RBDG-MAN-029-0103

Design guidelines

Adaptation to Climate Change

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Table of Contents

1. Introduction

This document sets out the requirements for the application of the additional risk assessment towards climate change and adaptation measures development for the Rail Baltica railway during design, construction and operation stages to enhance Rail Balticas resilience to the current and furture climate.

Adaptation to climate change faces great long-term uncertainty, therefore it is the task of the designer to define and implement robust and futureproof design solutions (adaptation measures) which both provide a benefit in the current climate as well as resilience to the range of potential future climate change effects.

In cases where national requirements or design codes do not yet incorporate consideration of climate change or have less stringent requirements, the guidance and values shall be taken from Design Guidelines. If no criteria or guidance is available, assumptions shall be made. Assumptions shall be notified to RB Rail and have to receive ex-ante approval from RB Rail.

Relevant information, regarding climatic data, risk asssessment and exisiting adaptation measures relevant to the design stage, is summarised in this document.

2. Climate change impacts and climate hazards relevant to Rail Baltica

2.1. Climate change trends

The up-to date scientific evidence of the changing climate in Estonia, Latvia and Lithuania is summarized as follows:

1. **Mild winters, less snow and lower spring peak runoff** (high confidence). Frost days will be reduced by up to 80 days per year for 2100. There is a very high peak of around 0 °C .The snow cover will decrease substantially and not permanently formed and the spring peak runoffs are earlier, lower and less steep. The frequency of freezing rain and hail will grow highly probably. Still, short periods of intense cold weather can occur. The biggest direct human risk where weather is a factor is passenger slip.

2. **Heatwaves** (high confidence). Heatwaves occur more often, rise of future temperatures, including summer maximum temperatures up to approximately 5°C, which could lead to maximum temperatures around 40° C, according to worst case climate change scenarios. Wildfire risk will increase.

3. **More storms, winter storms** (medium confidence). An increase in the average wind velocity in winter, with increased likelihood of storms, is forecasted, but average annual wind speed not expected to change much. Wind gust speeds and likelihood of storms may increase, especially during the summer period. The number of thunderstorms will grow.

4. **More heavy rainfall** (medium confidence). Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period in the RCP8.5 scenario. Heavy rainfall is characterised by a very high spatia-temporal variability causing pluvial floodings, ground instabilities.

2.2. Historic climate extremes and future projections

Historic data from the meteorological stations along Rail Baltica (Tallinn-Harku, Kuusiku, Pärnu, Ainaži, Skulte, Riga, Bauska, Lazdijai, Vilinius, Kaunas and Panevėžys) during period 1981-2010 or 1981-2017 (with some exceptions, due to data availability) and future projections of most relevant climatic variables based on relevant scientific evidence are presented in the table below.

Extreme temperatures and cold and heat waves, extreme precipitation events and relevant wind related variables during period 1981-2017, recorded in 11 meteorological stations along Rail Baltica, are presented in Figures 1, 2 and 3.

Registered climatic extremes or events near Rail Baltica corridor	Future projected climate change
Maximum recorded air temperature – +35.5 °C (Panevėžys in August 1992)	Maximum air temperature in the South-East part of Lithuania can reach almost 40 °C.

Registered climatic extremes or events near Rail Baltica corridor	Future projected climate change
Minimum recorded air temperature – -35.7 °C (Ainaži, 2003)	**Clear trend of increased temperatures in the winter periods.** However, the absolute minimum temperatures are modelled with very low certainty by current climate scenarios.
Maximum sum of 24-hour precipitation – 86,8 mm (Pärnu, June)	**Precipitation will be increased, especially during winter period. Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period and over 1.5 times in summer period.** However, the distribution of precipitation by intensity is not modelled by climate scenarios and the uncertainty of statements and forecasted data remains extremely high.
Maximum sum of one-minute precipitation – 6,6 mm (one-minute data only available for Lithuania) (Panevėžys, July 2010)	**As above.**
Maximum snow cover depth – 66 cm (Kuusiku)	**Clear trend of increased temperatures in the winter periods, projections for the end of 21th century show significant decrease of snow cover in Estonia. It is predicted that until 2035 the maximum snow cover thickness <u>will</u> decrease by 4-5 cm, until 2065 - by 5-9 cm, and until 2100 - by 5-14 cm in Lithuania.**
Rail Baltica crosses or is located near **14 national level flood risk zones** (12 different rivers and one lake – Pärnu, Gauja, Daugava, Misa, Mēmele, Mūsa, Nevėžis, Nemunas, Neris, Vokė, Želsvele and Šešupė rivers and Maardu lake.)	**Spring floods (main flood risk) will be less severe due to milder winters and inconsistent snow coverage. Maximum discharges of spring floods have decreased in the Baltics over the period 1922-2010.**
Maximum average wind speed – 20 m/s (Riga in January)	**The average wind speed is unlikely to change much, but wind gusts may increase, especially during the summer period. It is likely that the recurrence of storms and hurricane winds will increase, especially during the cold season**. **Likelihood of severe storms (21 m/s or more) might increase,** but there is much uncertainty in long-term predictions.
Maximum wind gust speed – 40 m/s (Ainaži in November and Bauska in January)	**As above.**
Highest average annual number days with thunder – 26 days (Lazdijai)	**Higher air temperature causes more intense formation of typical summer thunder clouds. Natural phenomena associated with thunder clouds will be more likely and with more severe consequences**, but more detailed projections are not possible due to uncertainty and random spatial nature of the thunder events.
Highest average annual number days with freezing rain – 7,7 days (Panevėžys)	Projections of increased temperatures in the winter periods with more precipitation and **increased likelihood of wet snow, freezing rain, glazed frost and ice forming events.**
Maximum frost penetration of soil – 190 cm (Keo measure point, located near Kuusiku station, in 2014)	No clear projections available about frost penetration of soil for Estonia, Latvia and Lithuania, though **the soil frosting would be affected by much warmer winters.**

