Climate adaptation in impact assesments for Dutch road infrastructure.

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Climate change is a global phenomenon that requires serious attention in responsible, future-proof planning processes. The long lifespan and lifecycle of road infrastructures and the related low flexibility for adjusting them to climate change make them susceptible to the impacts of climate change over decennia (Ligtvoet et al., 2015). Rijkswaterstaat[1] has started several initiatives (guidelines, research and pilot projects) on how to react on and cope with the challenges of climate change in road infrastructure planning.

1. Climate change in impact assessments (IA)

An integral instrument such as IA gives opportunities to link climate goals to other area-specific goals for example on biodiversity, landscape, cultural history and human health. An integrated assessment of climate objectives with these other area goals makes IA suitable for discerning the effects of policy strategies (Commissie m.e.r., 2015).

There are 3 levels at which climate change aspects can be included in IA (de Groot & Koomen, 2011).

1. A description of the impact of a plan or project on climate change related environmental aspects such as the impact on dikes or the water storage capacity of the project area
2. An assessment of risks and vulnerabilities as a result of climate change on the successful implementation of a plan or project. The IA includes an evaluation of climate adaptation options.;
3. Including climate change related uncertainties and indicators into the assessment of various environmental impacts. The IA describes minimum and maximum expected climate change risks and vulnerabilities based on climate scenario's. [2] The IA includes an adaptation strategy based on a bandwidth of climate change scenario's.

The 1st level requires expertise and models on local hydrology and soil composition. This information is generally available and/or developed for specific projects. The 2nd level requires spatial/map information on climate effects and vulnerabilities. In addition to spatial information, the 3rd level requires model simulations of different climate change scenario's (fig 1) and a translation of these scenario's to risks and adaptation measures.

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[1] 'Rijkswaterstaat is the executive agency of the Ministry of Infrastructure and the Environment. Its mission is to manage and develop the main road network, the main waterway network and the main water systems and endeavour to create a sustainable living environment.

[2] Factsheet Climate adaptation. Commission on Environmental Impact Assessment the Netherlands.

Climate change scenario's

The Royal Netherlands Meterological Insitute (KNMI)'14 climate scenarios has translated the research results on the global climate in the IPCC report (2013) to the Netherlands. The four KNMI'14 scenarios differ in the extent to which the global temperature increases ('Moderate' and 'Warm') and the possible change of the air circulation pattern ("Low value" and "High Value").

The scenarios are used to map the impacts of climate change to be able to evaluate the importance and the urgency of climate adaptation measurements.

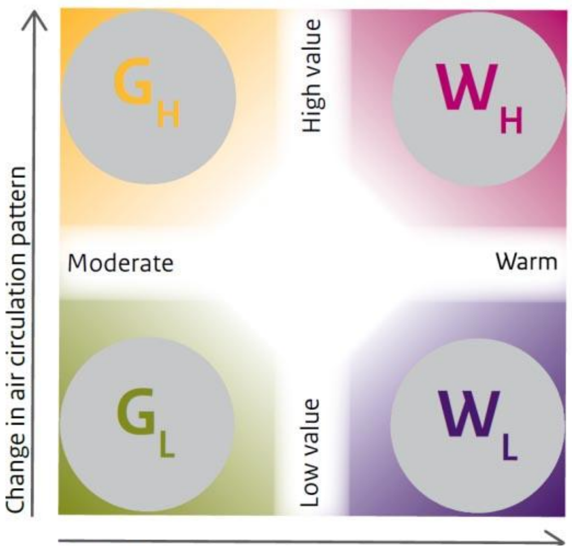

Figure 1: Schematic overview of the four KNMI'14 climate scenarios. (Brochure KNMI'14 climate scenarios, 2014).

Climate change risks for road infrastructure

Flooding

A significant part of the Netherlands, almost 60 percent, is prone to flooding in the event of high seawater levels and high river discharges (Planbureau voor de Leefomgeving, 2012).

