Climate changes in Norway: Factors affecting pavement performance

P. O. Aursand,
Norwegian Public Roads Administration (NPRA), Norway

R. Evensen,
ViaNova Plan and traffic, Norway

B. O. Lerfald,
Veidekke Industri AS, Norway

ABSTRACT: The R&D program "Climate and Transportation" in the Norwegian Public Roads Administrations (NPRA) has assessed the consequences of a changed climate for pavement performance of the Norwegian road network. This has been done through a literature study and calculations of pavement performance with ME-PDG for the present (2002-2008) and future climatic situation (2070-2100). The climatic changes in Norway implies an increase in temperature of 2.4 - 2.8 ^{o}C and an increase in precipitation of 15-25 %. Both the literature study and the calculations showed that higher maximum temperatures will lead to increased deformations of the bound layers. For unbound layer the deformations were expected to increase due to increased water content in materials with high fines content. On the other hand, decrease in frost index could lead to reduced bearing capacity problems in the spring thaw weakening period. Predicting the pavement performance in a changed climate is difficult due to the complexity of the road structure. To better understand how the single factors contributes to the pavement performance some special calculation analysis where made. The assessed factors were among others importance of increase in precipitation and temperature, variations between climatic zones, variation in sub-ground and road structure materials and importance of traffic volume on rut development. One of the main findings was that the effect of increased temperature and thereby less frost index showed to be far more important than the effect of increased precipitation. In the end the calculations showed an expected increase in pavement life time of 13-16 %. There is still some uncertainty linked to the calibration and the use of the Thorntwaite Moisture Index for Norwegian climate.

KEY WORDS: Climate change, pavement performance, bearing capasity.

1 INTRODUCTION

Due to the anticipated changes in climate, NPRA run an R&D program in the years 2007-2011 to evaluate the effect of climate change on the Norwegian road network and remedial actions. The main objective was to improve design, construction and maintenance of the road network in order to adapt to climate changes. One of the tasks was an assessment of the bearing capacity of roads. This was done through a literature study and calculations of pavement performance on the excisting road network with ME-PDG adapted to Norwegian conditions.

2 FACTORES AFFECTING THE DEGRADATION OF ROAD INFRASTRUCTURE

The degradation of the road infrastructure is affected by several parameters. Climate change will affect the function of different layers in the road construction. Table 1 gives a survey on how climate changes could affect different layers in the road structure.

Table1: Impacts of climate changes on layers in the road structure (Lerfald and Hoff, 2007).

	Asphalt pavement	Gravel pavements	Bound base course	Unbound base course	Sub base	Sub ground
Increased temperatures in wintertime	Low temnperature cracking	Shorter time of frozen ground		Frost heave	Frost heave	Frost heave
Increased temperatures in summertime	Deformation	Dust	Deformation			
More often spring thaw	Cracks	Bearing capasity		Bearing capasity		
Several feeze-thaw cycles	Durability					
More preciption	Durability	Saturation Erosion of pavment				
Shorter time with snow on the surface	Wear due to Studded tires	Ruthing				
Rising of ground water level				Bearing capasity	Bearing capasity	Bearing capasity
More use of salt	Wear due to studded tires					
Rise of sea level	Could impact on costal road networks, specially combined with storms.					
More wind	Could affect bridges, signs, etc.					
Flooding	Could have local consequences such as landslides. Generally the impact could be more erosion of the road construction.					

Low impact	Positive impact	Negative impact	Uncertain impact

Material properties of asphalt are closely dependent on temperature due to reduced stiffness with increased temperature. This will lead to reduced load distribution and increased loading on sub-layers. Temperature increase will also lead to changes in the frequency of freeze-thaw cycles. The number of freeze-thaw cycles will be less in some areas and more in some areas depending on today's climate. Increased temperature will also lead to less frost heave in some regions and reduced ”studded season” reducing rutting caused by studs.

