PROCEDURES OF THE IMPLEMENTATIONS

The impact of climate change preparation for the Kruunusillat project

Ramboll Finland Oy
19.2.2016

PROCEDURES OF THE IMPLEMENTATIONS

City of Helsinki

Contents

1 Introduction

1.1 Background and purpose of the study

Helsinki is planning a major transport connection which, if implemented, connects the Kruunuvuo to the metropolitan city. The link makes the suburb of the Kruunu Mountains part of the metropolitan area and significantly reduces travel time. The aim of the City of Helsinki has been to make the Kruunu Mountains area a strong public transport enthusiasm fromthe outset. A residential area of approximately 11 000 inhabitants of Kruunu Mountainta is planned for the west coast of Helsinki Laajasalo, which would also host around 1 000 jobs. The environment has been rehabilitated and pre-built, and residential construction started in 2014. Large-scale refurbishment has also been planned for the Broadcasting House.

The planning of the public transport system for Laajasalo started in 1999 in the context of the preparation of Helsinki's general public transport system in2002 and continued during the general planning of the district of Kruunumoranta. In 2008, the City Council of Helsinki decided to select a tramway and bridge-based solution, which includes a reservation on the high-speed rail route, as a basis for further preparation of the business link. Alongside public transport, foot access and cycling are also planned. The bridge link from the sub-city of Kruunuvuoranta to part of the metropolitan town would lead to a significant reduction in travel time. Helsinki wants to favour sustainable pitches such as rail and to increase the level of public transport. Between 2011 and 2013, a bridging competition was organised as a basis for further planning, which was won by a working group set up by WSP Finland with its proposal "Gemma Regalis".

Helsinki City Council decided to prioritise the implementation of the Kruunusillat public-transport link in autumn 2013. An assessment report on the environmental impact of the rail-implementation options in the Broadcasting House was completed in 2014. The aim is to start the first building phases by 2018 at the latest and to open the portfolio of projects to traffic by 2024. The implementation of the project still requires a decision of the City Council. The decision on the Kruunusillat project is expected to be taken at the earliest in spring 2016.

The preparation of the project design for the Kruunusillat project is ongoing. The aim of the-project design is to improve the management of the cohesiveness of the separate assignments forthe Cruunus Sites by describing the different stages of the process through the project and anticipating the necessary steps for implementation. The project design serves as a support and tool for the Helsinki City of Helsinki's decision-making bodies.

According to **the Helsinki Metropolitan Climate Change Adaptation Strategy (2012**), adaptation to change must be a key starting point for planning communities, steering construction and developing technical networks. Despite mitigation measures, the climate is warming due to the release of greenhouse gases into the atmosphere so far and in the future. Therefore, society needs to adapt to the consequences of the changing mast. Preparing for climate change is part of sustainable mouth mowing.

This study assesses the impact of climate change on the Kruunusillat project portfolio. The study identifies the main impacts on the project and climate change adaptation needs that should be taken into account in the further design of the project. The aim is to document the adaptation of the Kruunusillat portfolio to climate change and to demonstrate that the project is adequately prepared for climate change.

1.2 Scoping of the review

The study examines the effects of climate change from the perspectives of the Kruunusillat Bridge Fields, street and rail structures, mobility and transport and maintenance. The Kruunusillat project consists of the public transport service between the central Helsinki area and Laajasalo and the arrangements for its construction and operation (Figure 1). The commuter link is implemented as a tramway and affects the public transport system throughout the capital region. In addition to the tramway, the connection includes pedestrians and cycle paths. On completion of the Kruunu Mountain and the fishing port, the tram-link of the forecasts would be around 23 000 passengers every day. The distance from the Kruunu Mountain to the city centre of Helsinki is approximately 12 km. The Kruunu Mountain sea area is separated from the city centre by the maritime area of the Kruunu estuary, beyond which it would considerably reduce the distance to the centre. Transport links to the High Island will also be stretched considerably with the project.

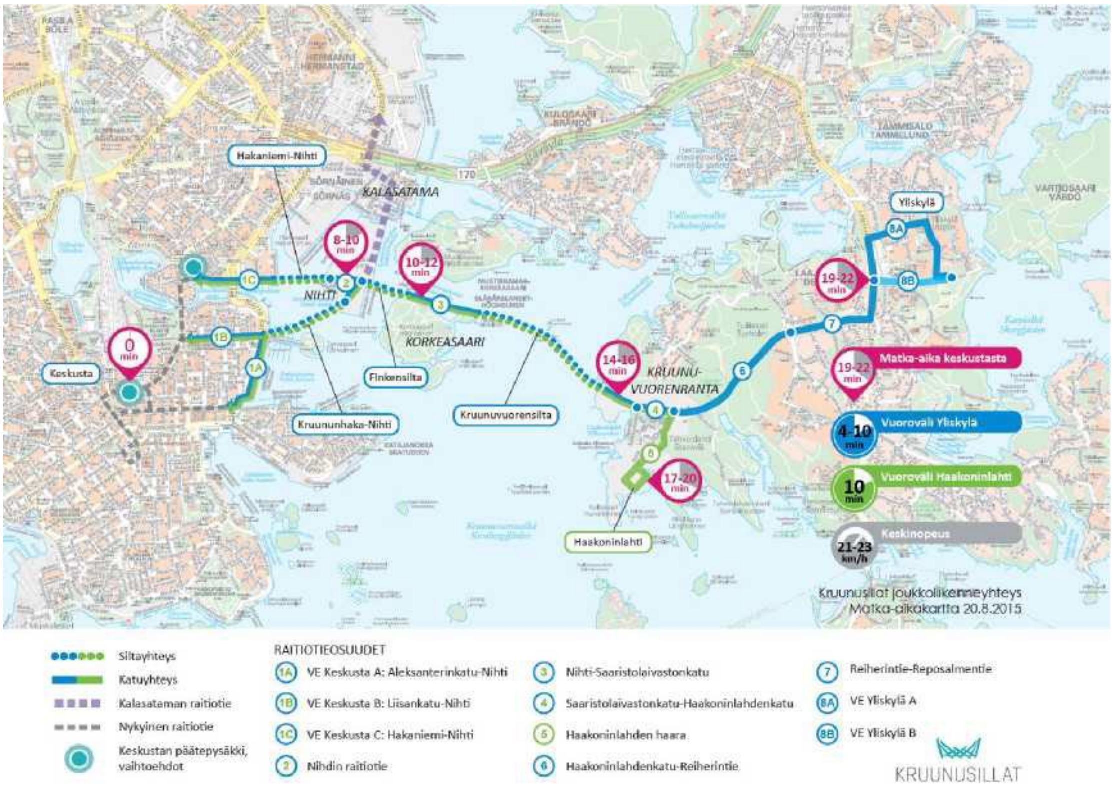


Figure 1 The public transport link 'Kruunusillat' comprises the public transport link between the central area of Helsinkiand Laajasalo and the arrangements for its construction and operation;

1.3 Guidance and implementation of work

The supervision of the work was carried out by a steering group led by project manager Ville Alajoki, consisting of Juha Sorvali from the street and park department of the City of Helsinki and Sito Oy, Sakari Grönlund and Ari Savolainen. The work was carried out by Ramboll Finland Oyas project manager Riina Känkänen and by Arto Ruotsalais (land use), Ilkka Vilonen (bridge planning), Jukka Lahtinpage (structures), Kalervo Mattila (maintenance), Jukka Räsänen (mobility and transport), Päivi Paavilainen (hulevedet), Juha Forsman (geotechnicalriveting) and Tommy Nyman (street design).

2 Materials and methods

2.1 Impact assessment

The assessment of the impacts of climate change was carried out as an expert and was based on awritten briefing, expert interviews and the results of the workshops. The evaluation identified projected climate change and assessed their impact on the project. The significance ofthe potential effects of a mast change was determined on the basis of the sensitivity of the target (project area) and the magnitude of the change (Figure 2). The objective of assessing the severity of impacts is to summarise the direction, magnitude and sensitivity of the impact and to increase the transparency of the assessment.