Sea level at the Dutch coast has risen 20 centimeters in the last century. On the basis of the KNMI'14-scenarios, sea levels can rise further between 15 and 40 centimeters by 2050 and between 25 and 80 centimeters in 2085 (KNMI, 2014). The average discharge of the Dutch rivers is increasing in winter and decreasing in the summer. In accordance with the KNMI'14 scenarios to 2100, average Winter flows are expected to increase 12 to 27%. The average summer discharge will change in the same period of -41% to + 1%

Floods can cause direct damage to the road infrastructure and cause indirect damage by cutting off the transportation of goods and people (Pereboom et al. 2014).

Heavy rain and/or high groundwaterlevels

Paved surfaces (asphalt, roofing) can hinder the quick disposal of water during heavy rain or failing sewage or other water disposal systems (Immerzeel et al, 2010). In July 2014 heavy rain in large parts of the Netherlands caused flooding. Several highways were closed, public transport was disrupted and thousands of households were without power.

Increasing frequency of heavy rainfall will diminish the reliability of the road infrastructure. Stagnating water can also cause direct damage to the road infrastructure by decreasing the stability of the road foundation (Bles et al., 2012).

Drought

Drought can lead to nuisance and damage to infrastructure in different ways. Drought may accelerate the process towards lower surface levels in peaty soils in the Netherlands. Soil subsidence or inclination can cause damage to the road foundation and road sections. In addition, dry spells may lead to an increased risk of forest and roadside fires. These fires can cause discomfort due to (temporary) road closures and smoke clouds may affect driving safety.

Extreme heat

Extremely high temperatures can cause asphalt to deform. Extreme heat can hamper the opening and closing mechanisms of bridges. The frequency of extreme temperatures is inspected to increase 22-70% in 2050 and 30-130% in 2085.

2. The Cases

With the conceptual and technical framework explained above we will now explore the experiences with addressing climate change in infrastructure planning and how these aspects were implemented in impact assessment for a number of concrete road infrastructure projects.

Starting with a short background resumé and project description each case is presented firstly by explaining how climate change was taken into account in the evaluation study with respect to traffic and accessibility, flood safety and soil and water system. Which risks were identified, what evaluations were carried out and what measures could be recommended to adapt to the future situation? Finally the similarities and differences in approach and outcomes will be addressed and commented.

All cases are part of the National Vision for Infrastructure and Spatial Planning (2011). Climate adaptation was included in de Strategic Impact Assessment (SEA) of the National Vision. The SEA only gave a limited description of the impact of the National Vision on climate adaptation related aspects because these are very case specific.

The A27 case

This project aims to add extra lanes to one of the main highways of the Netherlands connecting the center of the country with the southwestern cities and the Belgian urban centers beyond. The Impact Assessment (IA)[3] for the A27 was completed in April 2016. The highway section to be enlarged crosses three main rivers with low lying terrain and polders in between, often below sea level. Consequently climate change risks in the IA was limited to the impact of the project on flooding risk. Other risks were not included. A subsequent more in depth evaluation of climate adaptation in Dutch road infrastructure highlighted more climate change risks (Koekoek et al. 2016). These are mainly related to water issues such as extreme precipitation events, water logging, sea level rise and river floods with potential impacts on availability, traffic capacity and safety of the widened road and river bridges.

In the A27 case the climate risk analysis revealed three ‘red spots’ where water logging along the road will increase. Adaptation of water discharge management and incorporating retention areas in the water system in cooperation with the regional Waterboards can tackle these future problems.

At the river bridge crossings ‘first level’ flood safety may be jeopardized due to bottlenecks in the river system at the land abutments. To adapt to increasing discharges more room for the river

3 Project-MER A27 Houten – Hooipolder (28-4-2016).

including a bypass is planned in the floodplains according the overarching National Delta Program. Furthermore existing flood barriers will be strengthened.

