appropriate to disseminate information and guidance at certain times of the year when extreme weather is expected.

External Organisations

3.31. Communications with external organisations need to be set up as part of the preplanning exercise in order that appropriate contact names and numbers are established for all parties, as well as agreed thresholds and actions for coordination with external organisations and their passengers. This may require early consultation with external organisations that provide services such as, for example, highway gritting, as well as internally within the Light Rail system.

3.32. Such external organisations may include the following (not exclusively):

- Relevant Government Departments (transport, environment, etc.);
- Health and Safety Executive (or national equivalent);
- Relevant national response committee(s);
- Health Service Executive;
- Local Highway Authority(ies);
- Local Authority(ies);
- Emergency services (fire, ambulance, police, transport police, etc.);
- Light Rail system owner / promoter; and
- Network Rail.

3.33. As well as providing communications, external organisations can provide technical and practical support in the preplanning as well as during the event itself.

Passenger / Public Communications

3.34. Light Rail systems may like to consider the following examples of external communications, both preventative and reactive:

- Notices on ticket machines;
- Notices in car parks;
- Notices at tramstops including PIDs;
- Announcements at tramstops and on trams;
- Website;
- Twitter and other social media;
- Radio and TV updates;
- Communications with related agencies;
- Deploying staff at tramstops and other appropriate locations; and
- Regular seasonal / annual publicly campaigns.

4. Managing Impacts of Seasonal and Extreme Weather

4.1. This section presents the most common types of seasonal and extreme weather that affect UK Light Rail systems. However, they are not exhaustive and Light Rail systems should consider the types that are most likely to occur to their system. For example, coastal storm surge is not included below as it is not common to all systems, however, the impact of flooding is considered as a generic impact with a number of causes.

4.2. Certain groups of people are more vulnerable than others to the impacts of seasonal and / or extreme weather. Refer to LRG 8.0 Guidance in the Management of Vulnerable Persons for guidance in relation to the consideration of vulnerable people.

4.3. One of the main ways to prepare for extreme seasonal weather is from data from forecasts and warnings of instances of extreme / seasonal weather; refer to Section 3 for further guidance.

4.4. The following guidance describes potential impacts of certain weather types and also considers some potential prevention and mitigation measures.

4.5. In addition to the guidance below, driver training including refresher training should be undertaken to cover the effects of different seasonal and adverse weather on driving style.

Snow

4.6. Snow falls in the UK can quickly lead to impacts on Light Rail systems, highways and other transport networks. Snow impacts passengers and staff including drivers, as well as infrastructure such as overhead line electrification (OLE), points operation and loadings on structures, etc.

4.7. There are different impacts and risks arising from the various types of snow, for example, dry and powdery snow is more likely to drift, whereas heavier wetter snow will remain and is more likely to flood and freeze points.

4.8. When accompanied by strong winds, snow can drift causing large variations in snow depth making it difficult to clear tracks, platforms and tramstop areas, etc. as well as points, which may require manual clearing.

4.9. It is recommended that if tramstops are cleared of snow, the priority for clearance should be at least 1 metre from the tramstop edge. This would encompass a clear area that includes the provided tactile surface and a platform edge marking strip as provided in DfT Guidance[9].

4.10. In addition, all accesses and pathways in and around the tramstop environment may be cleared of snow using not only shovels, but also leaf blowers to clear light snow. Pre and post snowfall gritting of tramstops and other pedestrian areas and walkways also assist.

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1046126/guidance-on-the-use-of-tactile-paving-surfaces.pdf

4.11. There is an increased risk of road collisions at crossings and / or shared areas due to road users losing control of their vehicles.

4.12. The use of ghost trams to limit deposits of snow may be appropriate to aid the management of freezing of tracks and build-up of snow on OLE equipment.

4.13. If no sight of the rail head is possible, then consideration should be given to how this is going to be managed by the driver with guidance provided to them. Vehicle manufactures should provide guidance on the maximum depths of snow that their vehicle may pass through without compromising safety or component damage at time of supply.