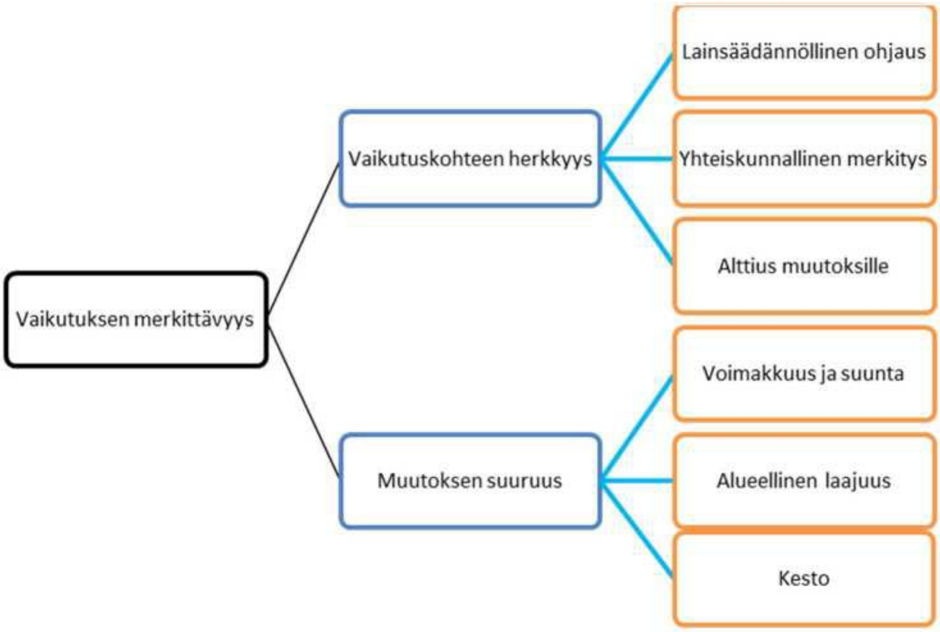


Figure 2. The significance of impacts refers to the magnitude of the change taking into account the sensitivityof the impact (project/area of project).

Changes in the climate can be positive or detrimental to the project. Changes in the UN's local climate factor, e.g. precipitation, can have a positive and negative impact on the project at the same time.

After the effect has been identified, the object's sensitivity to change is assessed. The assessment of vulnerability to change uses a number of criteria, such as, for example, the location of sites or areas of national or international conservation, or the presence of a large number of sensitive sites, such as the presence of endangered ten organisms. The resilience of the region and its sites to change, their adaptability, the diversity of the area and their vulnerability will also be taken into account. The sensitivity of the catchment area itself is not a negative or positive direction, but is determined by the mouth of the effect.

Criteria for the sensitivity of the site:

Vähäinen	Kohde/alue on vähän tärkeä tai vähäisessä määrin herkkä muutoksille kyseisen vaikutuksen osalta tai alueella vain vähän herkkiä kohteita.
Kohtalainen	Kohde/alue on kohtalaisen tärkeä tai kohtalaisen herkkä muutoksille kyseisen vaikutuksen osalta tai alueella jonkin verran herkkiä kohteita.
Suuri	Kohde/alue on erittäin tärkeä tai erittäin herkkä muutoksille kyseisen vaikutuksen osalta tai alueel-la runsaasti herkkiä kohteita.

After identification of the effect and sensitivity of the target, the magnitude of the effect is estimated. The geography of the impact as a whole is determined byits extent, duration and intensity. In terms ofgeographical scope, the impact can be local, regional, national or cross-border. The effect overtime can be temporary, short-term, long-term or permanent. The effectsmay be small, moderate or high. There may also be considerable uncertainties in the direction and magnitude of the impact, making it impossible to estimate at a sufficiently reliable level.

The positive effect has been described with green tones and negative effect with red shades. It is notable that the magnitude of the impact has to be assessed from several angles. For example, despite the high intensity of the impact, the impact may be moderate if the duration of the effect is short-term and reversible.

The assessment of the significance of the impacts was based on the assessment scale set out in Table 1.

Table 1 Scale for assessing the significance of the impact

Negative impact	Interpretation of significance	Positive impact
large (- — -)	**The significance of the effect is high if** the change is large and affects a medium or high object, or the change is very large, but the object is of low or moderate sensitivity. It may be important if the change is moderate and the sensitivity of the object is high or very high. When the change is small and the sensitivity of thetea is very high, it is of great importance.	**large (+ + +)**
moderate (- -)	**The significance of the effect is moderate if** the-other thost is moderate and the object's sensitivity-is moderate or high, **or** if the change is high and the object is moderately sensitive.	**moderate (+ +)**
small (–)	**The effect is of minor importance if the** change is small and if the object's sensitivity is low or-moderate, **or** if the change is moderate and the object's sensitivity is low.	**small (+)**
No impact	**A change may occur but the modification does not have a foreseeable impact on the project**. KOHtea sensitivity does not affect the result.	**No impact**
uncertain direction and magnitude of impact	**Thereare mo NIAuncertainties as to the direction and magnitude of the impact**, if there is a discrepancy between the known harsh results or if the prediction of the impact at a reliable level is too uncertain. The sensitivity of the target does not affectthe loin.	**uncertain direction and magnitude of impact**

2.2 Literature review

The potential impacts of climate change on the Kruunusillat projectwere identified through a literature analysis. The analysis was documented in a separate Excel table and the report reads-in month 4. The analysis served as a basis for expert interviews and impact assessments. Written sourcesare presented in chapter 6 of the report's source list.

2.3 Expert interviews

Expert interviews complemented the literature review and looked at how the Kruunusil-lat project design has already been prepared for projected climate change. Haas also discussed-the significance of the effects of climate change from the perspectives of bridge structures, street and rail structures, mobility and transport and maintenance.

The expert interviews were carried out through telephone or group interviews and were documented as interview notes. The following interview questions were sent to the intervieweesin advance:

1. What are the most important climate factors for the Kruunusillat project, whichare expected to change in the future, and how will these changes affectthem? Constructions here refer to bridge, tramway, stop and street structures.

2. How should the effects of such climate change be taken into account inplanning, building, operating and maintaining?

3. How do the contingency measures affect the cost of the project? To which stageof the arc (in question 2) does the project body cover the costs?

The persons interviewed in the project are shown in Table 2.

Table 2. Persons interviewed in the project

Name	**Organisation**
Risto Kiviluoma	WSP
Pekka Vuorinen	Construction industry ry
Jouni ticks	Betoniviidakko Oy
Kimmo Ruosteenoja	Department of Meteorological Sciences
Heikki Outflow	Department of Meteorological Sciences
Mikko Lensu	Department of Meteorological Sciences
Jouni Vainio	Department of Meteorological Sciences
Niko Setälä	KSV
Kaarina Laakso	KSV
Brother Rintala	HKL
Jani Toivonen	HKL
Erk horn	FCG
Eero Sihvonen	HKR
Timo Rytkönen	HKR
Juhani Hyvönen	Pontek

A workshop with experts

An expert workshop was organised on 23 September 2015 with 19 participants (Table 3). The workshop commented on the assessment of the impacts of climate change and preparedness. In addition, consideration was given to the factors affecting the overall sustainability of the project and the reindeer efficiency, as well as ways to improve these in the design, movement- and maintenance of the structures.

Workshop programme:

9.00-9.15 Opening event, project background and objectives, project leader Ville Alajoki (HKR)

9.15-9.30 Preparing for the impacts of climate change in the Kruunusillat project; TKT Jukka Lahti page (Ramboll)

9.30-9.45 Commentary on the general design of the project; MSC Karoliina Saarniaho (WSP)

9.45-10.15 What factors affect the overall sustainability of the project?

- Bridge management system, Siha, TKL Ilkka Vilonen (Ramboll)
- Resource efficiency indicators for construction and maintenance, FM Riina Känkänen (Ramboll)
- Οϖεραλλ sustainability of the Infra Project in the CEEQUAL 9 rating system, DI Veera Sevander (Ramboll)

10.15-10.20 Objectives, guidance and group allocation of group work

10.20-11.20 Small Group work

11.20-12.00 Presentation of the results of the work and final debate

12.00 Conclusion of the event

Group working questions:

1) PREPARING FOR THE IMPACTS OF CLIMATE CHANGE: Is the Kruunusillat project adequately prepared for the effects of climate change? What are (a) the main contingency measures? (b) follow-up recommendations on planning?

2) OVERALL SUSTAINABILITY ASSESSMENT: What factors influence the overall sustainability of the project? What criteria/meters should be used to assess overall sustainability? How could the overall sustainability of the project be further improved?

Table 3. Participants in the project expert workshop (23 September 2015)

Name	**Organisation**
Ville Alajoki	HKR
Annukka Eriksson	HKR
Sakari Grönlund	Binding
Juha Korhonen	The Environment Centre of the City of Helsinki
Jarno Portti	HKL- Infra-Services
Jouni ticks	Betoniviidakko Oy
Karoliina Saarniaho	WSP
Ari Savolainen	Binding
Matti Tauriainen	HKL- Infra
Minna Torkkel	Transport Agency
Timo Tirkkonen	Transport Agency
Jukka Lahti page	Ramboll
Veera Sevader	Ramboll
Ilkka Vilonen	Ramboll
Kalervo Mattila	Ramboll
Jukka Räsänen	Ramboll
Jukka Räsänen	Ramboll
Arto Ruotsalais	Ramboll
Riina Känkänen	Ramboll

3 The changing climate in Finland

3.1 Projected changes

In Finland, climate change has been assessed using 10 to 19 world-wide models, depending on thesize. Based on climate models, it is estimated that the average temperature will continue to rise, with increased tea, especially in winter, with heavy rainfall becoming more intense and the snow cover of Southern Finland becoming more thriving. In the future, Finland's climate will continue to be characterised by large fluctuations between years (Climate Guide.fi). The box below summarises the most significant changes in the Finnish climate expected by the end of the century, which will already have alegal impact on the Kruunusillat project (Ruosteenoja 2013, Jylhä et al. 2012, Jylhä et al. 2009). The impact assessment is presented in Chapter 4.

