

WHAT IMPACT WILL CLIMATE CHANGE HAVE ON ROADS IN SWEDEN AND HOW TO DEAL WITH IT

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ABSTRACT

The result of the national analysis of risks and vulnerabilities due to the impact of climate change has given rise to a number of in-depth studies of the first effect of more water, in different forms.

The national analysis pointed to the southwestern parts of Sweden as the most vulnerable due to the amount of rainfall, flooding, and rise in the sea level. This has resulted in a project for this part of the country which is planned to start next year. The main purpose of the project is to identify tunnels and parts of roads which are low-lying in comparison with sea level, and vulnerable parts of roads in relation to streaming surface water.

Another part of the road structure at risk is the drainage system, which in the future must be able to handle water in larger quantities than today. This problem is common to most parts of the country.

The first climate change impact to be noticed, however, according to the scenarios which have been formulated, is extreme weather such as cloudburst. This will, for instance, affect slope stability and give rise to flooding. The problem is common to the whole country and potential risks must be identified, for example, e.g. defects in road construction and the nature of the surrounding soil.

To meet the problem of extreme weather, a risk analysis method known as "vald vägsträcka (chosen road stretch)"¹ will be used, in order to identify points at risk in the road system. In the next long-term planning measure, money will be allocated for the reduction of hazards in the road system detected by this risk analysis method.

Another problem caused by rising temperature, in the longer term, is the loss of frozen soil or permafrost. In the northern parts of Sweden, frozen soil is an important load-bearing capacity factor. If the derived scenario for climate change is correct, this factor no longer will exist by the end of this century. The first effect of this will be felt in the forestry sector, but also in the mining industry. It will also demand an investment in roads to fulfill the requirements from these industrial sectors.

KEYWORDS

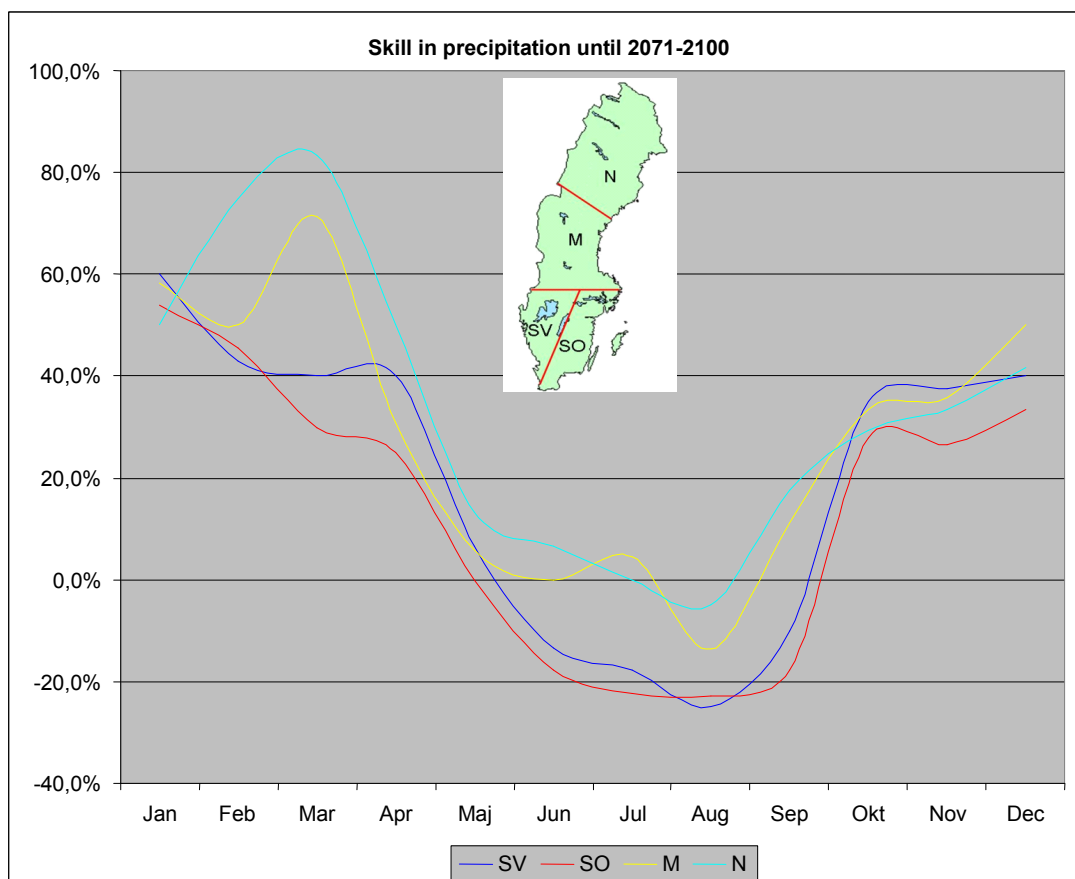
CLIMATE CHANGE / IMPACT / VULNERABILITIES