4.14. Adequate staff will be required with gritting and snow clearance, etc. Therefore, clear lines of communications and protocols need to be prepared including, where required, drafting in temporary staff to assist. As such, rosters need to be prepared as well as any appropriate training, especially for temporary staff, ahead of expected extreme and / or seasonal weather.

4.15. A build-up of snow may impact the functionality of the tram sanding system, for example, affecting nozzles, triggering the 'obstacle deflector', etc. Other preventative measures may need to be put in place for trams such as anti-freeze for window screen washers, increased 'in-service' thickness requirement for pantograph carbons, more frequent inspections of pantographs (especially if used for ghost tram activities), and leaving saloon heating on overnight, etc.

4.16. Exposure to snow and cold temperatures can also impact staff and passengers leading to different behaviours, and certain passengers and / or staff may be more vulnerable than others. In addition, the behaviour of motorists will also be different in shared and other highway sections where the tram vehicle interacts with motor vehicles.

4.17. The Light Rail system may consider drafting a reduced service or other alternative timetables for such occasions and / or occasions where continual night running may be the appropriate response. This may require preparation of draft duty rosters ready for such a scenario, with a clear system of communication established and similarly communicated to customers and users of the service.

4.18. When there is continual snow falling and forecasts have stated this will continue for some time, Light Rail systems may consider the suspension of services, or conversely, whether to continue running trams beyond the hours of their service to maintain clear tracks and assist maintaining a passenger service the next morning, with corresponding communications to customers and users of the service.

4.19. When making such decisions, the Light Rail service will need to consider the highway sections of their network and whether there will be sufficient clearing of snow on roads by the Local Highway Authority(ties) to facilitate this (if it is the responsibility of the Local Authority(ties)). In some circumstances, the Light Rail service may be able to assist the Local Highway Authority(ies) when seeking to continue / extending running of trams. As such, there need to be clear lines of communication established with the Local Highway Authority(ies).

4.20. The Local Highway Authority(ies) may need to be briefed on particular issues affecting Light Rail systems. For example, in extreme circumstances grooved rail can be compacted with ice that could serve to block return current leading to loss of power and increased risk of touch potentials or derailment risk. This extreme event can be exaggerated by a

number of factors taking place at once such as heavy road traffic moving slowly, heavy snow fall and very low temperatures, etc.

4.21. There may also be interruptions to power and / or other utilities and services either through an increased level of collisions with tramway infrastructure by third party road users, or by the extra demand put on the utility network.

4.22. When a Light Rail service can provide transport when roads are blocked, this may lead to a higher than usual number of passengers who are using the system for the first time and so Light Rail systems may need to be aware of the potential to react to this.

Extreme Cold (Ice / Frost / Freeze-Thaw)

4.23. Ice and frost can impact roads, tracks and access areas for passengers and staff. Appropriate gritting needs to be undertaken and as for snow, extra non-maintenance staff deployed if frost and ice is widespread. Rotas need to be adequately prepared in advance and a clear system of communication established and all staff provided with appropriate PPE.

4.24. The presence of black ice or conditions for this are especially problematic as it is hard to detect and thus hard to treat and warn people until it has been identified.

4.25. The Light Rail system may need to consider urban areas outside of the boundary of the Light Rail system where surfaces may not be treated and people may be at risk of slipping onto the tracks, for example, from an adjacent pavement or access pathways. This may require consultation with the relevant Local Highway Authority(ies).

4.26. Although rare, freezing rain can fall, freezing on contact with very cold surfaces such as roads and windscreens ('rime ice accretion'). This can lead to very dangerous icy conditions affecting the Light Rail system by causing reduced visibility, low adhesion (as detailed in Section 5) and an increase braking risk from third party interaction.