Temperature

- In particular, winter temperatures are rising: Average temperature rises between 3 °C and 9 °C in winter, 1-5 °C in summer
- Very low temperatures seem to be less frequent. The number of cooling melting cycles will initially- be adjusted as temperatures rise.
- Heat periods are becoming more frequent.
- The highest temperatures are likely to increase.
- The growing season is increasing and becoming warmer.

Rainfall

- Particularly in the winter of the year, rainfall is increasing and increasingly coming into water: Rainfall increases by 10-40 % in winter, by 0-20 % in summer.
- Heavy rainfall is expected to increase more than average rainfall.
- In winter and spring, the longest rainfall periods are somewhat shortened.
- In the summer, boom periods may even slightly increase.
- Humidity increases between 2 % and 4 % in winter.

Wind speed

- In spring and summer, there seems little to be any change in the wind climate in Finland.
- In autumn and winter, winds would blow slightly more snack in the future.
- The prevailing wind directions in the future will be the same as today.
- While the changes are small, they are in the same direction in most models.

Snow cover and crushing

- The snow cover period is reduced, the water value of the snow is reduced and the thickness of the snow is reduced.
- In Southern Finland, snow will only be occasionally present in winter, as is currently the case in- February. Individual harsh snowfalls that shock society will continue to occur. In most cases, however, the snow that was caught will soon melt out.
- The average depth of rum in snowless areas decreases by about 0.5 to 1.0 m today. This change is most pronounced in the southern part of the country.
- During rainfall and rainfall, the soil is often wet and has poor load-bearing capacity.

Concentration of CO_2 in air

- According to different scenarios, the current level of CO_2 will rise to around 400 km/h. 550-900 ppm by the end of the century.

Cloud and sunshine

- Winters become more dark.
- In the summer, cloudiness is likely to remain broadly unchanged.

Sea level and ice conditions

- In the Gulf of Finland, water levels may turn upwards and the sea in the Bothnian Sea isincreasingly retreating. In Finland, the rise in sea levels is influenced by the rise of land along the coast and by theair-wide rise in sea levels (Johansson et al. 2004). The rise in sea levels is influenced by the thermal expansion of water, the melting of mountain glaciers and the reduction of snow-covered areas.
- The ice cover in the Baltic Sea is decreasing.

In the future, climate change will depend on global emissionsof greenhouse gases. Finland's climate change is almost the same inall emission scenarios until around 2040. The natural variability of the climate will intensify and weaken changes in the coming decades. In the second half of the century, the differences will increasesignificantly depending on the level of emissions of VGs (Figure 3).

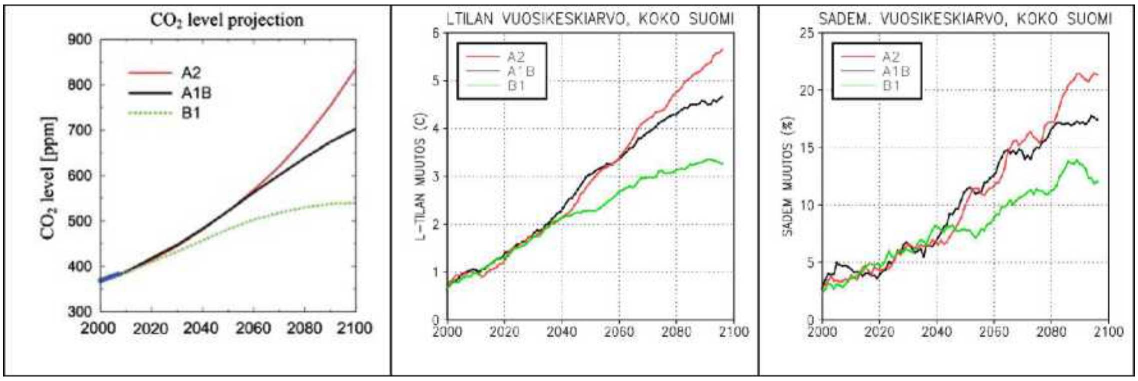


Figure 3. Climate change projections (Jylhä et al.) 2009)

3.2 Changes observed

Global warming is already visible in Finland. Since the mid-19th century, the annual average temperature in Finland has increased with a high probability of more than 2 °C (Figure 4). The temperature increase is statistically significant. Figure 4 shows Finland's fluctuations in the average of the lens-medium temperature in the period 1981-2010 [°C] between 1900 and 2014 (blueset and red columns). The values of the columns in the picture are based on grid data covering the whole of Finland. The ten-year moving average is shown on the black curve. The averagetemperature in Finland during the period 1981-2010 was 2.3 °C. Global warming is illustrated by the fact that the last columns of average temperatures in the individual years are mostly red and the black curve of a long-term trend has been predominantly upwards.

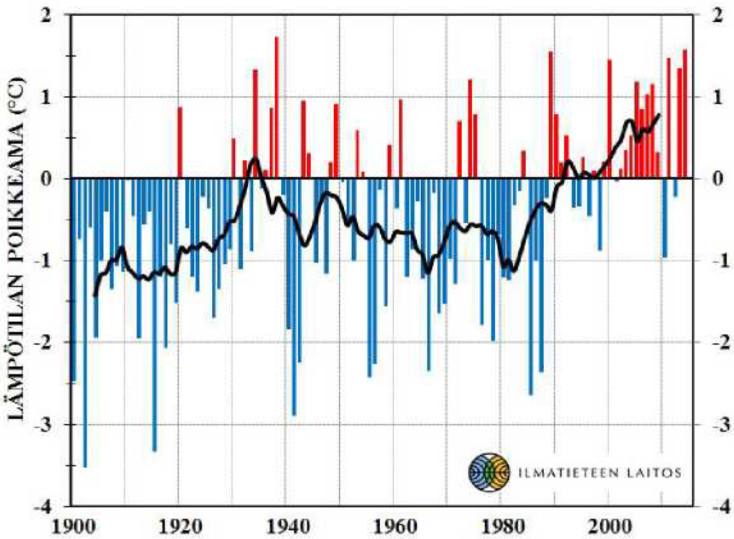
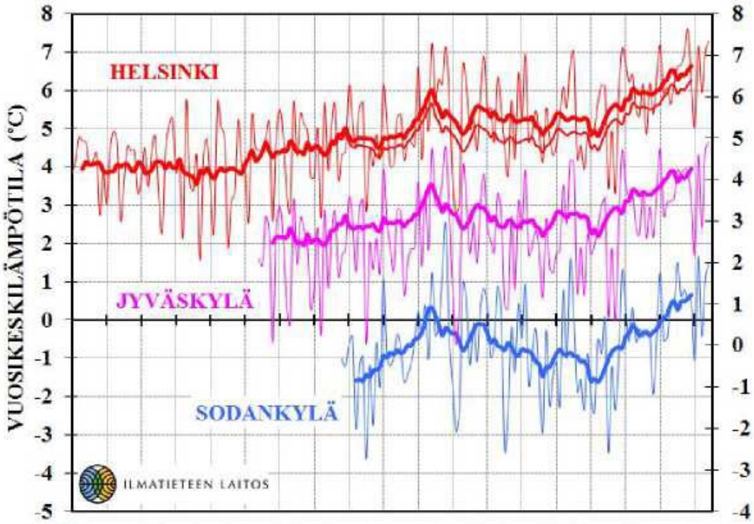


Figure 4 Deviations of the annual average temperature in Finland from the average of the period 1981-2010 [°C] in the period 1900-2014 (blue and red columns) (Methological Institute).

Figure 5 shows the average annual temperatures in Helsinki Kaisaniemi for the years 1830-2014,JY for Crown 1884-2014 and Sodankylä from 1908-2014. Helsinki's temperatures also includea drag on how much urbanisation has increased the temperature; the mid-thick line below the thick line illustrates the estimated temperatures if the increase in the city would not have affected the temperatures.



1830 1850 1870 1890 1910 1930 1950 1970 1990 2010

Figure 5. Annual average temperatures in Helsinki Kaisaniemi from 1830-2014, Jyväskylä 1884-2014 andSodankyläs here 1908-2014. The annual values are marked with a thin line and a 10-year rolling average is marked with a thick (air science institute).

Figure 6 shows the annual water and wipe rain in the period 1961-2005, both inland and coastal. In addition to the considerable fluctuations in rainfall, it can be seen from the descriptors that the inland waterand wipe rains have remained on average throughout the measurement periodat the same level as Solla, but the rainfall on the coast has increased to alower level than the hinterland in the 1980s and is still at a higher level.