A frozen road is very strong, and a reduced frozen period can lead to increased deteriation, but less frost could also mean less spring-thaw bearing capacity problems. Reduced frost index means there will be more critical where in the road structure the ice lenses from, and melting of the upper part of the pavement can lead to reduced bearing capacity if the upper layers are frost- and moisture susceptible. This will often be the case for low volume roads which often is constructed from low-quality materials. For high volume roads constructed with good-quality materials, the consequences will be smaller. The number of freeze-thaw cycles will increase in some areas and this can lead to several spring-thaw weakening periods during one single winter. For gravel roads this will mean more periods with poor accessibility and increased need for maintenance.

Precipitation increase will lead to higher ground water level and higher infiltration of rain water. Increased water content in unbound materials will lead to reduced bearing capacity (deformation properties and load distribution) and increased deteriation (rutting and roughness).

Unbound materials are more sensitive to changes in moisture content than bound materials, but bituminous materials are also affected. For bituminous materials moist can cause problems like oxidation, volume change, instability and increased stress levels. The moist susceptibility depends more on the type of aggregate and less on the type of binder. The initial crack development in bituminous materials happens faster if the material is wet, and the crack propagation happens faster if the aggregate is mica-rich. Moist pavement surface will also lead to increased wear of asphalt. Less snow cover and salting will also contribute to increased wear. There are some uncertainties on how climatic change will influence the aging of pavements, but ageing is influenced of both water and temperature.

From Table 1 one can see that the most negative impact on asphalt pavements will be deformations because of increased temperatures in summertime and increased wear. This can be solved by using better quality aggregate and stiffer binders or PMB. For unbound materials bearing capacity problems because of increased precipitation and changes in freezing conditions will have the biggest negative impact. This can partly be solved by upgrading base layers and drainage systems. The backlog of the drainage system should be removed. When building new roads non-moisture susceptibility course grained materials should be used in the sub-base and bound materials in the base.

3 CALCULATIONS OF PAVEMENT PERFORMANCE WITH ME-PDG

Assessment of the consequences of a changed climate for pavement performance of the Norwegian road network was done through calculations with ME-PDG, the predecessor of DarWIN-ME. The sources of data includes data on the road network, its materials and layering, climatic data for present (2002-2008) and future situation (2070-2100) and data on traffic volumes. The design process is shown in Figure 1. The future climate is described in the report “Klima i Norge 2100” (Norsk klimasenter, 2009) and is based on the IPCC predictions.

For the calculations Norway was split into 17 climatic regions. The climatic data for each region were based on recorded data for the years 2000-2008 and estimated data for 2070-2100 for climatic stations assumed to be representative for each of the climatic regions. Figure 2 shows a map of Norway with the climatic regions and Figure 3 and 4 shows some of the key data from the climatic data set used in the calculations. The hourly climatic data applied in the ME-PDG were produced by the EICM-program (Enhanced Integrated Climatic model).