As for the soil and water system in the area adjacent to the highway climate related soil subsidence may require adaptations to the road foundation. Three managed polder water sheds would need to be provided with extra measures to enhance retention capacity. Different standards between regional water boards in the highway area may lead to divergent interventions.

The N65 case

The project aims to upgrade the provincial highway N65 to a fully-fledged 4 lane motor way. Climate aspects were not included in the scope of the strategic environmental assessment SEA (Anthe Group, 2015). A post SEA evaluation (Koekoek et al. 2016) identified potential climate impacts. Risks for traffic and accessibility culminated in one 'red spot' on the middle section. At this point the design was adapted in the sense that the railway now underpasses the motorway. In this area first level flood safety is not an issue as the highway mainly resides on higher grounds. A next level adaptation measure to be considered would be to create an elevated road embankment which would act as retention compartment levee. This also improves 'third level' safety as heightening would bolster the N65 as a safe and robust evacuation route in case of severe flooding in the hinterland.

With respect to risk of extreme rainfall events and rising groundwater levels the road design might stipulate adaptation in height of construction or floor depth of underpasses. However the exact measures to be implemented require more precise modeling and monitoring of potential climate impacts on the local water system. The standard plan preparation phase does not cater for studying intricate interdependencies between river discharges, local ground water and retention capacities.

Case InnovA58

This project concerns adding extra lanes to the A58 highway connecting major cities in the Southern part of the Netherlands. The pilot planning and design process was geared to develop new approaches and innovative forward thinking in response to the challenges of the future in transportation and global changes. Developing a climate resilient and robust InnovA58 road concept was one of the sub-tasks to integrate adaptation measures in the project planning and design phase. For this pilot project an adaptation strategy was developed to assess potential need and necessity and cost effectiveness of measures for the future.

The top climate risks for this case are clearly water and precipitation oriented. Together with stakeholders in the region ROADAPT[4] tools were used to identify risks in a climate quick scan and the GIS based vulnerability assessment. More in detail (climate related) unwanted events affecting the road and its functionality center on flooding, erosion, landslides and reduced driving safety. Risks for the area at large include water logging in rural areas, urban neighborhoods, and changes in groundwater levels.

The vulnerability analysis method stipulates the following process steps per unwanted event:

1. Assess the relevant vulnerability factors; characteristics of the surrounding area or the road determining the whether or not occurrence of the unwanted event
2. Collect existing GIS information related to vulnerability factors

[4] https://www.deltares.nl/app/uploads/2015/04/brochure-ROADAPT.pdf

3. Generate additional GIS information for complete map layers, e.g. with expert input
4. Categorize vulnerability factors per layer and classify in vulnerability scores
5. Calculations per grid cell of normalized vulnerability score, summed up over all layers
6. Report and justify the process.

The tool thus identified the most vulnerable locations for effective measures on a GIS map. By checking against socio economic analysis the proposed measures with positive cost-benefit scores might be included in the adaptation strategy. We will zoom in on two of the main risk issues.

One of the identified top issues is flooding of A58 infrastructure caused by inundation of stream valleys in the area due to insufficient capacity of the valley bridges. Following the adaptation strategy this can be tackled in the short term either by enlarging capacity through more intensive maintenance or by developing contingency and restauration plans. These interventions are considered sufficient till 2040 within the scope of the most likely climate scenarios. Should things get worse realizing upstream water retention in the stream valleys could be enough to solve the issue and cost-effective as well at least till the year 2050. This measure could be sufficient even well into the next century depending on the applicable KNMI climate scenario. Measures effective till 2100 consist of enhancing the hydrological throughput capacity of the bridge and the heightening of the road embankment. However, these measures are expensive and implicate capital destruction when the existing bridges are not yet at their end of life time.