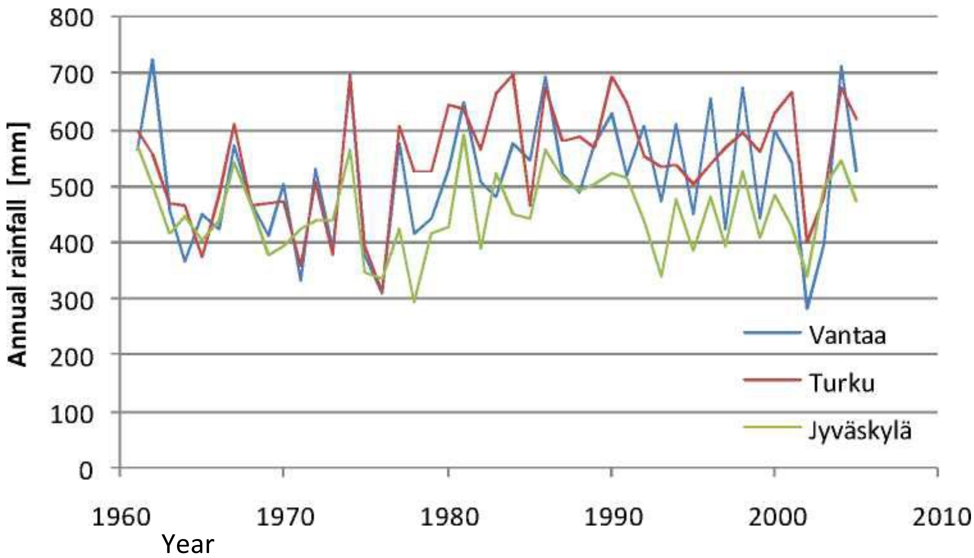


Figure 6 Annual water and wipe rain in 1961-2005 inland (Jyväskylä) and coastline (Vantaa and Turku) (Data page 2012).

Figure 7 The largest increase in rainfall occurs in winter, but July and August will continue to be the most precipitated months in Finland. Rainfall flood at Rongankadu, Tampere. (Ramboll)

3.3 Specific features of the project area in terms of climate

The Kruunu Mountain spine belongs to the archipelago of the northern coast of the Gulf of Finland, which consists of the inner archipelago, the intermediate archipelago and the outer archipelago. The Kruunu Mountain spine is the largest back of the Helsinki si-south archipelago, where the fresh water of the Vantajoki river and the sea water of the Gulf of Finland are mixed by the low and well-closed Vanhankau Town Bay. Its open part is around 12-15 m deep sea area. (Luode Consulting Oy and Sito Oy, 2015)

The sea flats the temperatures in the project area: cool in spring and early summer and heat in autumn and early winter. In winter, the temperature moves to zero on both sides and long periodsof frost rarely occur (Figure 8). Based on the long-term averages provided by the Marine Research Institute (Ice Statistics 1961-1990, Finnish Castle observation point), the sea area will, on average, be frozen in early January, when permanent ice cover starts to be formed. The permanent ice cover lasts approximately three months in the area and usually melts at the beginning of April. The ice finally leaves around mid-April.

The spring is usually the dryest period of one year, especially on the coast, with rainfall in May ranging from 30 to 35 mm. The August month is the month of rainfall with rainfall of around 80 mm. Evenon the coast, the float in October or November is also rather rain (70-80 mm). Low pressure activities and the warm sea together are the reasons for this. The autumn (September-November) is therefore moreprecipitated in summer (June-August). Based on approximately 100 years observations from the four observation stations shown in Figure 8, the number and length of drought periods during the summer half of the year are the highest on average in coastal areas and the lowest in Lapland (Hohenthal 2009).

In Helsinki, the sea water is generally at the lowest altitude in the spring in April/Mayand basket in November-December. The water level fluctuations are the lowest in the summer months and the strongest in October and March. Fluctuations in water levels includechanges in manoeuvring pressure, long-lasting parallel winds and typical swings of the water mass of the Gulf of Finland basin. In the surface layer, the directions of flow are more varied than in the ground layer. (Luode Consulting Oy and Sito Oy, 2015)

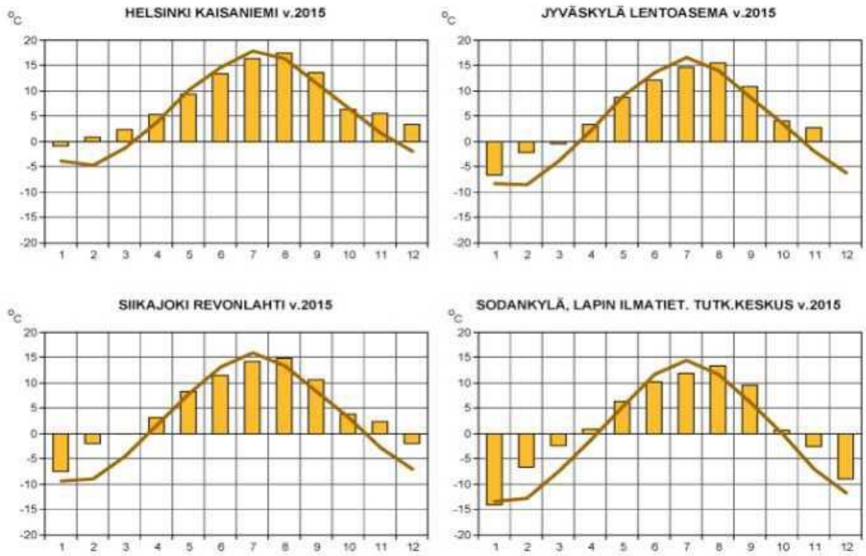


Figure 8 Average monthly temperatures in Helsinki Kaisaniemi, Jyväskylä, Siikajoki and Sodankylä

The wind conditions in the Danish straits have an impact on the flow of water between the Baltic Seaand the North Sea. Climate models predict the expansion of western winds in the Danish straits, which push more water into the Baltic Sea. As a result of the change in wind conditions, sea levelwars are estimated to increase on average around 6-7 cm off the Finnish coast by the end of the century (Johansson et al. 2014). Including land-grabbing also leadsto an estimate of the change in the average sea level onthe Finnish beach by 2100 (Figure 9).

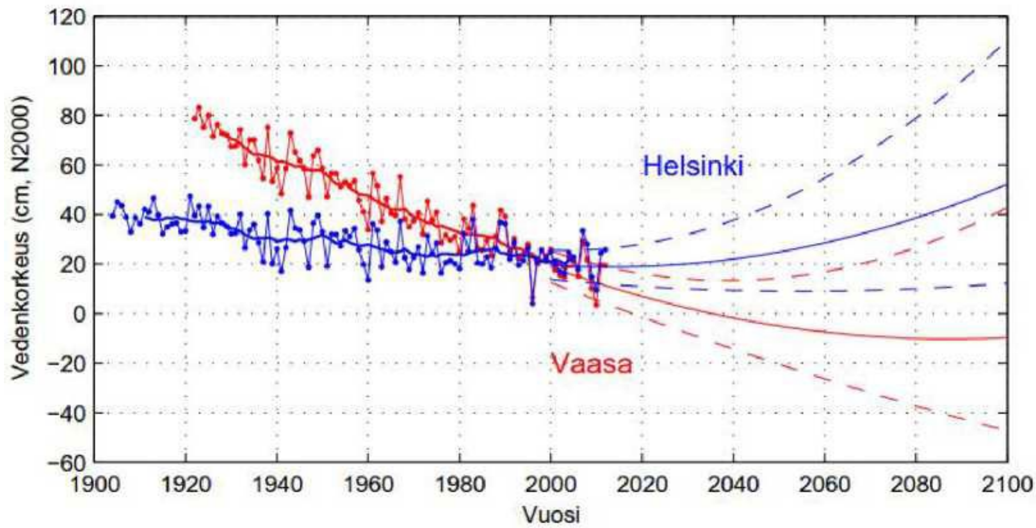


Figure 9 An assessment of the development of average sea levels in Helsinki and Vaasa by 2100. A uniform line is the best estimate, the dotted lines represent the uncertainty intervals. The scores are the observed annual average water level. (Kahma et al. 2014)

4 Impact of climate change on the project

4.1 Bridge structures

According to the current scenarios, the projected climate change will have an impact mainly on the shelf life of bridge fields and on future repair needs. The harmful factors ofclimate change are mainly related to increasing rainfall, increasingrainfall and increasing windfalls. The increase in the level of CO2 in the air will increase thecarbonisation of the fields at the end of the century. The essential factors for the stability of concrete structures are the protection against the corrosion of the scrapers and the anti-depletionof concrete.

Water, in its various forms, is an important factor in almost all babies ofconcrete structures. The most important impacts of climate change on the lifespan of structures are increasing rainfall and more rainfall becoming water, and the rhin was alsoseen during the winter season. Together with the slower drying of structures, this will result in a heavier melting burden on concrete structures and other porous building materials. In addition, the corrosion of uncorrosion-protected or low-protected steels is accelerated as the moisture content increases. The aesthetic rainfalls that affectthe structure will be adjusted as wind and rainfall intensities increase (Sweetteens 2013). By the end of the century, the number of cold melting melt cycles will decrease by about half today (Ruos teaet al. 2013). Pre-freezing pre-freeze pre-freezing pre-freezing (Bay den 2012).