4.27. With severe frost there is a risk of rail joints pulling apart. Network Rail Standard NR/L3/TRK/3013[10] details roles and responsibilities in the management of weather precautions relating to cold weather situations relating to track.

4.28. When extremely cold temperatures are experienced, small changes to tram maintenance / washing may be required, for example, not washing trams before / after service to reduce fleet issues and plant failure.

4.29. As above for snow, the use of ghost trams may be appropriate and a build-up of ice that may impact the functionality of the tram sanding system, for example, affecting nozzles, triggering the obstacle deflector, etc.

4.30. Ice may also affect the OLE; see Section 5 for further guidance.

4.31. Points, other track work and junctions need to be closely monitored as well as substations, for example, pre-planned checks of points heaters where they are fitted.

Rain / Drizzle

10 Management of Cold Weather Precautions (Track)

4.32. The main hazard from heavy rain is flooding. Flooding varies from being localised in a few places lasting an hour to widespread affecting buildings and submerging roads tracks and lineside equipment and buildings. If no sight of the rail head is possible, then consideration should be given in how this is going to be managed by the driver with guidance provided to them. Vehicle manufactures should provide guidance on the maximum depths of water that their vehicle may pass through without compromising safety or component damage.

4.33. Light Rail systems may want to undertake additional checks and maintenance of drainage systems as well as utilise pumps, including setting out specific locations for their use as well as appropriately training staff and agreeing specific measurements to be used, as would need to be detailed in the EWMP (refer to Section 6 for further information). Attenuation tanks may be required in some locations with additional pumps to ease pressure on attenuation tanks where required.

4.34. Where assistance may be required from the fire service, it is helpful to already have protocols and procedures agreed and in place that can be activated as and when assistance is required to deal with flooding.

4.35. In addition to flooding, tracks and highway conditions can be affected with water spray and standing water. The combination of rain and spray from trams may make visibility difficult for trams, pedestrians and other motor vehicles. Pedestrians in particular may not be able to see line markings and other boundary treatments and / or warnings. As such, emergency speed restrictions (ESRs) may be required in some locations and if so, pre-agreed thresholds and protocols agreed. There may also be interruptions to power and / or other utilities and services.

4.36. The functionality of the tram can be impeded, for example, impacting the sanding system by affecting nozzles, triggering the obstacle deflector, etc. In addition, rain can wash away lubricants, for example, at points and increase the risk of unreliability.

4.37. Light rain and / or drizzle can also affect a Light Rail system causing low adhesion (refer to Section 5) and lead to an increase in emergency braking, especially as there is often a reduction in visibility. Reduced visibility may also occur with a sudden clearing of skies combined with bright sun reflecting off a wet road surfaces, etc.

4.38. In addition, passenger and other persons behaviour may be different as people hurry to get out of the rain, to jump over puddles and / or handle their personal belongings, as well as congregating under canopies where available and / or away from drainage outfalls as this may create changing behaviours whilst at tramstops and boarding.

4.39. There may be a risk of landslides (with a need to take learnings from the landslide at Carmont[11] where relevant) and impacts on tunnels and other structures leading to changes in loading to the tunnel linings, etc which then could lead to more defects or damage, for example, a brick arch collapse.

Fog

11 Rail Accident Investigation Branch (RAIB) Report 02/2022 - Derailment of a passenger train at Carmont https://www.gov.uk/raib-reports/report-02-slash-2022-derailment-of-a-passenger-train-at-carmont

4.40. In continuous fog, drivers are more likely to drive slowly because of the constant low visibility conditions. However, when fog is patchy, drivers are more likely to vary their speed. Radio reports can assist in providing information about moving fog bands.