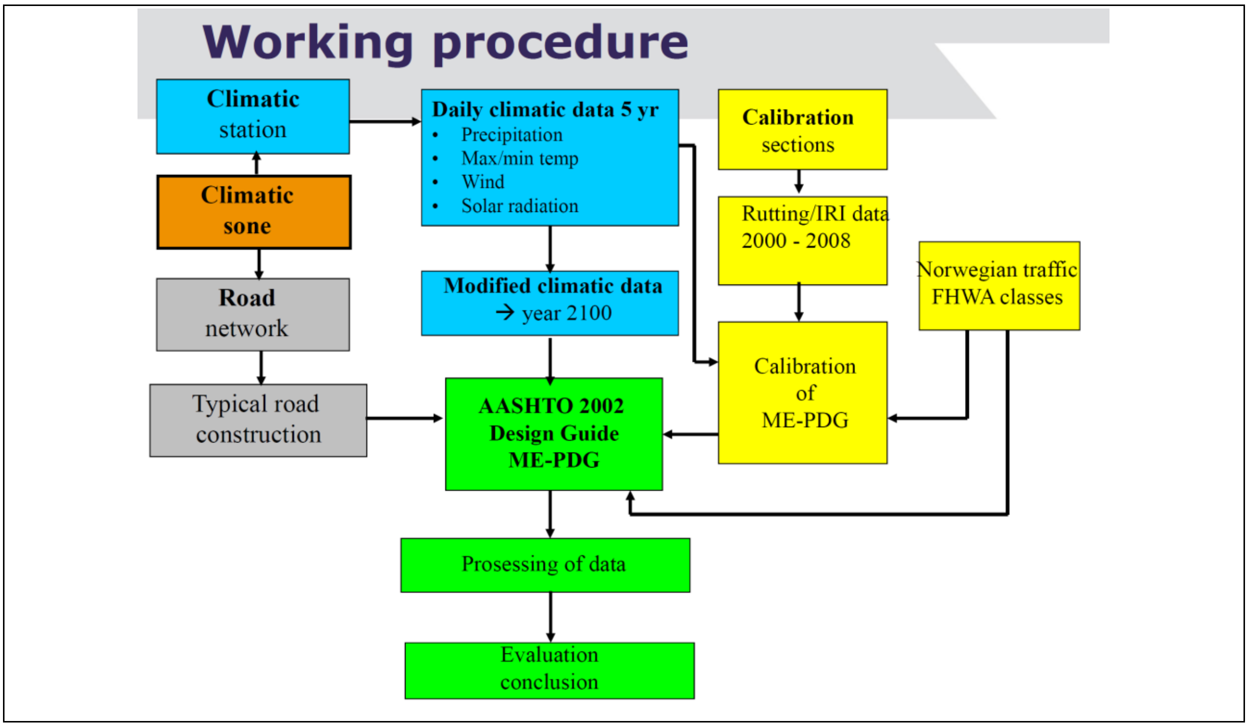

Figure 1: Working procedure

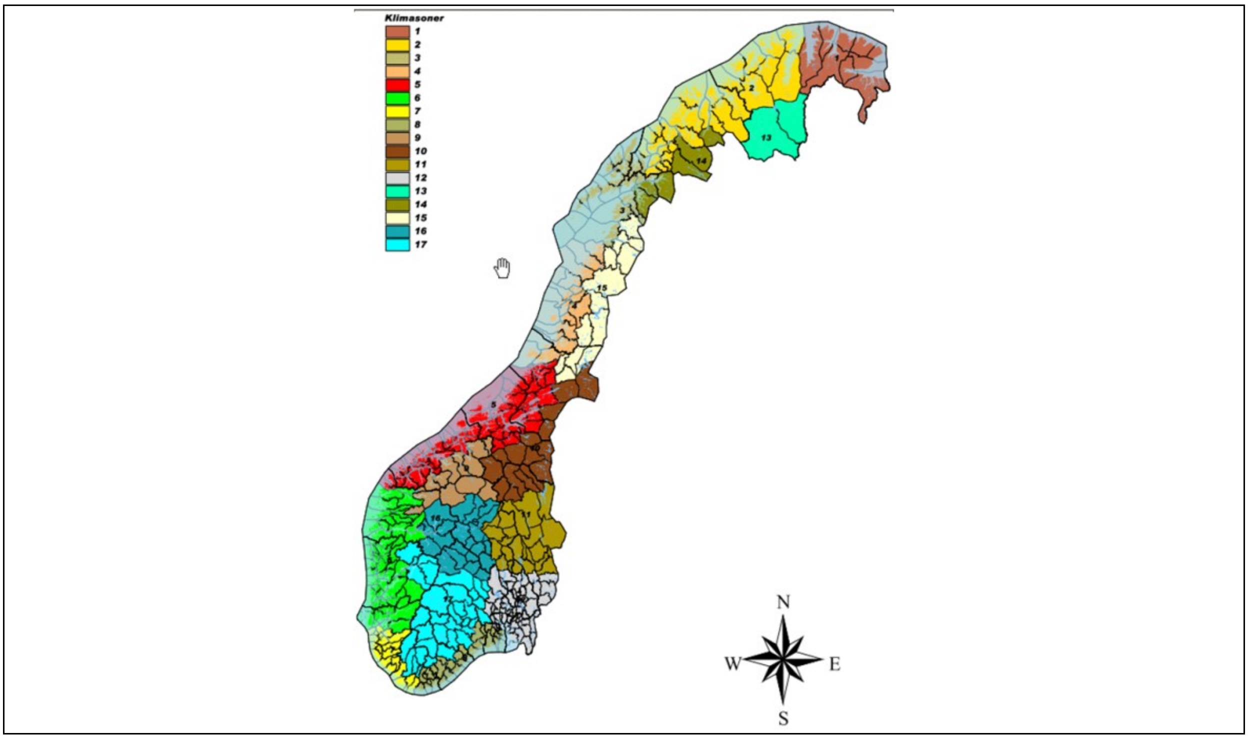

Figure 2: Map of Norway with 17 climatic zones (Evensen et al, 2011)