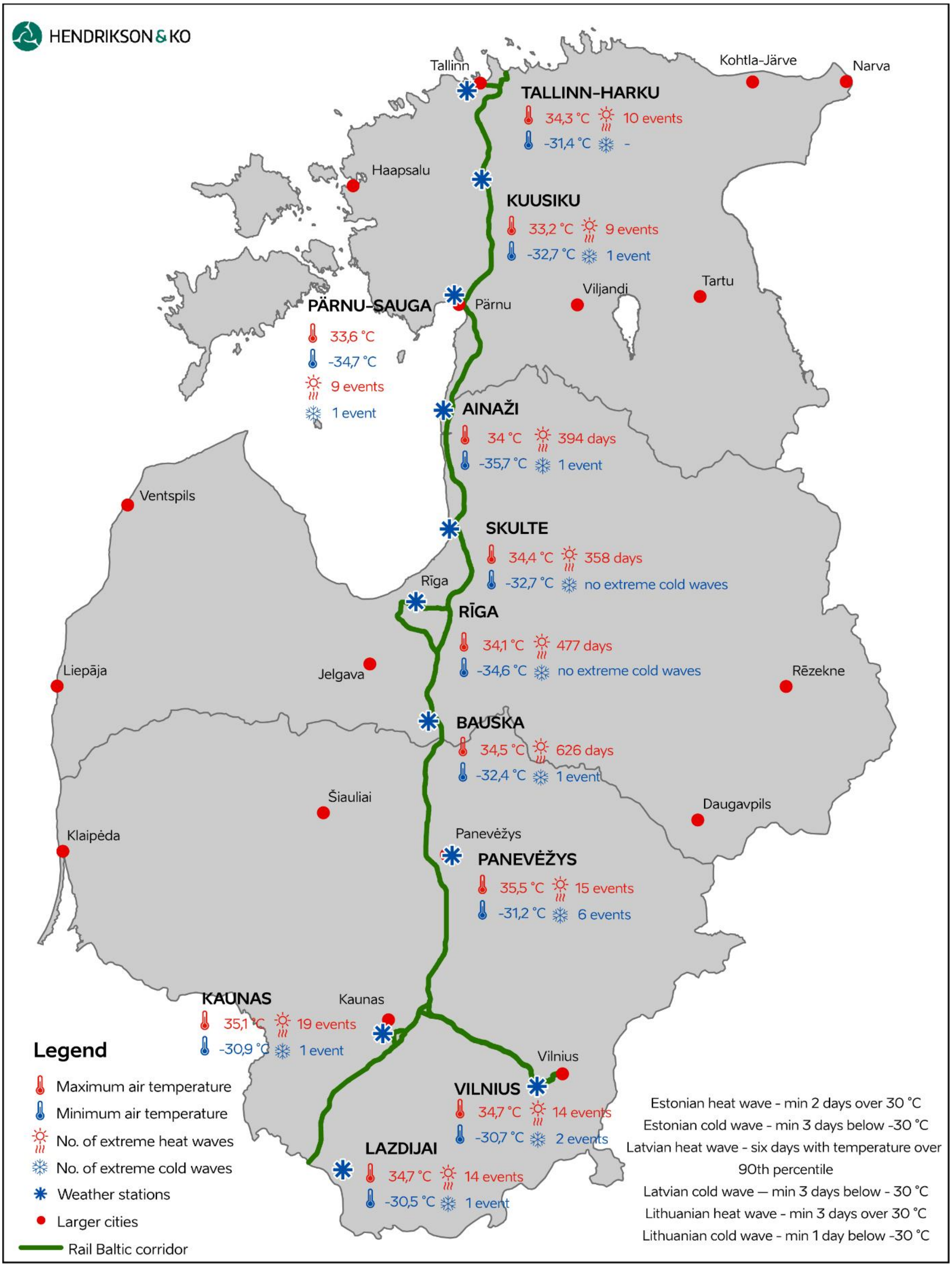


FIGURE 1 EXTREME TEMPERATURES AND COLD AND HEAT WAVES DURING PERIOD 1981-2017 IN 11 METHEOROLOGICAL STATIONS ALONG RAIL BALTICA