4.41. The Highway Code provides the following specific guidance for driving in fog (Rules 234 to 236[12]):

- (Rule 234) Before entering fog check your mirrors then slow down. If 'Fog' is shown on a sign but the road is clear, be prepared for a bank of fog or drifting patchy fog ahead. Even if it seems to be clearing, you can suddenly find yourself in thick fog;
- (Rule 235) When driving in fog you should:
  - Use your lights as required (see Rule 226[13]);
  - Keep a safe distance behind the vehicle in front. Rear lights can give a false sense of security;
  - Be able to pull up well within the distance you can see clearly. This is particularly important on motorways and dual carriageways, as vehicles are travelling faster;
  - Use your windscreen wipers and demisters;
  - Beware of other drivers not using headlights;
  - Not accelerate to get away from a vehicle which is too close behind you;
  - Check your mirrors before you slow down. Then use your brakes so that your brake lights warn drivers behind you that you are slowing down; and
  - Stop in the correct position at a junction with limited visibility and listen for traffic. When you are sure it is safe to emerge, do so positively and do not hesitate in a position that puts you directly in the path of approaching vehicles; and
- (Rule 236) You MUST NOT use front or rear fog lights unless visibility is seriously reduced (see Rule 226) as they dazzle other road users and can obscure your brake lights. You MUST switch them off when visibility improves. Law RVLR Regulations 25 and 27[14].

4.42. Tiny supercooled liquid water droplets in fog can freeze instantly on exposed surfaces when surface temperatures are at or below freezing ('rime ice accretion'). Such surfaces may include tree branches, stairs and rails, sidewalks, roads and vehicles, etc.

4.43. The main impacts of fog in relation to UK Light Rail systems are visibility as per line of sight operations and low adhesion (refer to Section 5). As such, ESRs may be appropriate in some locations and if so, pre-agreed thresholds and protocols agreed.

4.44. In severe and significantly reduced visibility, consideration may need to be given to suspending non-urgent maintenance or inspections if other additional risk control measures are not possible.

12 Driving in adverse weather conditions - Fog (234 to 236) - https://www.highwaycodeuk.co.uk/fog.html
13 Driving in adverse weather conditions - (226) - https://highwaycode.org.uk/rule-226/
14 Road Vehicles Lighting Regulations 1989 Regulation 25: https://www.legislation.gov.uk/uksi/1989/1796/regulation/25/made and Regulation 27: https://www.legislation.gov.uk/uksi/1989/1796/regulation/27/made

Thunder and Lightning Storms

4.45. Thunder and lightning storms can occur at any time of the year, although they are most common during the summer months. When frequent thunder and lightning moves across large areas there, is an increased risk of impacts including large hailstones, gusty winds and torrential downpours etc., and just a single strike of lightning can be enough to cause disruption and damage to Light Rail systems.

4.46. Impacts from thunderstorms can be very localised, for example, the amount of rainfall can vary over a short distance. Refer to further guidance in Sections 4.32-4.39 above in relation to rain and flooding and Sections 4.50 to 4.56 below in relation to high winds.

4.47. Visibility may be affected as per line of sight operations. As such, ESRs may be appropriate in some locations and if so, pre-agreed thresholds and protocols agreed.

4.48. Although trams and infrastructure have built in protection against lightning strikes with lightning arrestors, if there are not adequate tram vehicle / infrastructure spares, this may affect the number of trams put into service during or after a thunder storm.

4.49. Impacts may include disruption to power and / or other utilities, both in terms of the Light Rail system itself and to widespread impacts to the power causing prolonged interruptions to power and / or other utilities and services.

High Winds

4.50. Impacts of strong winds and storms include very low loose debris flying around, tree damage with branches and in some cases trees being brought down, as well as an increase in staff, passenger slips, trips, and falls, etc.

4.51. Light Rail systems may need to send out teams to check drainage systems and other parts of the Light Rail system infrastructure that could be impacted by a high volume and / or size of flying debris. Accompanying rotas and communications need to be prepared in tandem with such actions.

4.52. There may be structural damage to Light Rail system buildings and equipment such as OLE, tramstop equipment, etc. It is helpful when consideration is given to sheltering or strengthening equipment when the Light Rail system are being designed and constructed, for example, the appropriate use of foliage.