1. SWEDEN FACING CLIMATE CHANGE

The national analysis of risks and vulnerabilities due to the impact of climate change “Sweden facing climate change”² pointed out some specific problems that road owners have to prepare for. Most of the problems are related to water but also higher temperature and change in wind conditions will affect the road systems.

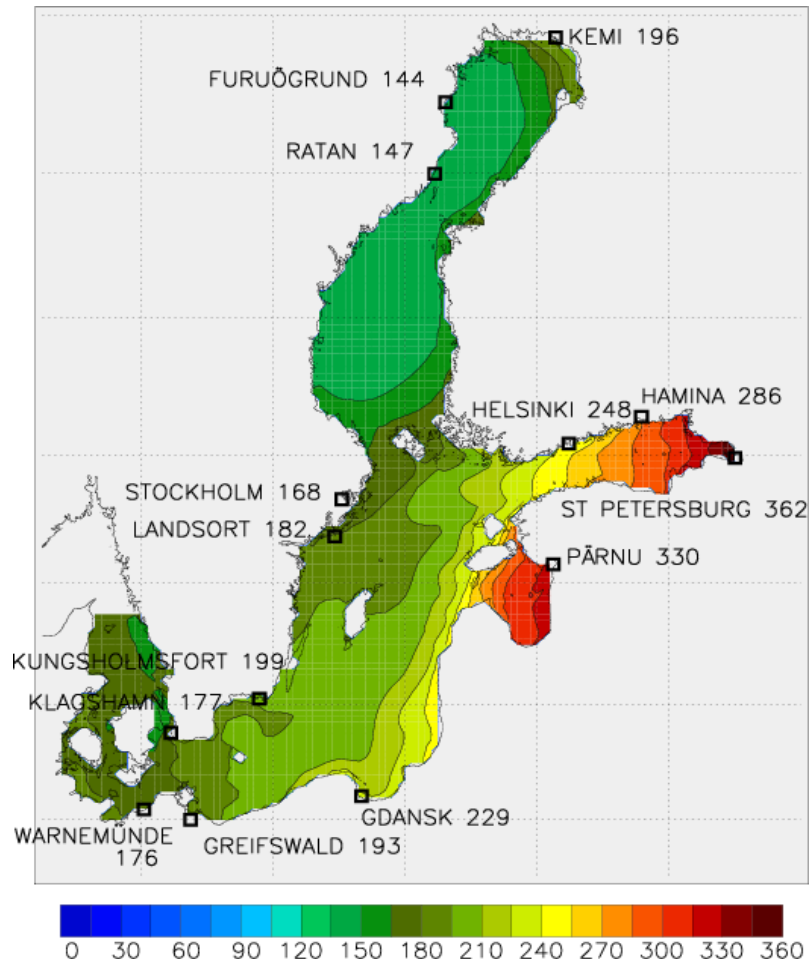
Among the identified vulnerabilities due to water are the following effects of climate change valued as the most threatening:

- The increase of precipitation
 - The changes fluctuates over the country, the highest increase will be in the south western and northern parts of Sweden.