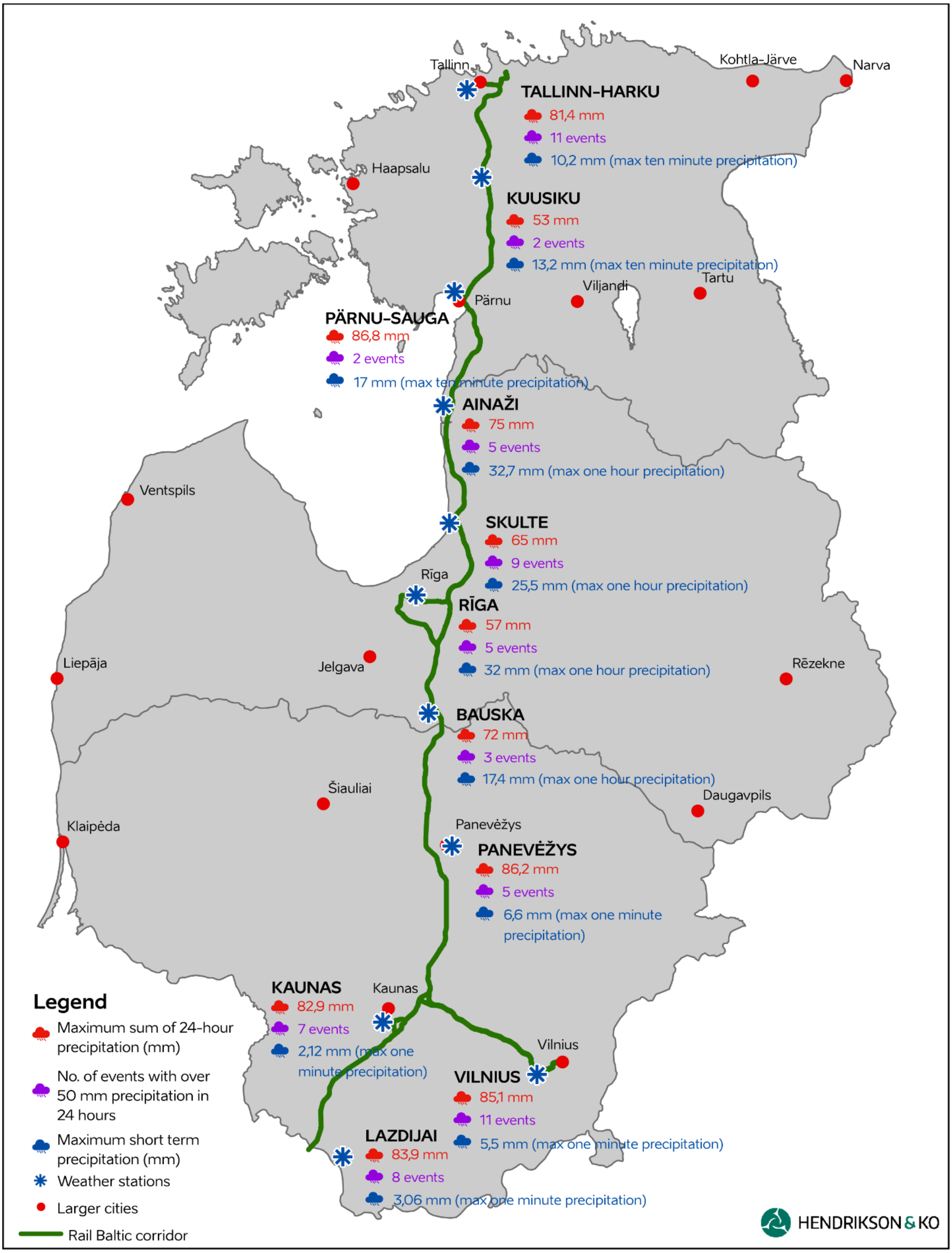


FIGURE 2 EXTREME PRECIPITATION EVENTS DURING PERIOD 1981-2017 IN 11 METEOROLOGICAL STATIONS ALONG RAIL BALTICA

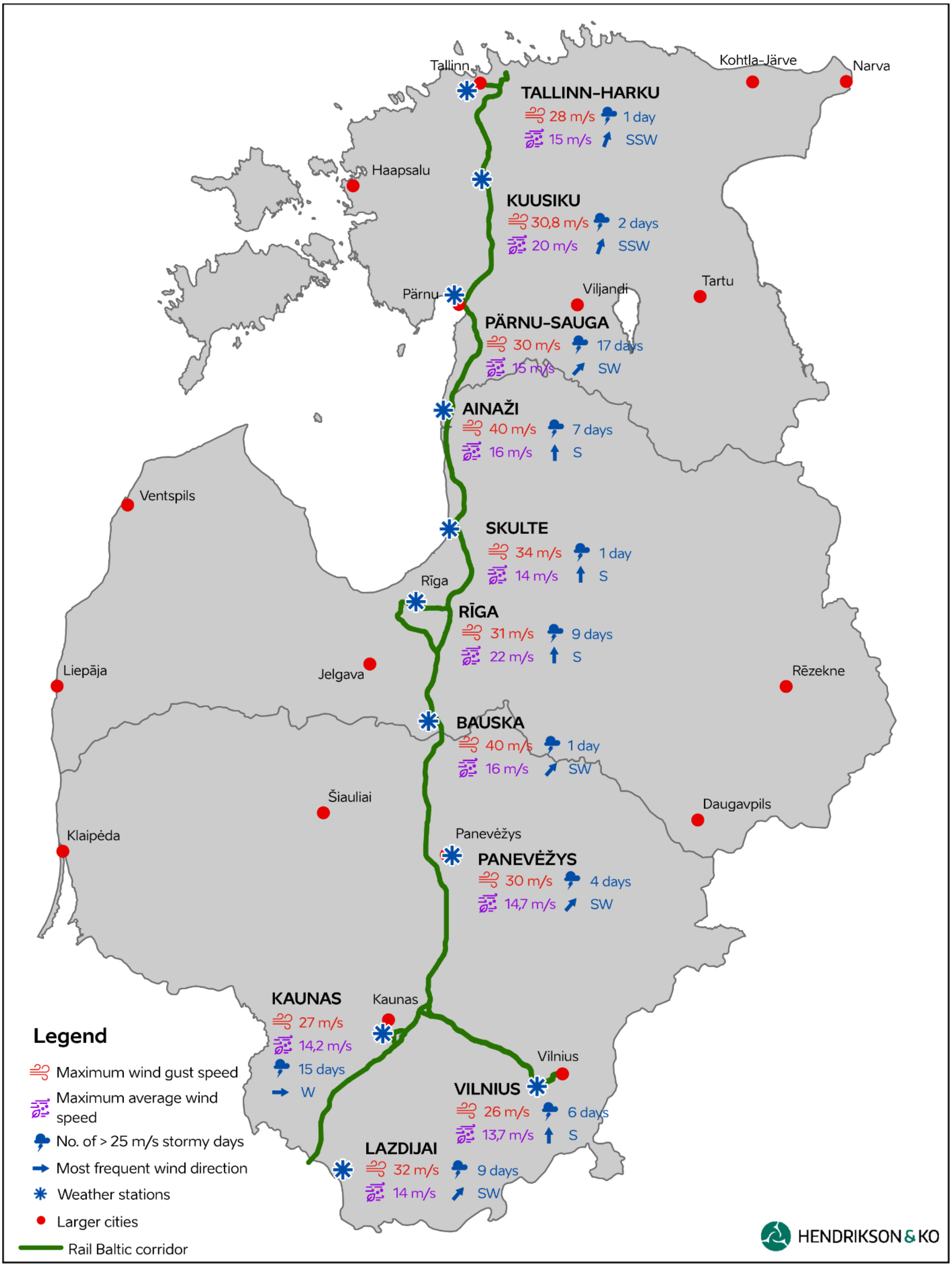


FIGURE 3 EXTREMES OF WIND CLIMATE DURING PERIOD 1981-2017 IN 11 METEOROLOGICAL STATIONS ALONG RAIL BALTICA

2.3. Climate hazards

The high and medium risk climate hazards defined based on the sensitivity, vulnerability and risk assessment:

- ✓ Flooding and heavy rain
- ✓ Wind and storms
- ✓ Ground instability and landslides
- ✓ Lightning
- ✓ Low temperatures
- ✓ Snow, freezing rain and glazed frost
- ✓ Frost penetration of soil
- ✓ High temperatures
- ✓ Fog
- ✓ Draught and wild fires

3. Adaptation plan

3.1. Risk assessment

Summary of the risk assessment results are presented in the Table below.

Climatic hazards and variables	Assets or services at risk	Consequences	Risk rating
Flooding and heavy rains	Track and embankment, catenaries, bridges, culverts, access and maintenance roads and road infrastructure	Fluvial and pluvial flooding of track or embankment resulting in instability problems in cutting areas, tunnels and lowlands with unfavourable runoff and drainage conditions (incl. problems with culverts). Fluvial flooding damage to bridge structures and embankment crossing rivers and streams and ditches. Damage to the access roads or road infrastructure and/or possible access restrictions to stations, track, substations, etc. due to general flooding of nearby areas.	**Medium**
Wind and storms	Train traffic and all infrastructure, but especially catenary, noise barriers, fencing and drainage	Failure of or direct damage to parts of structure or infrastructure as a result of changes in extreme winds and gustiness. Noise barriers, OLE and fencing are likely to be most at risk. Possible blockage of railway drainage systems due to obstructions and windborne debris from domestic or third-party objects, as well as potentially trees landing on track and causing damage to catenaries and fencing. Speed restrictions to trains due to high wind events.	**Medium to High**
Ground instability and landslides	Earthworks and structures (mainly bridges, OLE, access roads, noise walls, passenger stations, signs, safety barriers, utilities and cables)	Increased instability can lead to landslides, earthworks failures and damage to structures (mainly bridges, catenaries, noise walls, passenger stations, signs, safety barriers and cables).	**Medium**
Lightning	Buildings, structures and lineside equipment (signalling and track circuit) and traffic	Direct damage to buildings, structures and lineside equipment (signalling and track circuit) and indirect impacts (maintenance, traffic).	**Medium**
Low temperatures	Rails, underground cables and utilities	Increase risk of rail and weld breaks due to extreme cold conditions due to bad quality rail or rollingstock. Cable breaks due to embankment processes.	**Medium**