4.53. Trees can also be the catalyst for other impacts, for example, damage to adjacent structures / buildings, loss of power when a tree falls and blocks the tracks / highway, or onto power lines, etc. This causes an additional hazard if the power lines could potentially still be live and within reach of staff, passengers or others.

4.54. The Light Rail system should prepare to have lines of communications with the Local Highway Authority(ies) in relation to highway obstructions, including those caused elsewhere that then have an impact on traffic diverted to sections of the highway that are shared with the Light Rail system.

4.55. In some areas and / or on some structures, there may be unusual or heightened cross winds. ESRs and / or suspension of services may be required and if so, pre-agreed thresholds and protocols agreed. In addition, there may be higher than usual volumes of motor traffic on shared sections of the Light Rail system if parts of a highway network have been closed.

4.56. Drivers will also need to be aware that other road users, for example, high sided vehicles and cyclists may make erratic movements in high winds.

Extreme Heat

4.57. Extreme heat can place tension on the Light Rail system itself, both in terms of the infrastructure and staff and passengers.

4.58. ESRs may need to be in place in some locations if there are particular risks of drivers being dazzled by sunlight, etc. with pre-agreed thresholds and protocols agreed.

4.59. Some changes in working practices and daily routines may be required for staff and the Light Rail system, for example:

- Adequate access to drinking water (providing supplies);
- Allowing staff on-board trams to disembark and re-embark;
- Changes to uniform (removal of ties, etc);
- Instructions on best use of windows to be open or closed dependant on climate control available;
- Advice on passenger door opening all doors at every stop (dependant on available climate control); and
- Ventilation and / or air conditioning (HVAC) settings that provide the best results on trams.

4.60. Some heat sensitive systems and equipment may fail and therefore, Light Rail systems may want to increase maintenance and / or visual inspections of their systems. This may, for example, include monitoring track for risk of buckling (expansion gaps) and the loss of overhead tension with the sagging of OLE and overheating electronics, etc.

4.61. In addition to assisting when there are other types of weather, it is helpful at the design and construction stages of a Light Rail system to consider placing trackside equipment in areas that may provide shelter, for example, the planting of appropriately contained foliage near the equipment to shade from the sun or double skinned cabinets, as well as the colour of the paint used for the cabinets, etc.

Other Seasonal Impacts

4.62. In addition to the weather types above, there may be other seasonal variations, for example drought and / or leaf fall in autumn and blossom fall / springtime growth where additional measures and maintenance may be required, including measures in relation to low adhesion (refer to Section 5 for further information). This may include preventative measures such as the following examples:

- Removing rail head contamination in specific areas;
- Treating rail head for better traction;
- Placing ESRs at high risk locations;

- Temporary signage, radio announcements, etc. to advise drivers of reported problem areas;
- Engaging the relevant Local Authority(ies) / Local Highway Authority(ies) to assist alongside adequate pruning; and
- Maintenance of foliage alongside the proper design and landscaping of areas in and adjacent to Light Rail systems especially tramstops.

4.63. Further to Sections 4.37 and 4.58, winter sun can also be an issue, especially if it is cold and bright. The Highway Code states that if a driver is dazzled by bright sunlight, they should 'slow down and if necessary, stop'[15]. In order to mitigate against the 'glaring light', adequate provision should be made with sun downs and briefings to drivers, etc.

15 Driving in adverse weather conditions – Hot Weather (Rule 237) - https://highwaycode.org.uk/rule-237/

5. Infrastructure Considerations

5.1. There are a number of infrastructure issues in relation to weather and climate resilience. Although measures should be included in the design of the Light Rail system, enhancements may be considered to cater for weather. The two main issues are highlighted below.

5.2. In addition, there may be some additional considerations for the depot environment, for example, clearing and gritting, compacting of snow in parking areas, high winds through sheds, etc.