Another major issue concerns the reduced driving safety during intense rainfall. In view of the bandwidth of the KNMI climate scenario's the predicted increase of heavy rainfall events would not immediately jeopardize the level of driving safety under the condition that road cant would be at least 2,5 %. In principle up to 2015 no problems would be expected for the 2 x 3 lane sections of the renewed A58. If circumstances worsen road cant may be increased during the next major maintenance interval. Another intervention could be implemented if climate change urges for an increase of the thickness or the water retention capacity of the Very Open Asphalt Concrete layer in the next 10 year round of surface renovation. State of the art climate monitoring is important as adaptive management strongly depends on quality of information. In any case an optimally functioning water discharge system is vital. Thus climate adaptation urges for good asset management and road maintenance in general. Naturally adequate traffic management and steering the behavior of drivers in extreme rainfall events is equally important.

To enhance climate resilience and integration of adaptation measures in the A58 planning process a parallel landscape ecology study for the route area was conducted. Emerging from the awareness that landscape features and ecological conditions could be leading in the assessment of effective interventions. Climate proof road design needs to envisage ecological capacities from the start taking into account the KNMI climate scenario's.

3. Conclusion and recommendations

The practical surveys at hand show that climate change is not yet structurally addressed and included in Impact Assessments for Dutch road infrastructure projects. In road projects adaptation issues and proposed interventions are usually limited to current water systems and rainfall patterns. For the A27 the description of climate adaptation was limited to the first level: the impact of adding extra lanes to existing primary dykes and river bed water storage capacity of the project area. The SEA for the N65 lacked any description of climate change risks.

Post IA evaluations of climate risks and adaption measures for these projects show risks of waterlogging (A27 and N65) and flooding risks during peak river discharges (A27).

The pilot studies for A58 show important climate risks and vulnerabilities with potentially far-reaching consequences for traffic flows and accessibility. This is key information for decisions makers and urban planners and therefore an important argument to include climate change risks and adaptation measures in IA's for infrastructure planning.

To effectively address climate change issues in road planning and design adequate spatial information (climate impact atlas[5], dedicated GIS) needs to be available for an integrated assessment of vulnerabilities and effective adaptation measures. The climate adaptation evaluations that were done for all cases proved that there was sufficient map based information available to make an in depth assessment of climate change risks (Koekoek et al. 2016)). Therefore a lack of information or knowledge does not seem the be the biggest obstacle for including climate change risk assessments and adaptation measure in IA (second level).

The pilot study A58 is an example to describe climate risks in full (3rd level). In the pilot impacts at different time intervals and in the most pessimistic KNMI scenario are addressed. The study resulted in recommendations for state of the art monitoring and adaptive management. IA could be used to evaluate the impact of these adaptive management and contingency measures.

So what determines the choice of the level at which climate change aspects can be included in IA for a given infrastructure plan or project?

Practical reasons

One of the goals of IA is to evaluate alternatives. In the N65 case climate change risks were not considered to be a distinctive factor for the alternatives (Anthea, 2016). This was the major reason to exclude climate change from the IA scope.

Legislative reasons

Addressing the climate issue in planning and design preparation so far has not been duly entered in the regulation, although the new EU EIA Directive calls for national implementation in the member states. Therefore there are no 'perceived' legislative risks in terms of rejection of the project in case climate change is not addressed properly in the IA.

Lack of knowledge and expertise

A lack of understanding and uncertaintanty with proponents about climate change risks can be

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5 http://www.klimaateffectatlas.nl/en/

reasons for not addressing the issue. In the Netherlands a lot of effort has been made to share case information on climate adaptation measures and instruments (Kennis voor Klimaat). Climate impact maps haven been made at different time and geographic scales, based on KNMI climate scenario's. The case studies N65 and A27 show that lack of knowledge and information need not to be a major obstacle.

Time scale

The time scale at which climate change effects take place differs significantly from the planning time scale of road infrastructure. Most EIA studies look at a period of 10 -15 years post realization. Climate risks with the biggest impact manifest in general between 30 to 80 years after realization (Ministry of Infrastructure and Environment, 2016). This well beyond the planning horizon but still within the long life span of road infrastructure.

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