Climatic hazards and variables	Assets or services at risk	Consequences	Risk rating
Snow, freezing rain and glazed frost	Points operating equipment (POE), catenaries and overhead power lines, Station platforms, footways, stairs, etc	Points operating equipment (POE) failures due to snow and ice accretion. Damage to catenaries. Accidents due to slippery surfaces in station platforms, passenger walks, stairs, etc.	**High**
Frost penetration of soil	Railway and maintenance road embankments	Potential damage to the railway and maintenance road embankments through frost heave.	**Medium**
High temperatures	Rails, expansion joints and electrotechnical equipment	Rail buckling and/or associated misalignment problems due to Critical Rail Temperature (CRT) . Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to bridges structures and indirect of damage of other assets dependent upon bridge.	**Medium**
Fog	Operations, maintenance, staff and passengers	Operations (e.g. shunting), maintenance could be disrupted and passengers and staff risks increased.	**Medium**
Draught and wildfires	All infrastructure and services	Direct damage, disruptions due to flying ash and precautionary measures caused by wildfires.	**Medium**

3.2. Adaptation measures

Adaptation to climate change aims to make Rail Baltica railway assets, operations and maintenance resilent to adverse climate change effects. Thus, the design criteria shall be introduced in railway design phase and implemented in the railway construction phase.

Climate change adaption measures and principles for the design stage were developed for processes and assets defined having high or medium risk to observed or future climate conditions based on risk and vulnerability assessments.

Climate change adaptation measures and additional information for each specific measur (if necessary) are presented in subchapters below. These climate change adaptation measures shall be taken in to the account during the desing stage.

3.1.1 Peak flow calculations shall take into consideration the effects of climate change

Purpose of the measure - The same approach for the climate change allowance modelling should be applied in all the three Baltic countries to ensure a climate resilient railway.

Relevant climate change trends - Precipitation will be increased, especially during winter period. Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period and over 1.5 times in summer period according to the RCP8.5 scenario. However, the distribution of precipitation by intensity is not modelled by climate scenarios and the uncertainty of statements and forecasted data is extremely high. Extreme precipitation events have become already more frequent and intense during 1957-2009. Spring floods will be less severe due to milder winters and inconsistent snow coverage. Maximum discharges of spring floods decreased over the period 1922-2010 and this trend will likely to continue in the future due to milder winters and inconsistent snow coverage.

Additional information - Flood, HWL and peak flow modelling and calculations and technical solutions like drainage systems and pumping equipment (if required) shall also consider potential increase of ground level levels in future winter period due to increased precipitation and minimal evaporation in the winter period.

Climate change factor is not currently included in Estonian and Latvian (except Riga region) peak flow calculations. Latvia is expected to have new flood and peak flow estimations, which include climate change factor, by 2019. Climate change aspect on flood risk shall be considered in the design process. Not considering climate change in peak flow calculations may lead to under and over estimations, which would increase flooding events risk in first case and cost inefficiency for the latter.

Biggest rivers – Daugava and Neris - are regulated, their runoff is controlled and risks mitigated as dams and other hydroengineering is designed and constructed by the highest standards.

<u>The Pärnu River Case for declining flooding risk:</u> Pärnu river 100-year maximum peak flow estimation from Estonian Weather Authority is based only on historic data and maximum peak flows registered in 1920s, 1930s, 1940s or 1950s are determining values for future predictions. Maximum flow rate of 798 m^3 was registered on 25.04.1931 in Oore station on Pärnu river downstream. 42 highest peak flows were all registered during period 1922-1956. Followed by 43rd maximum peak flow of 515 m^3 on 06.04.2010 (highest during period 1957-2017). Applying peak flow runoff as 846 m^3, acquired on 13.08.2015 in Rail Baltica preliminary design stage from the Estonian Weather Authority and adding additional 0,5 m to the HWL as climate change allowance it woud mitigate in very high probability climate change risks.

3.1.2 Designer shall cooperate with National Weather Authorities to upgrade flood zone modelling and high-water level (HWL) and peak flow calculations (if necessary), to specify methodology which takes into account climate change allowance in the peak flow predictions.

Purpose of the measure - Up-to-date flood zone modelling, high-water level (HWL) and peak flow calculations methodology, taking into account climate change, would mitigate risks with optimal resource usage and cost efficiency.

Relevant climate change trends - Same as under measure 3.1.1.

Additional information – Same as under measure 3.1.1.

3.1.3 Sensitive areas, where water level monitoring is required due to risk of flooding or heavy rain, shall be proposed by designer, if necessary.

Purpose of the measure - Up-to-date flood zone modelling, high-water level (HWL) and peak flow calculations methodology, taking into account climate change, would mitigate risks with optimal resource usage and cost efficiency.

Relevant climate change trends - Precipitations will be increased, especially during winter period. Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period and over 1.5 times in summer period according to the RCP8.5 scenario. However, the distribution of precipitation by intensity is not modelled by climate scenarios and the uncertainty of statements and forecasted data is extremely high.

Additional information - Critical locations with potential flood risk (including due to third party risk) shall be defined by geotechnical and hydrological studies and potential locations for remote condition monitoring systems, for operation stage, shall be suggested during Detailed Technical Design stage, if necessary. Sensitive areas to consider (shall be elaborated in further stages) – tunnels, cuttings, areas with extensive artificial surfaces (cities). Designer shall propose a suitable location (including necessary connectivity solutions) to place the sensors. Sensors shall be compatible with centralized Rail Baltica monitoring systems.

3.1.4 Underground buried utilities and structures of above ground utilities shall not be foreseen at the location of instable ground and/or landslides as they can cause extremely hazardous situations (e.g. breakage of gas pipeline).

Purpose of the measure - To minimize the risk of damage to the infrastructure.

Relevant climate change trends – Same as under measure 3.1.3.

Additional information – It is necessary to consider potential increase of ground level levels in future winter period due to increased precipitation and minimal evaporation in the winter period.

3.1.5 Stability of the embankment shall be achieved by developing and using frost index. Frost Index (FI) and average annual air temperature data, covering the whole RB route, shall be developed (input to designers for selecting appropriate countermeasures, e.g. correct thickness of granular frost protection layer).