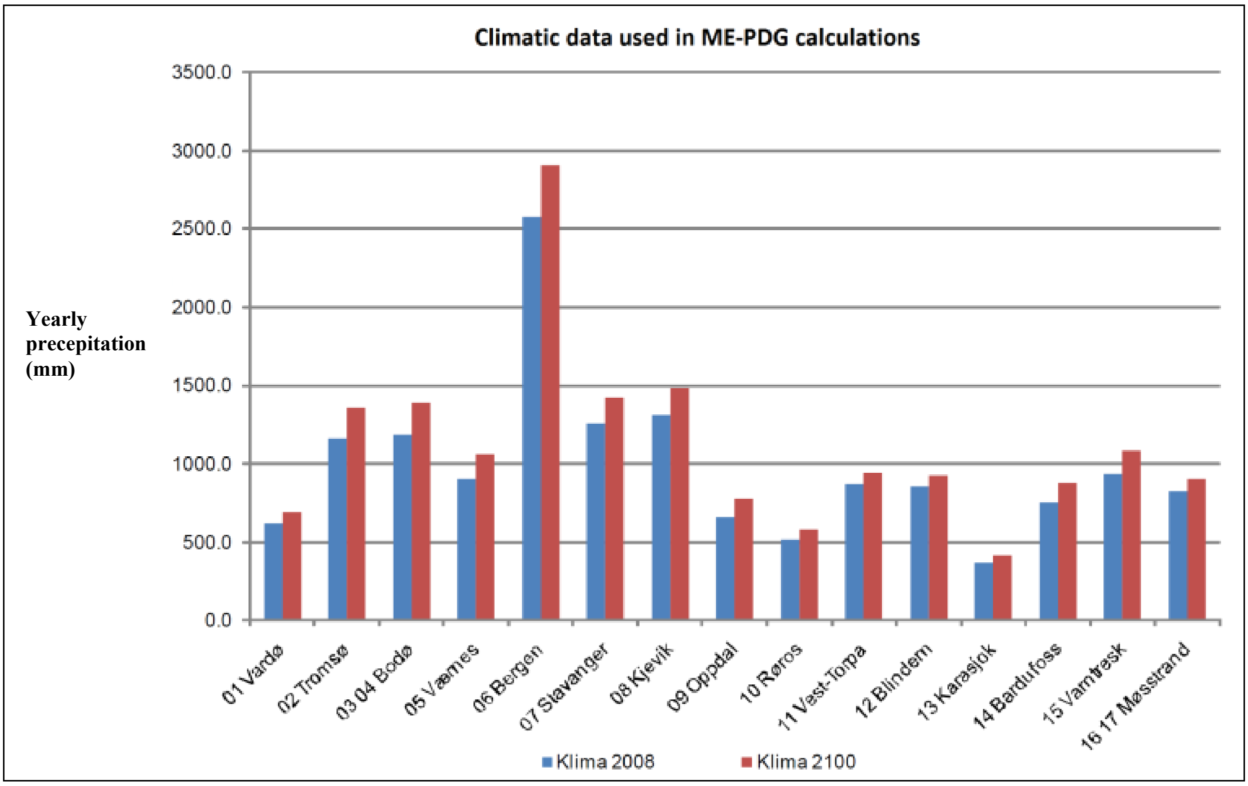

Figure 3: Present and future yearly mean precipitation for the different climatic regions analysed (Evensen et al, 2011).