In Finland, the direction of wind during water and wipe rains is typically south-east lunch — from the direction (Data page 2012; Lahti page etc. 2013). The wind direction during precipitation remains roughly present. However, on the basis of the reviews carried out, the southern structures will receive about 30 % more climb rain in the climate of 2100 compared to the 2000 climate. (Pakkala et al. 2014).

Climate variable	**Impact on bridge structures**
Air **CO2 concentration** —	The increase in the concentration of CO2 in the air will accelerate the carbonisationof concrete in future compared to the current state of the art. The current level of concrete protection is sufficient taking into account also the time of active corrosion, especially in rain-protected structures (Köliö et al. 2014)
Temperature No impact	– Rapid changes in air temperature can increase the heat expansionof the flame. Thermal expansion can give rise to tensions in structures that can lead to fractureand twisting. (Makkonen et al. 2009) – Longer periods of single hot and dry periods can cause dust nuisances on constructionsites.
Rainfall —	+ An increase in precipitation may, to some extent, reduce the salinity of the sea water off Hels'gin and increase the flow of fresh water into the sea along the Vantaa River. In the long term, the salinity of the sea water may to some extent:

			decrease, which reduces the concentration of chloride in structures. – Increased precipitation and flooding can lead to erosion, corrosion and leaching in connection with bridges, paddleways and terrace structures, e.g. larger drums under terraces are needed. Roads canalso add slippery to certain surface materials, which has an impact on road safety on the bridge. – The changes in the number of swords will be very significant. Winter (Makkonen et al.) 2009). The slide cleans the salt mist on the top of the structures. However, more attention needs to be paid to the choice of building materials, as the increase in symptom reduces the useful lifeof the outer upholstery surfaces (Makkonen et al. 2009). – Increased climate hardening in winter, with the consequence-of increasing the moisture load of structures (Yrjölä &Vita nen 2012) – Global warming and condensation can increase the corrosion-of fields. The time at which corrosion occurs is estimated to increase by up to 40 %. (Makkonen et al. 2009)
	Wind speed No impact	**US**	– In Helsinki, the load on the southern and south-western winds in particular is visible in structures and on terrain. High rail fields candivert the air flow into the street space. High slicing-and bulls are difficult to predict airflowsand turbulences, which may require special measures to ensure, inter alia, pedestrian and cycling safety (Wahlgren et al. 2008). – Long straight streets are easily windy and wind makes it possible forsuch street chickens to have a long turbulentflow. In open spaces of more than 30 metres, the wind drops down-to the ground and can blow sharply (Wahlgren et al. 2008).
	Snow cover, j crush —	**do and**	+ The risk of structural frost decreases by the end of the century as freezing melting cycles decrease.
	Cloudiness and sunshine —	**STE**	The increase in cloud and rainfall slows down the drying of structures and thus contributes to increasing the burdenof freezing melting cycles.

Sea level and ice conditions

– –

– Variations insea level: in the lower parts of the pillar, there will be-gentle to cope with ice loads and sea level variation;

– The wind from the wave is not significant, butsome hard wind may be significant.

– The main challenges to the sustainability of structures are salt; sea + road salt

– A globe can rise slightly higher than before,other steel surfaces are already protected against corrosion

Street structures

The most important impacts of climate change on street structures are the weatheringof rainfall, the proliferation of heavy rainfall and the increasing transformation of rainfall intove dex. As a result of global warming, winter rainfall in particular is becoming morefrequent. (Jylä et al. 2009). Changes in rainfall increase the risk of flooding if the sizing of the hulled water system is not sufficient for increasing rainfall. This should be taken into account when determining the sizing criteria for rainwater sewers, in particular for flood routes.

The increase in soil water content reduces the strength of the soil and reduces its load-bearing capacity. The number of irons will decrease towards the end of the century, but due to the variability of winters, the current crush protection ratio will continue to be necessary throughout the country in the future.

Climate variable	Impact on street and rail structures
Temperature — —	– The tempering of winters and the proliferation of freezing melting cycles on both sides of the zero degree increasethe stress on ka du superstructures. – The prolongation of individual heat periods increases the warmingof the asphalt layers of the street. Asphalt warming accelerates the grip of the street. – Longer periods of single hot and dry periods can cause dust nuisances on constructionsites.
Rainfall — —	– Aν average increase of 25 % in the six-hour and five-day accumulation of sa-drums and more than 50 % in some areas. The maximum intensity of short-term rainfall increases strongly (generally about 50 %) (Makkonen et al. 2009). The average growth rate of sa-drums over six hours and five days in Finland is 25-50 %. As aresult, the risk of heavy rainfall in the street environment increases (Sareer & Makkonen 2008). The increase in rainfall and the proliferation of heavy rainfall can also increase flooding, i—

	the sizing of the storm water system is not sufficient for increasing rainfall. – The current level of sizing of street drainage structures may be exceeded, causing flooding events, leading tomore frequent and growing damage caused by flooding (Sarelainen & Makkonen, 2008). Erosion that may result from flooding can cause structural damage in street terrace structures, dams, piping, etc. (Al-Outinen et al. 2004). – The soil's water content increases as rainfall increases, especially in winter. This reduces the strength of the soil and reduces its load-bearing capacity. As a result of increased rainfall, street structures are more frequent and longer than-before. Road grooves (deep depth) can double as the water content of the superstructure increases by about 2 %. The lifetimeof the streets can therefore be significantly reduced compared to thecurrent slope (Lower Outinen et al. 2004). – The increase in drought during the summer may lead to a decrease in the groundwater level, which in turn may lead to sleeping ofthe soil. – Precipitation situations may increase the start-up of contaminated soil harmful substances (Ruuhela 2012)
Wind speed —	+ The prevailing wind directions remain roughly the same. – Ωεστ winds blowing from the side direction of the bridge will become more commonif they were received. Storm winds and increased wind density can increase the risk of trees falling on rivers and streets and affect the electrification of the tram line and poles (Ruuhela 2012). Preparing for storms may require the planning of substitute links.
Snow cover, ice and groats — —	+ With climate warming, soils are no longer frozen as deep as today. However, in the future, the number of rums will varies from year to year. Reduction of the amount of iron can reduce to some extent cold structures and construction— the need for crushing of the nucleus towards the end of the century. However, dueto the variability of tallows, the current crushing dimension will continue to be necessary throughout the country in the future until a sufficiently long observation period, possibly modified onthe cruise, has accumulated. – The freezing of structures is becoming more common, as the sea is open at along distance in winter. The molten sea increases moisture, which remains in the structure. – In particular, the increase in slippery may require lightness

			checking fairways and avoiding steep slopes(Lower Outinen et al.) 2004)
	Cloudiness and sunshine No impact	**STE**	No impact
	Sea surface height and meteorological relationship Uncertain impact	**N** **No**	—Τηε rapid changes in the water level along the Baltic Sea are mainlydue to heavy winds and differences in atmospheric pressure, as well as back-to-back fluctuations in the Baltic water level. The impact of tidal in the Baltic Sea is small compared to fluctuations caused by wind and atmospheric pressure. The highest water levels usually occur at theturn of the year, when the total water supply in the Baltic Sea is often high and hard winds occur. However, high water levels are possible at all times of the year. Wind conditions due to changingrelationships are estimated to increase on average around 6-7 cm along the Finnish coast by the endof the sister (Johansson et al. 2014). The calculationsfor sea level rise-scenarios are low, but it can be estimated that the current recommendations provide adequate flood protectionfor conventional constructions at leastup to next century. Uncertainty will decrease as research progresses in the coming decades, so it is necessary to regularly update the estimates. (Kahma et al. 2014)

4.3 Railway structures

The most important impacts of climate change on track structures can be theextension of track temperature associated with prolongedperiods and the number of heat days, an increase in the density of windstorm and wind, loads caused by wet snowby wires, icing of structures and an increase in the number of thunderstorms.

Climate variable	Impact on street and rail structures
Temperature **—**	– On the other hand, the prolonged heat periods and the adjustmentof the number of heat days may increase the thermal expansion of tracks due to rapid changesin the temperature of the air. Heatexpansion can lead to tensions in structures that can lead to fractures and decomposition of joints. (Makkonen et al. 2009) – Longer periods of single hot and dry periods can cause dust nuisances on constructionsites.