Purpose of the measure - To minimize the risk of damage to the embankment.

Relevant climate change trends - Clear trend of increased temperatures in the winter periods. However, the absolute minimum temperatures are modelled with very low certainty by current climate scenarios. Similar cold waves and absolute minimum temperatures as registered during the period 1981-2017 (Figure 3.1), could still occur in the near future.

Additional information – Climate change projections – Average annual temperature is expected to rise 1.5-5.5 °C by year 2100. Clear trend of increased temperatures in the winter periods, which would result in decrease of frost penetration depth (Keskkonnaagentuur, 2014; Latvijas Vides, ģeoloģijas un meteoroloģijas centrs 2017; Kilpys, J., Pauša, K., Jurkus, N., 2017). Similar frost penetration of soil depths registered (Estonia – 190 cm, , Lithuania – 132 cm) or calculated (Latvia – 126 cm) (Chapter 4.1.9, Tables 4.18, 4.19 and Figure 4.76) may still occur in nearest future, despite general climate warming trend.

The frost penetration depths indicated in the Rail Baltica Design Guidelines (RBDG-MAN-016) - are currently as follows:

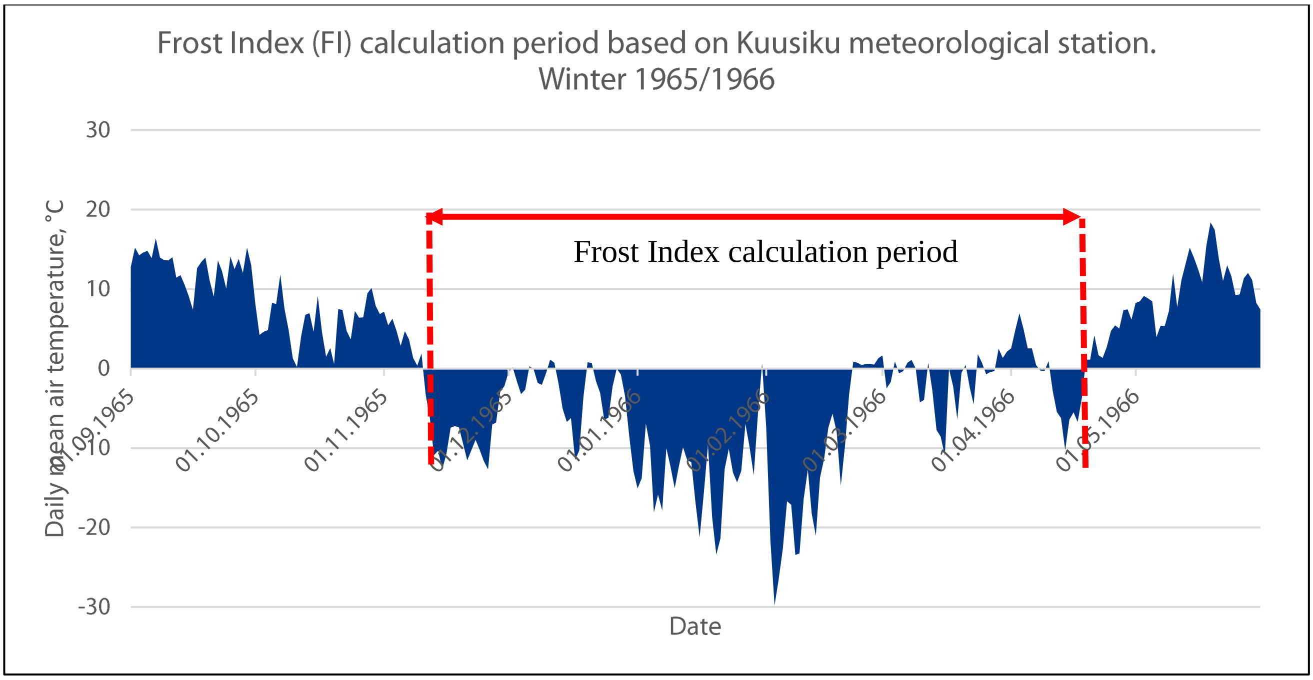
- Estonia: 2.05 m;
- Latvia: 1.74 m;
- Lithuania: 1.70 m.

Aforementioned values do not take into account different climatic zones within each county, which may lead to under or over estimations of frost penetration depths in specific regions (e.g. coastal areas, inland) In case frost penetration depth is underestimated, it may lead to problems related with frost heave during the freezing period (winter) and loss of bearing capacity during the thawing period (spring) which will increase track maintenance costs in the operating phase (OPEX). In case frost penetration depth is overestimated, it will increase construction costs without additional benefits to track performance during the construction phase (CAPEX). Currently selected approach is to follow UIC 719R for designing the track pavement and in order to select appropriate frost protection layer thickness, two input values must be determined – Frost Index (FI) and average annual air temperature. It must be taken into account that according to UIC 719R, FI and average annual air temperature must be selected based on the harshest winter experienced in specific location (i.e. meteorological station).

Frost Index (FI) or sometimes referred to as Freezing Index is combined measure of magnitude and duration of freezing temperatures (below 0°C) within given freezing season and it's used to express the severity of winter and estimate frost penetration depths for given location. FI is expressed by cumulative degree-days for one freezing season and total annual Frost Index is calculated by adding all the negative average daily temperatures for a specific location during the time period starting when freezing period's area under during the degree-days curve is larger than following short period of thawing in autumn (if there's such period) and ending when thawing period's area under the degree-days curve is larger than previous freezing period's area. See an example based on Kuusiku weather station data below (Total FI = 1068 °C x days).

$$FI = \sum (0°C - T_{d,i})$$

FI – freezing index (cumulative), degree-days (°C × days) for a given period of time
$T_{d,i}$ – average daily air temperature for a given day



NOTE: The start of the calculation period is 11.11.1965 and end is 18.04.1966. It can be observed from the graph that there was a short thawing period from 29.03.1966 to 06.04.1966. Due to the fact that the area under the date-temperature curve for period was smaller than the area of the following freezing period (from 07.04.1966 to 18.04.1966), the end of calculation period is 18.04.1966.

3.1.6 Utilities must be foreseen located deep enough or insulated that freezing of carried liquid would be prevented. Casing pipes have to be foreseen to eliminate possibility for leakage into the soil/embankment when pipe breakage should take place. Application of leakage detection system

must be evaluated by Designer based on risk assessment and agreed with Client and utility owner/operator. Solutions of monitoring system to detect leakages, if applicable, must be agreed with relevant utility owner/operator.

Purpose of the measure - To minimize the risk of damage to the infrastructure.

Relevant climate change trends – Same as under measure 3.1.5.

Additional information – None.