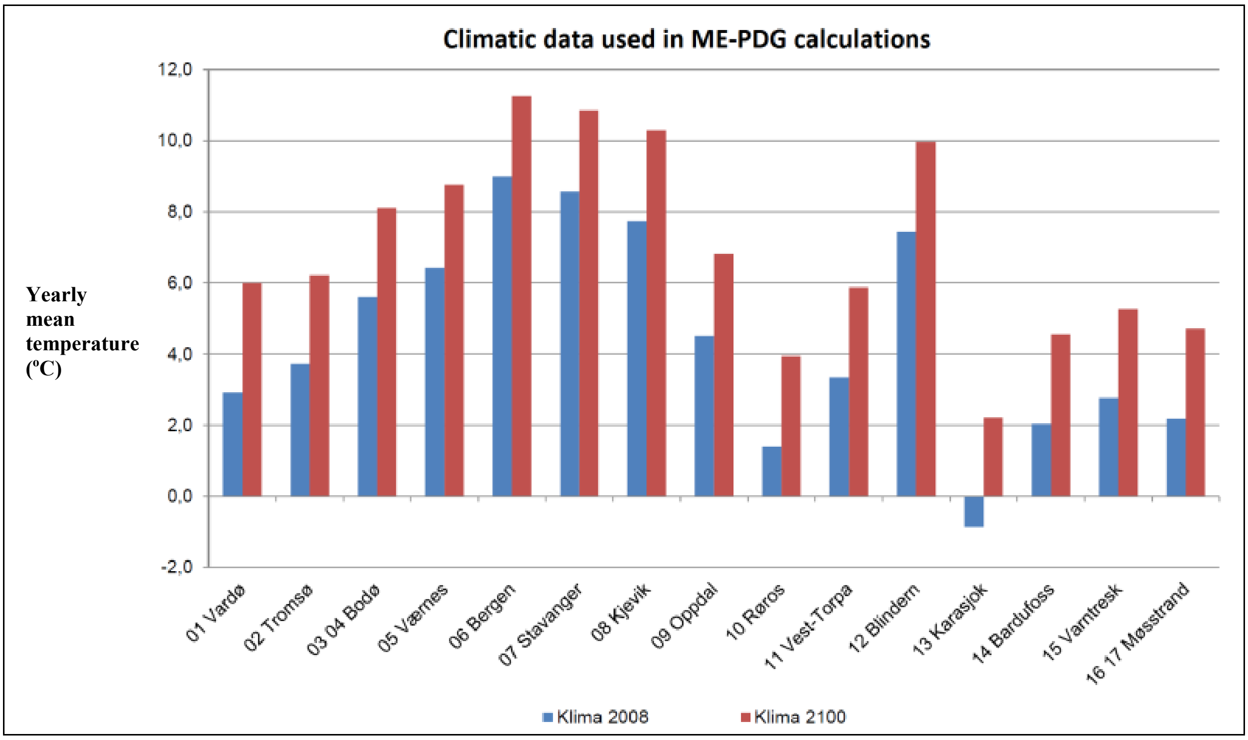

Figure 4: Present and future yearly mean temperature for the different climatic regions analysed (Evensen et al, 2011).