Rainfall			– Thecorrosion of metallic wires and other metal lids mounted on the ground may increase to some extent as a result of the increase in the frequency of birth of the subsoilden (Ala-Outinen et al. 2004).
No impact			
Wind speed			– Ωεστ winds blowing from the side direction of the bridge will become more commonif they were received. Storm winds and increased wind density can increase the risk of trees falling on rivers and streets and affect the electrification of the tram line and poles (Ruuhela 2012). Preparing for storms may require the planning of substitute links.
—			
Snow cover, ice and groats			– Wet snow loads with track leads become more frequent- (Makkonen et al. 2009) – The freezing of structures is becoming more common, as the sea is open at along distance in winter. The molten sea increases moisture, which remains in the structure.
—			
Cloud and sunshine			– The prevalence of chicks is increasing (Makkonen et al. 2009). UK machinerycan cause damage both to the electricity supply and to thefield control and safety equipment. There is therefore a need for a preventive increase in the protection of thunderstormsin traffic control and safety equipment. Earthing resolution and over-voltage protection should take intoaccount the best solutions and assess the need for investment inthe thunder protection of installed equipment (Sarean & Makkonen, 2008)
—			
Sea level and ice conditions			No impact
No impact			

4.4 Movement and transport

Climate change affects movements on land and at sea. The most changing winterconditions in traffic. Extreme weather events, such as heavy rainfall and snow storms, also cause problems such as road and rail transport. The appropriate time for cycling increasesclimate change. The extension of the unconscious period makes cycling easier, but the increase in wind androads may from time to time make it less attractive for the future.

Climate variable		**Impact on mobility and transport**
Temperature **+ +**		+ Temperate winters, reducing snow-covered time. This helpsto facilitate cycling and extends the cycle period at both ends, as the streets will be longer in the future Sulina. Rising temperatures also inspring and autumn can attract more wheels to the back. – Prolonged heat periods and adjusting the number of heatdays may increase to some extent the need to cool the means of transport, machinery and other equipment. (Yrjölä & Viinanen 2012). Heat in the means of transport poses a particular risk to drivers. – Slippage problems are estimated to increase in winter time dueto an increase in exceedances. This needs to be taken into account in thedeck structures of walking and cycling lanes, etc., and duringthe maintenance phase in the slide control.
Rainfall **—**		– Winter rainfall and winds increase, which can reduce the attractiveness of cycling and outdoor travel. Rainfall, hard wind and low and very high temperatures have been shown to have reduced cycling or lowtemperatures. In wind and cold weather, humidity further increases the discomfortof wedding (the feeling of coolness). – Heavy rainfall can increase the flooding of storm water sewers on thestreets and make it more difficult to move. – In the future, the sea will be open off Helsinki ata longer distance in winter. The ice-free sea increases the amountof mist from the sea, which can hamper visibility and reduce the safety of cycling and walking on the bridge. This must be taken into account, inter alia, in the design of bridge lighting and-safety rails.

	Wind **speed -**	**US**	– The prevailing wind directions remain roughly the same. The south-west and west winds, which laterally blow to theSIL, tend to increase to some extent, especially in autumn and winter, whenthe winds are slightly more harsh than they are today. – Hard winds in some places can make urbanareas unhappy. In particular, open street spaces areunprotected. High air currents make outdoors cold and dangerous to move on the street, especially slipsin catalysing conditions. – On the other hand, winds are beneficial as they ventilate gas andother air pollutants (Wahlgren et al.) 2008). – Under the bridge, wind can be dangerously strong, which can affectboating and navigation (Wahlgren et al. 2008).
	Snow cover, j crush — —	**do and**	– Short-term severe snow rains that disrupt traffic are becoming more frequent (Makkonen et al. 2009). This has an impact on traffic flow and security. Rail traffic and lighttraffic are particularly sensitive to strong snowfalls. – In the event of a severe snow storm, walking on the bridge may become more difficult when the wind makes the bridge at the top of the wind shield and blows and quizzes inside the snow rail on a light traffic path. This shall be taken into account inthe maintenance and snow removal of the silver. – Slippage problems are estimated to increase in winter time dueto an increase in exceedances. This affectstea footfall and cycling (Makkonen et al.) 2009). The liukmay also occur on rails, in particular on sub-cooled water precipitation. In this case it may cause disturbances in acceleration and braking situations. The freezing of switches and platforms is a problem with a mild frost eye when the surface is cushionedand water is available, e.g. when temperature fluctuates two sides ofthe point of contact. (Island & Makkonen 2008). – The incidence of defrost and frost is increasing. Rumours and spices accumulate onthe overhead contact lines and function like insulation, which may, for example, reduce the electricity supply of the conductors. – The tempering of winters and the proliferation of melting and freezing cycles on both sides of the zero degree can increase the heating demand of switches and crossings. – The proliferation of melting-freezing cycles, in particular by heavy wind, may increase the risk that a puncture attached to bridgestructures will ice on walkers and cyclists.

	Cloudiness and sunshine —	**STE**	Winters are likely to be more cloudy and fogged. This must be taken into account in lighting planning.
	Sea surface height and meteorolo gical relationshi p —	**N** **No**	– The reduction of sea ice off Helsinki may increase the proportion ofwind, which has an impact on road safety at the bridge. – The long-term rise of the sea level off Helsinki may have an impact on the bridge overhead height and thus, for example, on pleasure boating and the bunkering of the Hanasaari power plant.

Maintenance

The reduction in the length of the snow period, the quantitative change in snow rainfall and the reduction of snow cover have a major impact on the winter management of tracks and streets. Lu-mentation and slip protection are becoming increasingly demanding. The increase in rainfall and the spread of heavy rainfall may, to some extent, increase the need for repair of certain structures andcoatings. Soil erosion that may result from flooding can cause structural damage in street terrace structures, dams and piping.

Climate variable		**Effects on maintenance**
Carbon dioxide in air —	**sporadicity**	Aν increase in the concentration of CO2 in the air will speed up the future bonatisation of concrete compared to the current level. Refreshments need to be carriedout where necessary, where too little protective concrete cover has been left;
Temperature —		– During winter melting ice cycles, the need for melting drums may increase significantly on the southern coast. – The increase in water rainfall during the winter season may make melting ice cycles after rain more severe and thus increasethe need for refilling or locating the coatings.
Rainfall —		– Increased rainfall and the proliferation of heavy rainfall can reduce the durability of certain structures and coatings (e.g. natural stone surface with sandy bonding or sauma) – Increased flooding and increasing flows can suppress the risk ofdams and slides, thus causing erosion damage and drum blockages in the open-loop network.

Wind nop No impact	**EUS**	– No direct impact on the maintenance of structures – Hard winds can increase to some extent the maintenance of lighter equipment and furniture (e.g. signage, litter containers, traffic signs) – An increase in wind density can increase fatigue in the columns, support structures and overhead contact lines of the rainlines; with their current renewal every 10 years, the future needfor renewal can be every 5 years.
Snow cover, j and groats — —	**No**	– The reduction in the length of the snow period, the gross changein snow rainfall and the change in the thickness of the snow cover will have an impact on the wintermanagement of tracks and streets. Winter care for streets is estimated to increase in January for the increase in snow andsnowin February. On the other hand, as a result of the condensation of March, November and December, maintenance needs may even decrease, as rainfall would become water in particular in November (Alo-Outinen et al.) 2004). – The need for snow removal is expected to increase inthe future. In front of Helsinki, the sea area will be increasingly melted inwinter, when rainfall is typically snow. The number of snowfalls varies most to the south of Salpausselä, in the Uusimaa region. In the future, provision will also be made for the rainfall ofsnow. This may require the development of new snow removal methods and may affect, among other things, the choice of equipment for winter care. Severe snowfall can also block and cause malfunctioning ofthe equipment. – The need to combat slurry in relation to de-icing andleachate at frost temperatures close to 0 °C also changes due to the mild winters (Sarelainen & Makkonen, 2008). Liuk season control will also become more demanding, which may require, among other things, the development of new means of slide detection (e.g. use of sensors on a bridge). The use of salt and sand for soil control is likely toincrease. The increase in the need to controlliquor may require the development of new anti-slip agents. New types of soil control agents may have an impact on the environment (marine nature) and structures.
Cloud and sunshine No impact	**siting**	– In the future, increased cloudiness may reducethe need for painting sites of structures, whichare typically caused by sunshine. – Increased cloudiness, combined with increased rainfall, slows down the drying of the structures andthus accelerates their damage.

Sea level and ice conditions	No impact
No impact	

5 Impact preparedness and adaptation

5.1 Design of structures

5.1.1 Protection against corrosion of ironings

The protection against corrosion of concrete structures is based on both chemical and mechanical protection. Chemical protection means that the high alkalinity of concrete constitutes a passivity film on the surface of steels, with the effect that steels do not corrose under wet conditions. Te's surface passive film can be broken either by chlorides in concrete or by the loss of subtraction due to the carbonisation of concrete (e.g. Bakker 1988). Although chloride stress is generally considered to be worse than the corrosionl of scrapers, corrosion caused by the carbonisation of concrete causes 2/3 of structural damagein concrete structures exposed to climatic stress (Parrott 1996, Jones et al.) 2000).

As the concentration of CO2 in the atmosphere increases, the carbonisation of concrete will-increase now. As the climate becomes more precipitated during the winter season, the use of slide-proof tasting conditions may thus increase and thus the infiltration of chlorides into concrete. Both of these can be influenced by the thinness of concrete and the packet of sheeting. According to recent studies, the increase in the level of CO2 in the air does not require action on current planning practice (Köliö et al. 2014). This can still be easily verified, e.g. by-means of a carbonisation factor for concrete from the Bridge Register or the so-called observation times.