3.1.7 Technical solutions and materials, which will greatly decrease risk of slippery surfaces, shall be specified in the passenger areas, which are exposed to climatic variables like rain, snow, ice, freezing rain and glazed frost.

Purpose of the measure - To minimize the risk and consequences of accidents and injuries in station areas.

Relevant climate change trends - Clear trend of increased temperatures in the winter periods with more precipitation and increased likelihood of wet snow, freezing rain, glazed frost and ice forming events.

Additional information - Main goal of the measure is to use solutions (roofs, heating, etc) and materials, which would minimize the risk of incidents with passengers due to slippery surfaces. Material with as high as possible (feasible) slippery resistance shall be used in passenger areas.

3.1.8 Solar radiation factor shall be considered during the specification of temperature range values for rails (incl. sub-system compatibility) and thermal expansion joints and potential locations for remote condition monitoring systems, where rail or thermal joints temperature is critical, should be suggested.

Purpose of the measure - To minimize the risk of damage to the rails/expansion joints or traffic restrictions.

Relevant climate change trends - There is a clear consensus about the rise of future temperatures, including summer maximum temperatures up to approximately 5° C, which could lead to maximum temperatures around 40° C, according to worst case climate change scenarios. Significant changes in solar radiation during the warm season are not expected and existing solar radiation data shall be used.

Additional information - Technical requirements in urban areas for rails, expansion joints and electrotechnical equipment shall also consider the heat island effect, which will further enhance the impact of rising summer maximum temperatures. Special requirements shall be considered in urban areas because of this. In regard urban heat island (UHI) effect, the temperature is higher in urbanised Greater Tallinn that in the surroundings by 3-5 °C.

Multi-year (1991-2014) maximum direct normalized irradiance at surface (W/m^2) in May-July varies from 280 to 360 W/m^2 in the locations of Rail Baltica (Solar Atlas 2019). Greatest one hour direct solar radiation amounts in Estonia are recorded in mid-days in June on average – 1.18 MJ/m^2. Greatest recorded daily direct solar radiation amount is 27,7 MJ/m^2 (in Tõravere on 20th of June 1979).

Different technologies may be investigated and most appropriate implemented. Some example mitigation possibilities (WRWRP, 2016):

- strengthening plates may be installed at sites of tight curvature,
- glued ballast may be used on some embankments
- painting the rail white

3.1.9 Heat from direct solar radiation shall be considered during specification of requirements on electrotechnical equipment containers and design of its locations.

Purpose of the measure - To minimize the risk of damage to electrotechnical equipment.

Relevant climate change trends – Same as under measure 3.1.8.

Additional information – Sames as under measure 3.1.8.

3.1.10 Alerting and emergency notification systems for staff and passengers shall be elaborated.

Purpose of the measure - To minimize the risk and consequences of railway associated accidents and injuries during decreased visibility heavy fog.

Relevant climate change trends - No clear projections about future fog events.

Additional information – None.

3.1.11 Peat land fires near or under the railway and other wildfire sensitive areas – special and high impact risk enhanced by climate change, shall be considered in the design stage.

Purpose of the measure - To minimize the risk and consequences of increased fire hazard risk, which is especially important in peat land areas where the potential consequences may cause major damages.

Relevant climate change trends - There is a clear consensus about the rise of future temperatures, including summer maximum temperatures up to approximately 5°C, according to worst case climate change scenarios. Likely increase in the frequency and intensity of storms (with some uncertainty) according to the future projections.

Additional information - Technical solutions in peat land areas shall be designed so embankment stability is preserved in case of a peat land fire.

3.1.12 Multi-hazard risk (high wind in combination with increased likelihood of wet snow, freezing rain or glazed frost) shall be considered during specification of POE-s, catenaries and overhead, ETCS markerboards and other sensitive systems. Improved design parameters for sensitive assets.

Purpose of the measure - To minimize the risk and consequences of damage to the catenaries, ETCS markerboards and other sensitive systems or traffic restrictions.

Relevant climate change trends - Likely increase in the frequency and intensity of storms (with some uncertainty) according to the future projections. Clear trend of increased temperatures in the winter periods with more precipitation and increased likelihood of wet snow, freezing rain, glazed frost and ice forming events

Additional information – None.

3.1.13 Lightning risk assessment shall consider the possibility of more frequent thunder clouds with more severe consequences in the future.

Purpose of the measure - To minimize the risk of damage to electrotechnical equipment.

Relevant climate change trends - Higher air temperature may cause more intense formation of typical summer thunder clouds. Natural phenomena associated with thunder clouds will be more likely and with more severe consequences, but **more detailed projections are not possible due to uncertainty and random spatial nature of the thunder events.**

Additional information - Lightning risk assessment shall include principles of a suitable and efficient dissipation array system (DAS). Risk assessment shall also consider third party (electricity sources, telecommunication systems) risks associated with lightning.

3.1.14 Design principles of stormwater systems in artificial environments, considering historic data and relevant climate change trends shall be implemented.

Purpose of the measure - To minimize the risk of pluvial floodings in the critical areas (e.g. cities and built-up areas).

Relevant climate change trends - Precipitation will be increased, especially during winter period. Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period and over 1.5 times in summer period according to the RCP8.5 scenario. However, the distribution of precipitation by intensity is not modelled by climate scenarios and the uncertainty of statements and forecasted data is extremely high.

Additional information - Currently, pluvial flooding caused by very heavy rain and flash floods is the most frequently exposed climate risk in the Baltic countries. So, it may be transferred to the Rail Baltica corridor, by third parties. There is one event with 6.6 mm of rain in one minute in Lithuania during period 1981-2017 (only Lithuania has precipitation data with 1-minute precision). DG-s currently state that all systems need to be designed against 6 mm per minute rain. It is advised to revise and potentially upgrade stormwater system design in the critical areas (e.g. cities and built-up areas).

3.1.15 Potential wind corridor locations (coast, relief, man-made structures, open landscape, long bridges) shall be identify during design stage. Wind sensitive infrastructure shall be determined and measures implemented accordingly.

Purpose of the measure - To minimize the risk of damage to the sensitive assets due to the cumulative effect of local conditions and high wind speed events.

Relevant climate change trends - Likely increase in the frequency and intensity of storms (with some uncertainty) according to the future projections.

Additional information – None.

3.1.16 Areas where 40 m (or similar area) tree free zone is not allowed/possible shall be identified of during technical design and environmental assessment stages.

Purpose of the measure - To minimize the risk of damage to railway assets or traffic restrictions.

Relevant climate change trends - Likely increase in the frequency and intensity of storms (with some uncertainty) according to the future projections. Milder winters with more precipitation.