The average values of the E-modules of the various materials, such as asphalt surface and base materials, crushed rock and crushed gravel base and subbase as well as subgrade of massive and fractured bedrock, frost sensitive and non-frost sensitive moraine, gravel, sand, soft and stiff clay, were adjusted according to Norwegian experience. However for the temperature sensitivity of asphalt and moisture sensitivity of granular materials the default relationships of ME-PDG were used.

The estimations of the composition of the heavy vehicle classes as well as the axle load distributions for single axles, tandem axles and triple axles were based on BWIM measurements in Sweden, made disposal to the project by the Swedish Public Roads Administration. For two of the heavy vehicle classes adjustments were made in the axle load distributions in order to appreciate the difference in the allowable total vehicle weight in Sweden and Norway.

The calculations of yearly increase in rut depth in the ME-PDG appreciate only account the deformation of the pavement and subgrade materials. To these results the rut depth development caused by the wear of studded tyres was based on the wear model of VTI, the National Road and Transport Research Institute, Sweden.

Calculations of the pavement performance with respect to rut development were made for a large number of pavement sections based on a split of the road network into four intervals of traffic (AADT), up to six classes of the bearing capacity of the subgrade and whether the granular material in the pavement were frost susceptible or not. The length on the road network and the average total asphalt and pavement thicknesses for each combination of climatic regions, traffic and subgrade materials were obtained from the Norwegian National Road Database.

The results show considerable variations which is a result of the complexity of pavement performance factors in a road structure. The interaction between the climate and the road structure has a great impact on the pavement performance, but the anticipated changes in climate is of less importance compared to other deteriation factors. For the Norwegian road network the anticipated development of ruts will be about 0.2 mm/year less in the future as a result of the estimated climatic changes. This is similar to 13-16 % longer pavement service life. The positive effects of less frost and frost heave, which will lead to fewer problems with loss of bearing capacity in the spring-thaw weakening, are bigger than the negative effects of increased water content in the subgrade and the granular materials in the pavement caused by the increased precipitation. Figure 5 shows the weighted averages with respect to rut development for the main roads in the various climatic regions.

There are still some uncertainty linked to the calibration, lack and/or quality of road structure data and the importance of the ground water level. The project has come up with some climate adaption advices like the use of stiffer binders for future pavement maintenance and increased focus on rehabilitation of the drainage systems.