- Rising sea level

- Will affect the coast line from the border to Norway in the west down to the south and up to about Stockholm on the east coast. Further north on the east coast the elevation of the land will neutralise the effects of sea level rise.



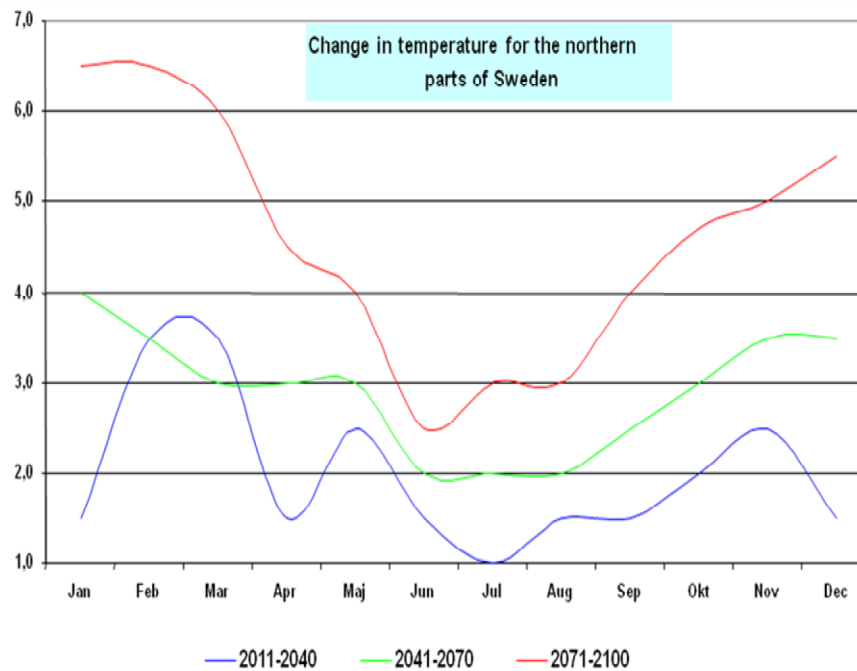
Sea level rise of 88 cm will increase so called 100 year waves at the level (cm) on the map on the left

- More frequently extreme weather such as cloudburst

- This will strike the whole country, even the southeast parts which will have a decrease in precipitation.

Among the vulnerabilities that are not water related the following threat is valued most threatening:

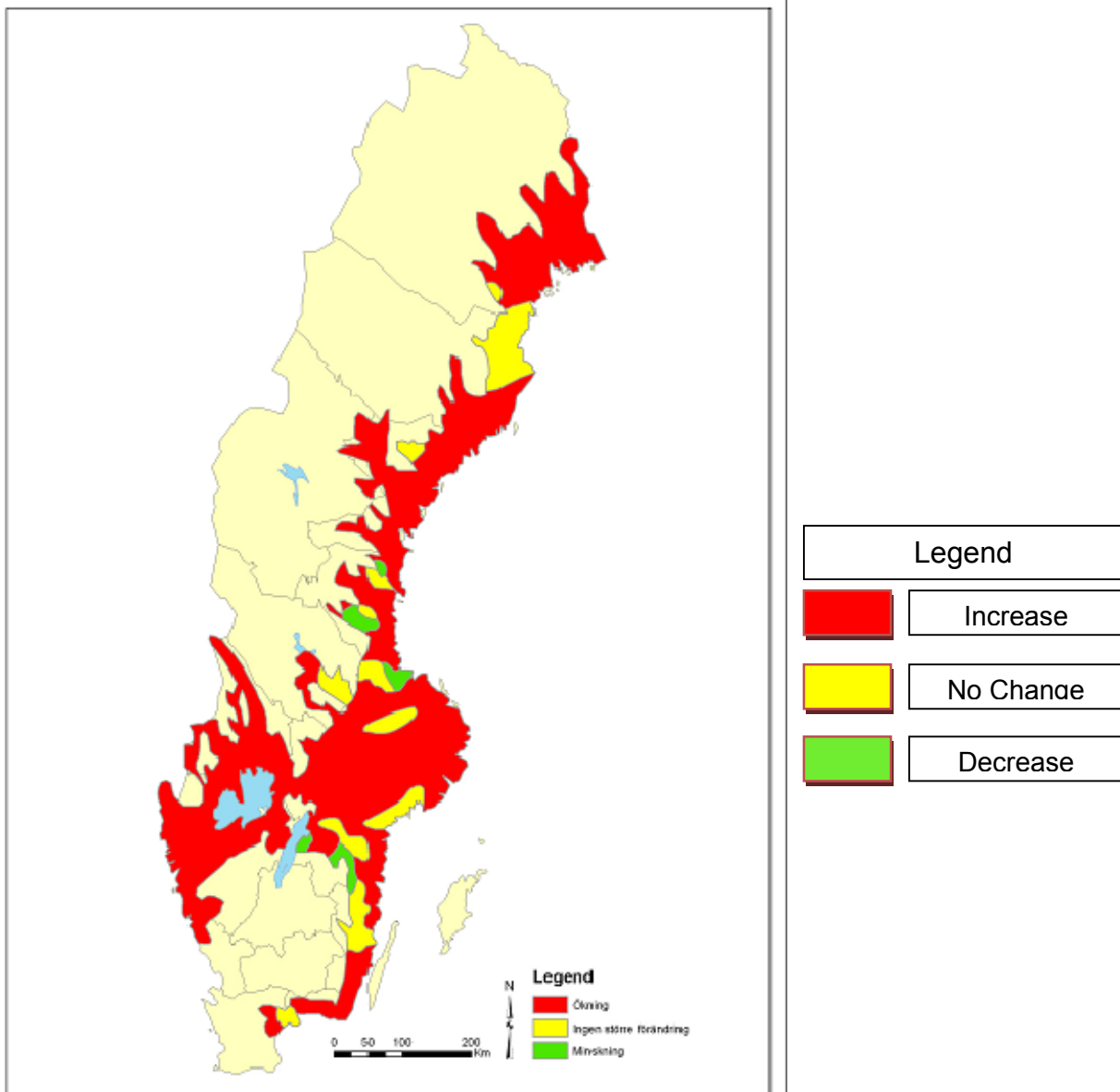
- Higher temperature
 - The northern parts of Sweden will get the highest increase in temperature during the winter.



2. IDENTIFIED VULNERABILITIES

The increase of precipitation, particularly in the southwest, and the fact that this part of the country also often consists of silt or quick clay creates a potential future risk for the roads. But this vulnerability is not only located to this part of the country.

The Swedish Geotechnical institute have produced a map showing change in probability of landslides caused by climate change:



Map of Sweden with known risk of landslides marked

The precipitation also increases risk of flooding, particularly in the southwest and northern parts of the country. The identified vulnerabilities caused by this are as follow:

- Stemming at low bridges and culverts
 - Irrespective of the watercourse width
- Culverts and bridges over small watercourses
 - Especially related to intensive rainfall on small catchment areas
- Erosion damages on bridge support

An example of this problem is shown in the picture below. In the northern parts of Sweden, both the road and the railroad were flushed away after a stemming in July 2006. The circumstances were an intensive rainfall on a small catchment area (about 100 mm during 1 hour) which lead to an intensive flow in a small watercourse during a short period of time:



Landslide at Enafors, Jämtland, 2006

The effects of climate change concerning flooding as described above is not only a summer problem. When taking into account the change in temperature it will be a replacement during some parts of the winter from snow to rainfall. The effect of a cloudburst in winter could be much more damaging than in the summer, depending on the fact that the ground is frozen and culverts could be stemmed by ice and snow.

Another winter problem due to increasing precipitation and higher winter temperatures is the loss of frozen soil. The roads in the northern parts of Sweden are depending on the frozen soil as a load-bearing capacity factor. If this state will no longer exist in the future, it will create big problems either for the industries (closed roads for heavy vehicles during the winter) or for the road administration (spoiled roads). In the future, a decision has to be made whether to reinforce the roads or allow them to deteriorate and repair them afterwards.