Low Adhesion

5.3. While low adhesion is not manifested solely as a result of weather, it can be a contributing factor and risks associated with this are certainly increased during certain times of the year.

5.4. 'Wet-rail' phenomenon is thought to be produced by low levels of water on the railhead. As such, low adhesion incidents are more likely to occur on mornings when there is dew on the railhead, or when there is drizzle, fog or frost, etc. When the rail surface or the wheels are coated with contaminants, there is an increased risk of low adhesion.

5.5. The effect of low adhesion is that it limits the acceleration and braking capability of trams as the wheels slip or slide on the rails, which can lead to the following impacts:

- Trams running too far or too fast: potentially leading to a movement authority being exceeded (signal passed at stop (SPAS)), an intended stopping place being overrun, derailment or a collision;
- Collision with another tram vehicle or tram infrastructure due to the inability to bring the tram to a stand short of the conflict point due to wheelslide;
- Derailment due to the loss of tram detection through the non-operation of track circuits;
- Damage to wheel or rails as wheels slip or slide during acceleration and braking;
- Injuries and fatalities leading to damage to the industry's reputation and if involving staff, an impact on timetables and staff resources, all of which are costly in different ways; and
- Failure to clear excess sanding in the groove rails can lead to excessive wheel slide.

5.6. Guidance on the management of low adhesion is detailed in RIS-8040-TOM (Issue 2)[16]. However, Light Rail systems may have their own procedures for the management of low adhesion.

5.7. Clear recommendations relating to low adhesion are set out in RAIB Report 17/2016[17]. These include to actively review and recognise any risks arising from low adhesion conditions, and then to proactively manage these risks.

16 Managing Low Adhesion - RSSB (Rail Safety and Standards Board) rail industry standard
17 Collision between two trams at Shalesmoor: https://www.gov.uk/raib-reports/collision-between-two-trams-at-shalesmoor

5.8. Measures for mitigating the impact of low adhesion can be both proactive and reactive, for example, the following proactive measures (not exclusively):

- Cleaning and prevention of contaminated rail;
- Increased groove cleaning activities;
- Monitoring of identified high risk areas for leaf fall including pre planning regular sweep of the tracks affected with any additional cleaning as required;
- Obtaining detailed weather forecasts to indicate the likelihood of low rail head adhesion conditions and then the dissemination of this information to tram drivers and to the infrastructure team responsible for cleaning the contaminated areas;
- Carrying out pre-emptive applications of traffic film remover to the rail head in areas known to be at risk of low adhesion;
- Assessing the need for any additional staff resources and training within the infrastructure team during peak seasons;
- Ensure that the OCC staff are made aware of the importance of passing driver's reports onto the infrastructure team responsible for cleaning the contaminated areas;
- Periodic reviews of the effectiveness of adhesion management;
- Collection and review of data relating to reports of instances of low rail adhesion; and
- Introduction of a daily low adhesion notice based on leaf fall forecasts and the predicted level of risk for that day, categorised as green, amber, red and black.

5.9. Reactive measures include the following (not exclusively):

- Cleaning and prevention of contaminated rail;
- Tram drivers reporting to the OCC if they have experienced wheel slide caused by low adhesion;
- The OCC logging reports and advising the infrastructure team;
- Suitably qualified infrastructure staff visiting the reported location, and treating the railhead, for example, using a tested and agreed film remover product; and
- Vegetation management to reduce risk of leaf falls in track areas.

Ice on OLE

5.10. Ice on the OLE causes power to be lost and can generate damaging arcs, disturbing the modern engine control units and destroying both the pantograph and the overhead wire.

5.11. In severe cases, the contact wire or even the entire catenary system may break down under the load of ice. There is also the risk of icicles forming in tunnels where they can come into contact with the OLE. In addition, ice may cause arcing and lead to excessive wear to the pantograph conductors.