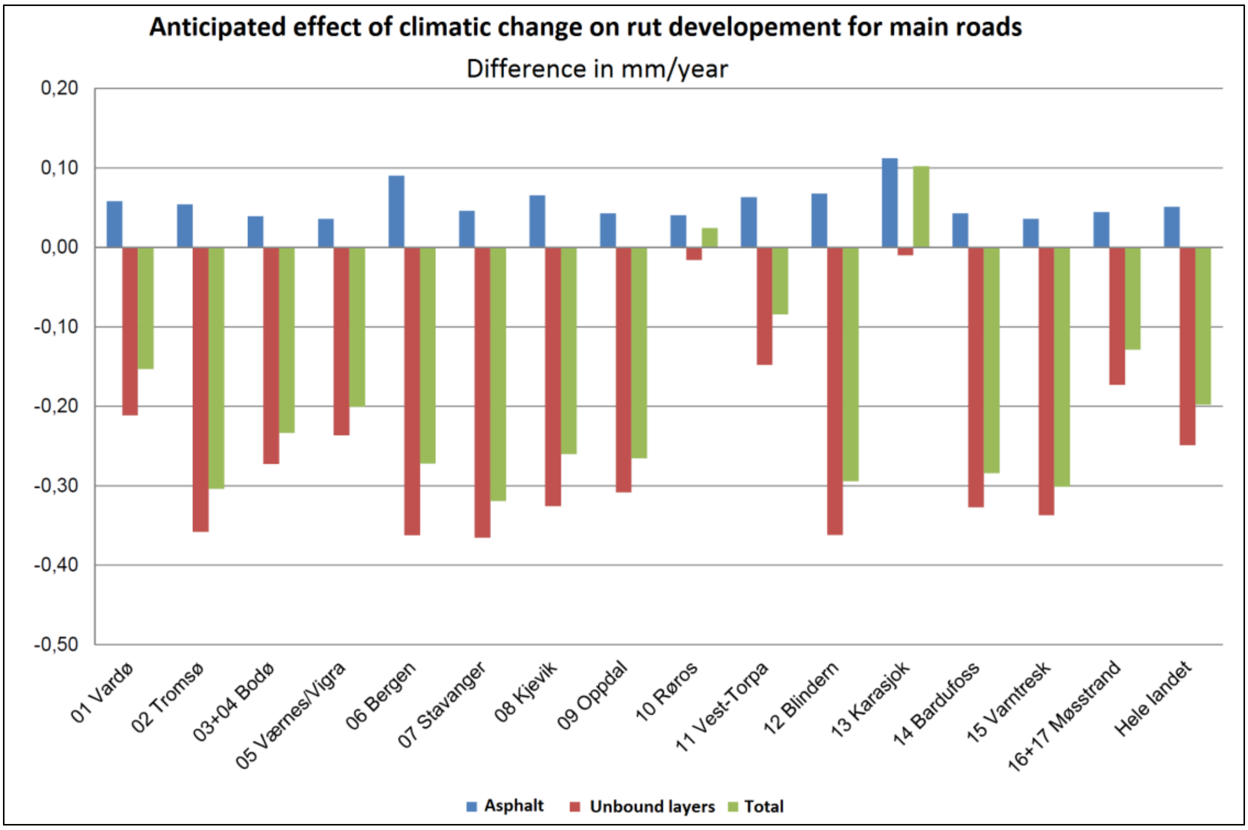

Figure 5: Results from the calculations. (The figure does not show the differences between the different regions because other parameters like traffic, road structure materials etc. within the different regions are included in the input data.) (Evensen et al, 2011).

4 CONCLUSIONS

Due to climate changes the following recommendations are given by Lerfald and Hoff:

1. The drainage system and road structure of the road network should be reviewed to assess where and how roads can be improved, when this should be done and what financial impact this will have. This requires precipitation forecasts describing rainfall intensity, which requires new model runs with time analyzes, higher time resolution and possibly higher geographical resolution.
2. Maintenance backlog increases negative effects of increased precipitation and flooding. Cost need to fix the lag should be investigated especially for those stretches of road where road ability is strongly affected if the road structure collapses.
3. It should be considered in what way contingency should be improved and increased. Forecasts and transport information systems should be better utilized.
4. Risk related to road safety as a result of increased probability of landslides, floods and fury projections should be reviewed so that the scheduled closing and reopening a greater extent can be used instead of the road to be closed once the damage has occurred and it may have been an accident.
5. Impacts on groundwater and surface water with respect to water pollution should be investigated further.

With respect to the influence of the climate change on the service life of the road network in Norway the analysis indicate that the effect of increased temperature and thereby less frost, showed to be more important than the effect of increased precipitation. The calculations indicate an expected increase in pavement life time of 13-16 %. There is still some uncertainty linked to the calibration of the ME-PDG to the Norwegian Road network, including the use of the Thorntwaite Moisture Index for Norwegian climate.

An increase of the summer temperatures and the expected increase in permanent deformations in the asphalt layers can to some extend be reduced by the use of harder bituminous binder in future resurfacings. However, there are many roads in Norway with low bearing capacity where the use of soft bitumen is required.

REFERENCES

Lerfald, B.O. and Hoff, I., 2007. *Klimapåvirkning av vegbyggingsmaterialer. State of the art studie.* SINTEF rapport, SBF IN A07014.

Evensen, R. et al, 2011. *Tilstandsutvikling på vegnettet. Virkninger av endret klima på sporutviklingen på veger med bituminøst dekke.* Vegdirektoratet rapport no. 26.

Norsk klimasenter, 2009. *Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilpasning.* Norsk klimasenter, foreløpig utgave juni 2009.