In order to prevent the intrusion of chlorides, a concentrated concrete, i.e. shallow aqueous cement wedge, good condensation of concrete casting and careful aftercare. It is possible to consider chloride penetration into bridge structures in the same way as the carbonisation factor.

Table 4 Stability requirements for concrete structure (100 years, corrosion of scrapers)

Structural component	**Minimum characteristics of concrete**			**Cover thickness of steels**	**Cracking of concrete**
	Strength class	W/c	quantity of cement		
Bridge lid	C30/37	≤ 0,50	≥ 250 kg/m^3	≥ 40 mm	≤ 0.14 mm
Border bar	C35/45	≤ 0,45	≥ 320 kg/m^3	≥ 45 mm	≤ 0.07 mm
Aid for land	C30/37	≤ 0,50	≥ 250 kg/m^3	≥ 40 mm	≤ 0.14 mm
Concrete-structures in contact with sea water	C35/45	≤ 0,45	≥ 320 kg/m^3	≥ 45 mm	≤ 0.07 mm

The effects of spray water can be addressed by identifying areas exposed to spray water and by implementing protective measures. In particular, the impact of spillage of seawater on bridge structures must be considered.

5.1.2 Prevention of the depletion of concrete

Concrete frost is the most significant decay in Finnish bridges and inconcrete structures exposed to outdoor air stress. Concrete frost resistance can also beobtained by additional screwing, which is required to be used for all concrete structures that are vulnerable toweather stress.

Research on adaptation to climate change of concrete structures in the CIS has shown that the-frost resistance requirements for ny high concrete standards are sufficient also for the future climate (Pakkala et al. 2014). On the other hand, freezing melting cycles are decreasing towards the end of the century, while winter rainfall becomes more resilient and abundant. This means-that further porosing must always be successful!

A total of 57 cases of alkaline aggregate reaction (AKR) have been detected in current concrete structures over the past 10 years, of which 23 have been detected at the time (e.g. 2012). Recent TIY studies have shown that an emerging AKR in a thin thice is present at around 40 years of age (Lite page & Husaini 2015, unpublished). Both studies have found that typically in the bridges from which AKR was found, the cement was for the most part Portland cement. Reacting rocks have varied considerably, but they alsohave highly stable granite and gneiss and other metamorphic rocks. (See, etc.) 2012; Lahti page & Husaini 2015).

There is no guidance in Finland to avoid an alkaline stone reaction, as rockspecies of the Finnish Kalliope rän are generally considered highly stable. The risk posed by cement is described asthe so-called sodium oxide equivalent, i.e. Na2OEQ [%]. In several guidelines, Na2OEQMaximum Ar Vona is considered 0.60 % (NBN B 12-109, 1993; DIN 1164-10, 2008; BS 4027, 1996). The Na2OEQ of the most commonly used Finnish cements varies between 0.8 % and 1.35 %. As a result of climate change,its projected increase in rainfall increases the risk of alkaline rock reaction, which justifies the use of less alkaline cement to ensure a long life.

Table 5. Stability requirements for the concrete structure (100 years, depletion of concrete)

Structural component	**Minimum characteristics of concrete**	**Blocking the AKR**	**N.B.:**
	Resistance to frost	NA_2O_{EQ}	
Bridge lid	P50	≤ 0.60 %	
Border bar	P80 + attestation of eligibility	≤ 0.60 %	Renewal every 30-50 years
Aid for land	P50	≤ 0.60 %	
Concrete-structures in contact with sea water	P80 + attestation of eligibility	≤ 0.60 %	

The water insulation on the bridge deck typically has a lifetime of 30-40 years, after which it will haveto be renewed. In bridges where chlorides are used to control slurry, the lifespan of the edge bar is significantly shorter than the target of 100 years now.

When leaking on the bridge, the mosquitoes of the deck irrigate the structures of the bridge, resulting in abrutal higher humidity burden on them. Transport welds typically have a lifetime of between 25and 35 years after which they have to be renewed.

As a result of climate change, the burden on these structures is higher,and it is already assumed that their lifespan will also be shorter than expected. Special attention should be paid tothe detachment of the bridge and to the design of the drainage of the bridge. It is recommendedto use materials that last for a long time and the detalides are designed in such a way that the local leaking of joints and water insulation is minimised to the detriment of thetoni structures.

5.1.3 Protection against corrosion of steel structures

In bridges, protection against corrosion of steel structures is provided by different combinations of coatings. Earthwashing processes are carried out in the context of mechanical engineering, making conditions more manageable. These combinations of paintings, which are currently commonly used, will not be affected by climate change. Climate change is predicted to increase cloudiness and thus toslightly decrease the effect of sunshine on painting.

The useful life of the main steel supporters of the bridge is the life of the structure as a whole,i.e. 200 years in this case. The main supporters are very well protected from weather stress under deck, so no significant additional burden on these structures is expected as a result of climate change. However, the exceptionally long life-time target requires carefulcorrosion protection during painting already on the machine. Special attention should be paid to thehandling of painted steel grains due to their large size, so that the paint-surface is not broken during installation.

Maintenance painting of steel structures during use can be programmed in line withcurrent practices in painting processes.

5.1.4 Follow-up recommendations on planning

Follow-up recommendations on planning

Resistance of reinforced concrete structures

- Specific design attention shall be given to concrete tipping, as thinning affects the penetration of both chlorinedies and CO2 into steel concrete structures.
- The protective concrete coatings of reinforced concrete structures must comply with the current guidelines. Alienationscannot be allowed.
- The use of stainless welded steels shall be considered as far as possible. However, they shall be insulated by plastic connectors from conventional irons.
- Particular attention to structural management and repairs to structural protection

Protection against corrosion of other structures

- As regards corrosion of steel structures, account must be taken of the effects of climate change on maintenance intervals and painting systems.
- Special attention shall be paid to the protection against corrosion of sparkling cables (lifespan 80 years)
- The corrosion capacity of the loops shall take into account a lifetime of 200 years, soils with sulphide clay and chlorides shall be taken into account in material choices.

Water management

- Planning shall take into account the discharge of water from the bridge deck and structures. Further investigate how rainwater is discharged into the sea. Examine whether the drainage systems in the bridge are adequate in relation to the predicted increase in rainfall. Particular attention to the need for sufficient capacity, conduits and drops of conduits
- Design shall take into account how to prepare for heavy rainfall (railway wells and number and layout of the pipes) for the drainage of the bridge;

Other comments

- More detailed description and corresponding design of the rubbish areas of the Crown Mountains
- The long bridge structure has greater movement than usual, which needs to be taken into account, among other things, in the dimensioning of the circulatory plateau (including handrails) and in the prevention of their leaks. The formation of ice in structures should also be taken into account.
- Design and implementation of 200-year structures with special concern
- Structural components with a significantly shorter lifetime, such as typically physical welds, water insulation and edge beams, are designed to be renewed in the same cycle;
- The design shall take into account the accumulation and drying of structures due to changes in sea level levels and the variation of temperatures on both sides of the sea. This shall be further examinedas a pre-label for the choice of superstructures.
- Vegetation should not be attributed to bridges. The effects of vegetation on beach structures must be assessed (e.g. the need for root protection)

Traffic planning

5.2.1 Transport solutions

From the point of view of mobility and mobility, the integration of climate change into accountof climate change is more clearly linked to overall sustainability and climate change mitigation than toadaptation.

Connecting to stops and stations is an integral part of the public transport system. At theend of the LAA, in order to improve the accessibility of thesystem, pedestrian and cycling links shall be ensured throughout the line. For bicycle parking, coveredand centralised solutions are recommended close to stop platforms in both the Broadtail and Sompa Islands. Attention should be paid to accessible walking links on the periphery side of the city, but pol-bridge parking is also recommended close to the base city stops.

Walking and cycling are more easily connected tothe rest of the region’s transport network. At the western end of the bridge, connection to the existing walking and cycling network is clearly organised in the Hakaniemi option, but in the case of Kruunuha, the transversal connection to the west of Liisankatu requires more action. It is important to considerthe smooth and secure connection of the Kruunusillat cycling network to Helsinki’s future Banana network in all the-conditions of the convenience of the city. On the bridge itself, the dimensioning of the traffic technology is related to the smooth running and safety of movement.

As far as the rail network is concerned, the Hakaniemi option may create a bottleneck with the capacity of the long-milebridge, which already runs around 25-30 trams per hour in their directionduring a fall, and according to the 2014 alignment plan, wagons would run up to one minuteof bread.

5.2.2 Ensuring fluidity of traffic

Roughly half of the new tram passengers come from car users and the other half from walkers and cyclists. This in itself facilitates the smooth running of car traffic by slowing down the growth of car traffic.