The sea level rise is another problem where water is involved. The problem is, as mentioned above, only a problem where the sea level rise is larger than the elevation of the land. The exposed objects to this vulnerability are low-lying road stretches and tunnels. A project is initialized to identify vulnerable objects and probably will different solutions be used to solve identified problems. Embankments, different kinds of pump systems and relocation of the road are probable solutions.

One of the biggest challenges according to climate change is how to lead away water from the road structure. The drainage system will increase in importance and the road maintenance and operations due to this will get a key role. Ditches and culverts must be given much higher priority and resources given.

According to "Sweden facing climate change" the first effects of climate change will be more frequent and intensive extreme weather such as cloudburst. As mentioned above, this will affect the entire country. Therefore, it is important that a risk analysis of the entire road system is accomplished. Swedish Road Administration has developed a method called "Vald Vägsträcka (chosen road stretch)" which is in use in the ongoing risk analysis

3. SWEDISH ROAD ADMINISTRATION'S RISK ANALYSIS METHOD

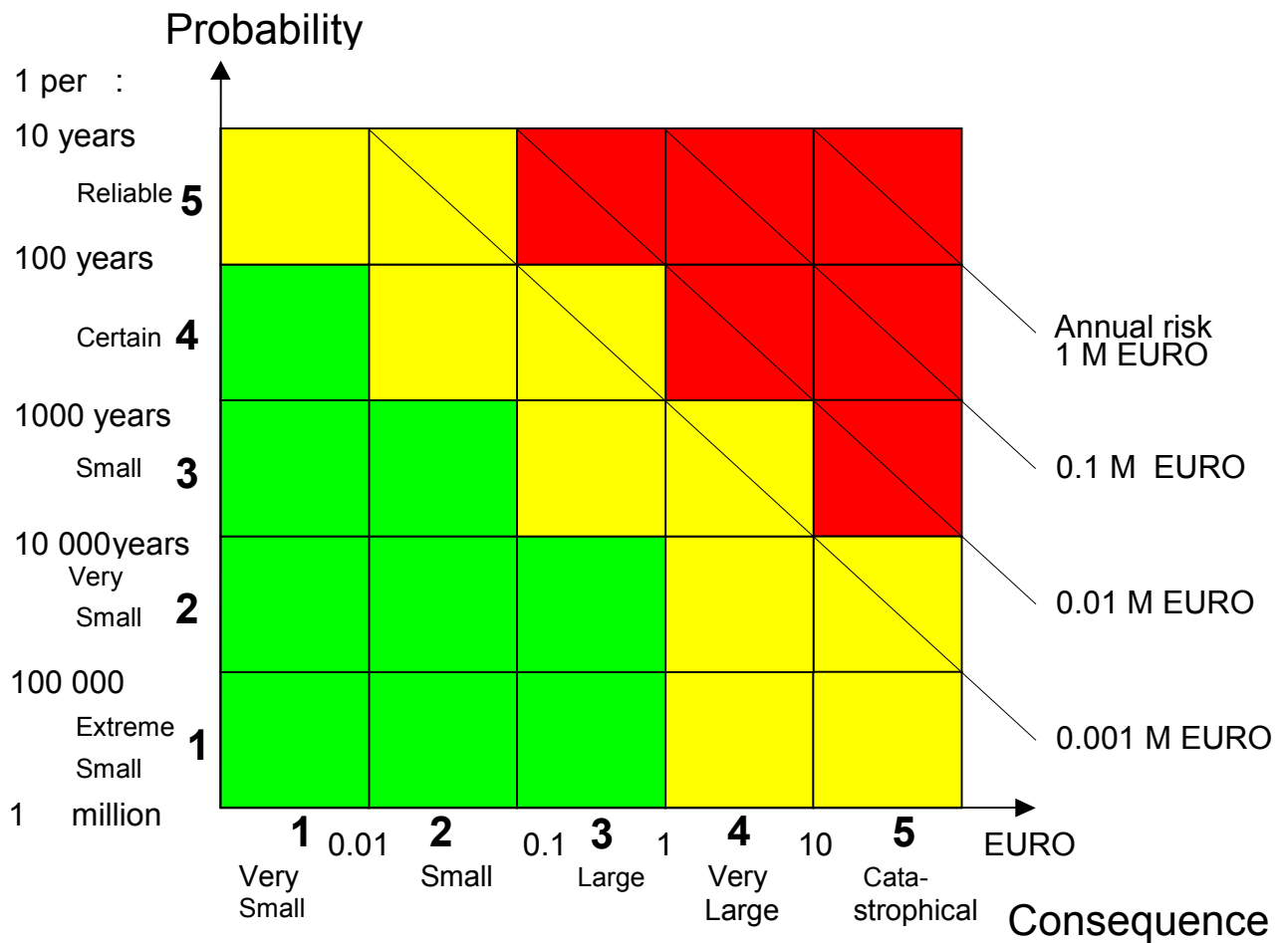
Up until now, identification of the vulnerabilities in the road system has been poor. Only in the last couple of years, analyses of the roads in a structured way have been made, and much is still to be done before all of the risks are identified. To realize the risk analysis support was needed, and hence in 2005 the instructions for the method "risk analysis chosen road stretch (vald vägsträcka)" was published.