Additional information - Storms and wet snow loads may topple trees more frequently as roots rise easily from moist and soft ground.

3.1.17 All third-party utilities shall be grounded for lighting near the railway to avoid EMD and electric surge to railway and its structures. Third-party utilities with potential EMD and electrical surge risk to RB shall be determined during the design stage.

Purpose of the measure - To minimize the risk of damage to electrotechnical equipment.

Relevant climate change trends - Higher air temperature may cause more intense formation of typical summer thunder clouds. Natural phenomena associated with thunder clouds will be more likely and with more severe consequences, but <u>more detailed projections are not possible due to uncertainty and random spatial nature of the thunder events.</u>

Additional information – None.

3.1.18 Monitoring locations shall be suggested for areas with landslide and ground instability risk.

Purpose of the measure – To minimize the risk of damage to the railway infrastructure and potential traffic restrictions.

Relevant climate change trends - Precipitation will be increased, especially during winter period. Climatic projections estimate increased likelihood of more severe heavy rains and flash floods in the future, with likelihood of extreme precipitation (over 30 mm per day) can be increased up to 4 times in winter period and over 1.5 times in summer period according to the RCP8.5 scenario. Potential increase of ground level levels in future winter period due to increased precipitation and minimal evaporation in the winter period.

Additional information – Critical locations with potential landslides, ground instability (both railway embankment and slopes in wet cuts) and high ground water level risks shall be defined by geotechnical and hydrological studies and potential locations for remote condition monitoring systems, for operation stage, shall be suggested during technical design stage, if necessary. Sensitive areas to consider (may be elaborated in further stages) – slopes in cuttings and slopes of larger water bodies, which Rail Baltica crosses. Designer shall propose a suitable location (including necessary connectivity solutions) to place the sensors, if justified. It is advised to specify the sensor type and associated specific requirements prior to the design stage and not include this as a task for designer, because of the potential problems integrating different sensors (chosen by each designer for different sections of Rail Baltica) into centralized Rail Baltica systems.

4. Guidance on climate change impact assessment for the design stage

4.1. General requirements

The designer shall analyze climate change impacts and risks during Value Engineering and Master Design stages. The high and medium risk climate risks are listed in the Chapter 2.2. The design proposals shall be developed considering potential climate risks and adaptation measure presented in Chapters 3.1 and 3.2 and more detailed information available in the design stage. Risk assessesment and adaptation measures development shall follow the principles presented in the Chapters 4.3 and 4.4. against the potential hazards listed above.

In principle, an approach to estimate (in either qualitative or quantitative terms) both the costs of implementing a measure and the potential benefits from doing shall be needed. Benefits can be thought of as climate change impacts (or damages) avoided or positive effects taken advantage of.

Designer shall assess climate change imapcts on operational, environmental and social performance, and market conditions, which could result in:

- asset deterioration and reduced life of an asset,
- increases in OPEX and the need for additional CAPEX,
- loss of income,
- increased risks of environmental damage and litigation,
- reputation damage,
- changes in market demand for goods and services,
- increased insurance costs or lack of insurance availability.

The assessment shall cover full asset lifetime as defined by Design Guidelines RBDG-MAN-012 General requirements.

4.2. Risk identification and assessment

The climate change adaptation measures shall be identified and assessed in an early stage against climate change associated risks for the design, construction, maintenance and operations of Rail Baltica railway. Thus, the pre-designed infrastructure, the infrastructure design proposal and option vulnerability shall be assessed, and feasible climate change adaptation measures are proposed and implemented in the design.

Climate change impact assessment refers to research and investigations designed to find out what effect future changes in climate could have on human activities and the natural world. Climate change impact assessment is also frequently coupled with the identification and assessment of possible adaptive responses to a changing climate to the extent that adaptation can reduce impacts.

The magnitude of climate change impacts estimated from an assessment is often very sensitive to the assumptions made about adaptation. It is difficult to predict exactly how something will respond to climate change. It is therefore important to consider adaptation at the design phase of the assessment and to decide how it is to be brought into the impacts research at an early stage.

Pre-designed infrastructure vulnerability and risk assessment methodology for the railway design, construction and operation phases is presented in the Figure 4 Risk matrix example, used for developing risk raiting is presented in the figure 5.