There is no actual forecast of the number of walkers and cyclists on the bridge, but at least the number of bicycle journeys predicted is significant. The promotion of cycling and the increased popularity of cycling, as well as the increase in e-bikes such as e-bikes, will probably increasethe number of cyclists and increase the average cycling season. Light electric motored mobility devices, which are similar to pedestrians, can also be expectedin the future and their space requirements differ slightly from pedestrians. Although the cross-section and capacity of the high quality track is sufficient for walking and cycling, desnow during winter may lead to a combined width of up to 8 metres for walking and cycling lanes to ensure safety and tolerable conditions.

Difficult weather conditions set their own requirements to ensure the smooth runningof traffic. Darkness, obscurity and fog lead to the need for smart lighting adapted to the situation. Wind intensification can be partially offset by wind protection barriers. The bridge deck’sslip during the season or exceptionally heavy winds can be communicated on smart panels or other real-time systems.

Social security, monitoring systems and general cleanliness as such improve the acceptability and usability of a long bridge for different user groups.

5.2.3 Ensuring the functioning of transport

Winter management of the Kruunusillat project will be the main challenge for transport efficiency if the effects of climate change are predicted to materialise. Walking and lying connectionsto stops, snow off the bridge (trackway, walking and cycling) and the slide torn must-be adapted to the need. Proactive smart policy guidance is a prerequisite for ensuring the-functionality of the field and the attractiveness of the bridge.

The connection of the new tram line to the network of the centre with transmissions also presents additional challenges, including winter care. On the network, a single problem situation is rapidly reflected in a large area.

5.2.4 Follow-up recommendations on planning

Follow-up recommendations on planning

Transport solutions
- Rotary parking, in particular for stops on the Broadsalo side (start of bridge, tramway stops)
- Barrier-free access to rainbow stops
- Seamless connection of cycling links to the main city network, which needs to be prepared for increasing numbers of cyclists;
- Sufficient capacity, in particular the width of the cycle lanes (e.g. railway Bana capacity is already fully utilised from time to time)
- The lack of a high level of public transport between the construction decision and the execution;

Ensuring fluidity of traffic
- Smart lighting adaptive to need
- Wind protection rails
- Social security, surveillance systems
- General cleanliness
- Effective snow and slip control

Ensuring the functioning of transport
- Bridge monitoring and warning systems for extreme weather events, traffic management
- Smart and proactive winter care management
- Sufficient width, sizing taking into account management equipment, more than one avoidance room/spray, sufficient roof coverings for hard wind/storage

Maintenance planning

5.3.1 Salvage treatment

Due to the proliferation of sudden snowfalls, it is necessary to design an efficient snow-free method for the light traffic path on the bridge and also for the tracks. The options for snow removal are either the spinning of snow at sea or the loading and transport of snow to the snow reception site. Handrails or wind shields entering the bridge should be designed in such a way that any snow discharge into the sea is not hampered. The size and efficiency of the equipment for snow removal is also essential. In the above options, the equipment is different and the working speed is different. Sea-linking is a much more cost-effective method than snow shearing, loading and transporting to theplace of reception. It is also possible to load snow with centrifuge, which can be absorbed inthe choice of method.

The winter management of the tracks is carried out by a different organisation than the light bus, so they use separate snow removal equipment (e.g. a work wagon with snowand de-icing, curtain and vibration tracks, and which can also be used for defrosting). However, the fundamental issues concerning the removal of tramway snow are partly similar to those of the light road. The heavy snow precipitated on the tracks has to be removed either by trapping or by convexingthe line. However, more snow can be placed on the tramway edges than on the edges ofthe light road path, as the only criterion is the running of the tram. In addition, the-tramway consists of two pairs of rails, providing more certainty for tramway traffic in winter.

The difference between snow ploughing or centrifugation is also apparent from the point of view of the interim storage of snow. In theAU rail, snow moves to the edge of the light traffic fairway, e.g. the hub of thepavement. The intermediate storage period of snow at the edge of the pavement depends on the quality ofwinter care. Snow accumulates next to the bridge's handrails, also as a result of quincing.

Temperatures moving close to zero lead to an increase in the need tocontrol slippage. Water bridges tend to accumulate moisture and slippery more often than on the asphaltpath leading to sil. In this case, it is of great importance to detectthe slide well in advance or even by anticipation of the slippage. It may be possible to use friction sensor technology or optical meters as a means of detection.

There may be a need for further development in the area of anti-convenience materials. Salting is an effective method to control the liquor if its use is possible, taking into account the impact of salt on structural stability. However, the circumstances require good protectionagainst corrosion in each case (see section 5.3.1). The salting of light roads is allowed in thewinter management product specifications of the Helsinki City Construction Agency. Salting hasbeen used on light traffic routes, in particular during the first spring of the autumn. Sanding is also a suitable method, taking into account the demands of cycling in thegrain size of the sand/black sand. However, in spring, sanding will cause additional care inthe form of de sanding.

In some Finnish bridges, automatic salting has been tested in the slip control of roads in vehicles. In the method, the sensors recognise the slippage and the salt is applied from nozzles located either on the surface of the coating or at any other point of the structure. In the case of runways, this is a light fairway slip control and the price/quality ratio and rationality of this method should be clarified.

However, the most efficient ice and snow removal is achieved by surface heating. For surface heating, electricity or district heating is usually used. It is generally accepted that the MIM 300 m^2 floor space is a limit for electricity heating and therefore, due to the large area of the bridge, electricity heating is not cost-effective.

The questions of the winter care method are crystallised in the quality standards for bridging winter care. For example, are the requirements of class A for light roads sufficient, or are there some specific requirements necessary? The main quality requirements are the starting point and time of operation for snow and shooting and snow control, as well as snow transfer and-transport. In this respect, an appropriate price-quality ratio should be found, taking into account the possible active useof the bridge by the municipality during the winter season. Examples include the current lighttraffic paths:

Requirements for the removal of category A snow and slush:

- Starting threshold: 5 cm thickness of snow layer or 3 cm sorghum.
- Intervention time after the end of the snowfall: snow that fell between 17:00 and 3:00

is removed by 7 a.m. on the following morning and snow that felled between 3:00 and 17:00 is removed within 4 hours.

5.3.2 Surface structures and coatings

Climate change will not lead to major changes in the maintenance of surface structures and coatings in the future. In general, it is advisable to design surface structures that can withstand-the maintenance burden and do not increase the need for maintenance. An example of a more difficultsurface mater is the use of a sliced rock surface, which makes it more difficult to clean up the surface.

An increase in the need for coating due to melting freezing cycles can be preparedby plating more resistant coating types. It is possible to prepare for increasedrainfall by minimising objects with non-binding material surface or joint material. The increased need for thawing drums does not give rise to specific needs for preparedness.

5.3.3 Furniture

Climate change does not result in major changes in maintenance of equipment and furniture. The increased need for replacement of equipment/fittings caused by open winds can be anticipated for critical support or control structures by designing more sustainable solutions that reduce the need for maintenance.

The layout of equipment and furniture is an essential element. Many equipment and furniture as well as vegetation increase the need for manual winter care, i.e. increased costs. Examples of this are the possible resting points on the light traffic fairway, litter containers, beech buckets, etc.

5.3.4 Follow-up recommendations on planning

Follow-up recommendations on planning

Salvage treatment:
- Winter care planning is based on current practices. Clarify whether the wintermanagement of some sections of the transport link requires capacity or quality higher than the current practice (e.g. higher quality standards that require more resources to be implemented). The quality requirements highlight the starting thresholds and time limits for snow removal and slip control.
- Explore snow removal options on the bridge: transport of snow off the bridge or centrifugation of snow at sea: e.g. snow-carrying and possible loading and transport, fleet requirements, the impact of the necessary snow equipment on the design of structures, the effect of snow removal on the-bridge's use and road safety, etc.
- Explore alternative means of soil control and slide prediction on the bridge: e.g. access to sensor technology or optical meter for slip detection, space charge requirements for multiple ratch systems
- Explain how to deal with ice falling from structures in winter management;
- Identify the needs and possibilities for monitoring and warning systems and heating systems;

Cleaning:
- The design of the structures must take account of the fact that all points of the structure can be cleaned. Special attention shall be paid to cleaning of structures under the bridge. The cleaning operations of the structures shall be planned in advance.

Vegetation:
- It is useful to favour a diversified, resilient, sustainable and easily managed vegetation in Finland. The design of beach vegetation should take into account, among other things, that the roots of the plants do not damage the beach walls.
- Further study the impact of vegetation on structures

Structural management and maintenance:
- Define a target renovation age for consumable structures. All consumable structures are planned fora specified renovation age.
- Examples of painting of Norwegian beach structures could be explored for the design of painting systems

Equipment and furniture:
- Explore possibilities for sourcing "smart boars"
- It is necessary to test bridge lighting under extreme weather conditions (e.g. impact of sea fog on visibility). The effects of humidity and ice on the luminaires shall be further investigated. The criteria for the purchase of luminaires should favour longevity and dependency. The responsibility for the maintenance of the luminaires and thecourse of action shall be determined.
- To be considered during the design phase: the layout of equipment and furniture should be such that the equipment and furniture themselves, as well as their surrounding areas, require as little as possible manual tal-care work;

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