The method description primarily handles the analysis of risks of varying character and concerns roads and bridges, as well as risks associated with construction that concerns the surrounding area.

In the in-depth part, which is an application aid, the emphasis has been placed on

- Landslide and collapse risk
- Risk for damage on road and bridges with high water flow
- Risk of flooding
- Risks due to accidents with dangerous goods

To help ranking identified vulnerabilities a matrix based on probability and consequence is included in the instruction:



Risk classes in matrices:

- Class 3, high risk level, not accepted in general
- Class 2, medium risk level, safety action should be considered
- Class 1, low risk level, accepted in general

Probability	Word	Figures	1 time per	Consequence	Word	Figures
1	Extremely small	10^{-5} - 10^{-6} per year	100 000 year – 1 million year	1	Very small	<0,01 M EURO
2	Very small	10^{-4} - 10^{-5} per year	10 000 year – 100 000 year	2	Small	0,01-0.1 M EURO
3	Small	10^{-3} - 10^{-4} per year	1 000 year – 10 000 year	3	Big	0.1-1 M EURO
4	Certain	10^{-2} - 10^{-3} per year	100 year – 1000 year	4	Very big	1-10 M EURO
5	Reliable	10^{-1} - 10^{-2} per year	10 year – 100 year	5	Catastrophic	>10 M EURO

4. PROPOSALS IN THE LONG-TERM PLANNING

In the Swedish Road Administration long-term plan for the years 2010-2021 allotments have been addressed to measures to prevent negative effects caused by climate change. Most of it is related to preventive measures but also to the following subjects:

- Improvement of competence
 - Level of competence ought to increase in the Swedish Road Administration concerning effects of climate change. One responsible specialist on the subject should be appointed.
 - Level of competence also ought to increase among the regions and groups of specialists.

- Research and development
 - Research and development ought to be done together with other countries. The work in ERA NET ROAD and PIARC are good examples.
 - It is of the highest importance to develop risk analysis methods for storm floods and landslides.

- Review of rules and regulations
 - When constructing new roads the effects of climate change should be a part of the dimensioning.
 - Risk based functionality specifications ought to be introduced for all components in the whole road network.
 - Criteria for accepted risk levels ought to be decided.

- Risk analysis of existing constructions
 - Areas with higher risk due to climate change should be specifically noticed at risk analysis.
 - The fact that smaller roads often have the highest risks, depending on construction, must be taken into consideration.
 - Preventive measures are carried out when the risk level is not acceptable or when the measures are motivated on a national economy level.

- Studies of vulnerable areas pointed out

REFERENCES

[1] Swedish Road Administration (2005). Instructions – Risk analysis chosen road stretch

[2] Government of Sweden (2007). Final report from the commission on climate change and vulnerability
“Sweden facing climate change” <http://www.sweden.gov.se/sb/d/574/a/96002>