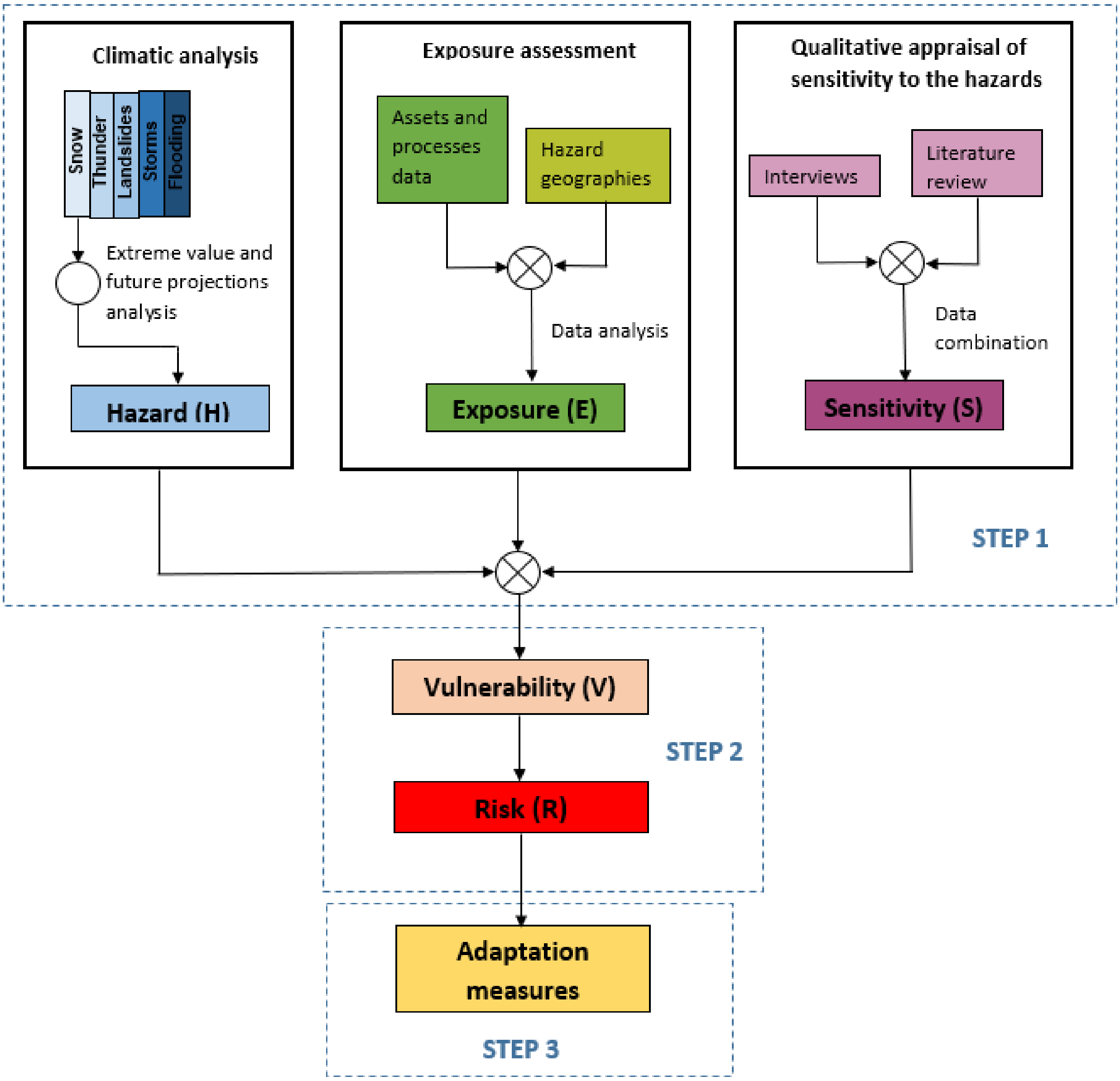


FIGURE 4 RAIL BALTICA CLIMATE CHANGE RISK ASSESSMENT METHODOLOGY

RISK RATING MATRIX					
LIKELIHOOD	CONSEQUENCES/IMPACT				
	Insignificant	Minor	Moderate	Major	Catastrophic
Very likely	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Unlikely	Low	Medium	Medium	High	High
Very unlikely	Low	Low	Medium	Medium	Medium
Extremely unlikely	Low	Low	Medium	Medium	Medium

FIGURE 5 RAIL BALTICA CLIMATE CHANGE RISK RATING MATRIX

Likelihood level	Likelihood description
Very likely	Event is expected to occur often during the 100-year design life of the infrastructure or 50 years for systems or 10 years for construction, due to clear and significant adverse changes in the relevant climatic variables and hazards.
Likely	Event is expected to occur several times during the 100-year design life of the infrastructure or 50 years for systems or 10 years for construction, due to clear or significant adverse changes in the relevant climatic variables and hazards.
Unlikely	Event is expected to occur at least once, few times during the 100-year design life of the infrastructure or 50 years for systems or 10 years for construction, due to clear or meaningful adverse changes in the relevant climatic variables and hazards.
Very unlikely	Event is not expected to occur more than once during the 100-year design life of the infrastructure or 50 years for systems or 10 years for construction, due to unclear or minor adverse changes in the relevant climatic variables and hazards.
Extremely unlikely	Event only occurs in exceptional circumstances and would not be expected to occur during the 100-year design life of the infrastructure or 50 years for systems or 10 years for construction, due to positive changes in the relevant climatic variables and hazards.

Consequence level	Consequence on human health and infrastructure	Consequence on environment and reputation
Catastrophic	Fatalities and/or extensive damage to critical infrastructure	Significant and irreversible adverse environmental impacts and/or significant long-term impact to reputation
Major	Multiple serious injuries and/or major damage to critical infrastructure	Major and long-term adverse environmental impacts and/or major long-term impact to reputation
Moderate	Non-permanent injuries, but hospitalization is needed and/or moderate damage or significant degradation of infrastructure	Moderate adverse environmental impacts and/or moderate impact to reputation
Minor	Some medical treatment at a hospital needed, minor damage or degradation of infrastructure	Minor short-term adverse environmental impacts and/or minor short-term impact to reputation
Insignificant	Only minor first aid treatment may be required and /or slight degradation of infrastructure	Insignificant short-term impact to environment and/or insignificant short-term impact to reputation.

4.3. Adaptation option development

Proposals shall be made by the designer for the specific climate change adaptation measures to be implemented in the design, construction and operation phases of Rail Baltica.

Assessment of adaptation options requires an understanding of what is meant by adaptation. Assessment of adaptation also requires evaluating how well different practices and technologies will avoid adverse climate change impacts by preventing or minimizing them, by enabling a speedy and efficient recovery from their effects, or by taking advantage of positive impacts section addresses the evaluation of adaptation measures.

Weather resilience and climate change adaptation actions include a range of measures appropriate to the strength of evidence and level of risk which may include changes to processes, standards and specifications, increasing knowledge and skill base, measures that increase the resilience of the assets to current and future impacts, cost-efficient adaptations and investments.

The identification of adaptation shall focus on options which reduce vulnerability to past and present climate variability. It is recommended to develop and compare different adaptation options for a particular case:

- An option which is to be implemented on infrastructure and thus implemented in design,
- An option which is to be implemented in operations with partly or no need for implementation in design.

Adaptation option development shall include:

- Identification of adaptation options,
- Appraisal of adaptation options,
- Integration of adaptation option in design.

Cost estimates of the most feasible adaptations shall be developed. The cost estimates shall consider entire asset lifecycle, thus life-cycle cost approach and value engineering shall be used.

5. Glossary

The table blow provides a glossary of words, terms and acronyms used throughout the report.

Words term or acronym	Definition
Adaptation (climate change)	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation can also be thought of as learning how to live with the consequences of climate change.
Climate	The weather conditions prevailing in an area in general or over a long period. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.
Climate Change	Achange of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
Climate Projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Extreme Weather Event	An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations.
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
Impacts	The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential and residual impacts. Potential impacts are all impacts that may occur given a projected climate, without considering adaptation. Residual impacts are the impacts that would occur after adaptation.

Words term or acronym	Definition
Representative Concentration Pathways (RCPs)	Four RCPs (RCP2.6, RCP4.5, RCP6 and RCP8.5) were selected and defined by their total radiative forcing (cumulative measure of human emissions of GHGs from all sources expressed in W/m^2) pathway and level by 2100. The RCPs were chosen to represent a broad range of climate outcomes, based on a literature review, and are neither forecasts nor policy recommendations.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.
Risk Management	The plans, actions or policies to reduce the likelihood and/or consequences of risks or to respond to consequences.
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. a change in crop yield in response to a change in the temperature) or indirect (e.g. damages caused by more frequent coastal flooding due to rising sea levels).
Uncertainty	Uncertainty relates to a state of having limited knowledge which can result from a lack of information or over disagreement over what is known or even knowable. Uncertainty may arise from many sources, such as quantifiable errors in data, or uncertain projections of human behaviour. Uncertainty can be represented by quantitative measures or by qualitative statements.
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.