5.12. Icicles can form in tunnels, under bridges or other overhanging structures that can either cause damage to pantographs, come into contact with the OLE or create a dropping hazard to those underneath.

5.13. There are a number of methods available to alleviate impacts caused by ice, including the following:

- Use of ghost trams;
- Pre-season inspections on equipment tolerances, for example, ensuring the OLE system is set up correctly for tension and sag stresses;
- Inspection of pantograph carbons;
- Application of propylene glycol as a prevention;
- Application of glycol to remove ice;
- Ice pantographs;
- Electrical traction filters; and
- Software prediction tools.

5.14. In Continental Europe, automated systems are used where a fluid is applied to the overhead line via a contactless spraying unit either on a road rail vehicle or modified tram vehicle. In some applications, this covers up to about 30km of overhead lines per hour.

5.15. Direct installation methods are also available which apply efficient electrical heating into the contact wire / overhead line to bring the temperature above freezing point. These systems are controlled using air temperature, wire temperature, humidity, dew point and / or the weather forecast where the system will wirelessly monitor and report failures and ensure optimum energy saving / use for the entire network.

6. Extreme Weather Management Plan

6.1. An Extreme Weather Management Plan (EWMP) can assist a Light Rail system to pre-plan for weather impacts by establishing appropriate actions and procedures including 'readiness' plans. The EWMP provides a guideline for all levels of management, supported by more focused and comprehensive 'emergency plans' for singular, complex, and / or high-impact events.

6.2. Information on network system design parameters and the actual setup of the system should be fed into the EWMP to provide a starting point for determining any seasonal preparedness requirements for the infrastructure.

6.3. The EWMP should set out a clear hierarchy of responsibilities, delegations and communications (including some of those listed in Section 3.23-3.33), clearly defining activation thresholds and responsibilities for all designated staff.

6.4. Adequate and appropriate staff resources need to be addressed within the EWMP so they are available, planned and coordinated to sufficient levels with adequate training and information including for 'non-operational' staff who may be deployed along with sufficient equipment (for example, sun screen, water, warmer PPE / hoods (where permitted), etc.).

6.5. Staff welfare planning needs to be included, for example, collecting and dropping off staff during extreme weather or to deal with subsystem failures, such as detraining passengers from stranded vehicles, etc.

6.6. Equipment checklists should ensure adequate equipment is available in the appropriate locations including a maintenance check of any specialist equipment to ensure it is in working order since it was last used. If there is any specialist equipment, adequate training in each location may need to be deployed especially if it has been newly acquired, for example, the use of water pumping equipment or snow clearing equipment.

6.7. Provision checklists should also be detailed in the EWMP to ensure adequate supplies are in stock and assigned to the right locations so they are available when required, for example, supplies of gritting salt. Checklists also need to be appended in relation to preparing tram vehicles.

6.8. The setting up of an Extreme Weather Response Group (EWRG) will ensure that the EWMP is in place and is followed, to ensure preplanning has been undertaken sufficiently. The membership should reflect situation assessments and ensure decisions can be made efficiently and effectively in line with health and safety best practice. They will also consider all perceivable risks and ensure the risk register is up to date in relation to weather impacts.

6.9. The EWRG should meet at an appropriate and sufficient frequency. This would include ahead of seasonal changes, for example, a meeting held each September could look ahead to the winter season, as well as different frequencies and / or ad hoc frequencies in response to different levels of weather warnings.

6.10. External organisations such as those listed in Section 3.32 can provide practical, technical and practical input into the EWMP and preplanning, as well as during the event itself. Communication and coordination with external organisations is key. For example, making

sure that snow ploughing activities on highways do not leave a ridge of ploughed snow across the tracks at crossings, etc.

6.11. The EWMP should be reviewed at appropriately regular intervals, for example, annually, following a seasonal / extreme weather event, and / or following the highlighting of additional risks from the occurrence of a weather event at a different Light Rail system, etc.