Title : Flood risk of highways in The Netherlands, measures, cost-benefit assessment and policy making

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ABSTRACT
Fifty to sixty percent of The Netherlands are susceptible to flooding, due to its location below sea level or outside of levees, and in other cases when rivers overflow their banks. As a result, The Netherlands have a long history of fighting floods, reclaiming land and establishing high flood protection standards. The local individual risk of death due to flooding is low, at less than 1 in 100.000 per year. Despite the low risk of individual fatalities due to flooding, major damage to inhabited areas and infrastructure can still occur. Extreme rainfall exceeding the design standards of local water systems can also lead to flooding, like in 2021 in the southern part of The Netherlands. Due to climate change this may happen more frequently.

The Delta Decision on Spatial (climate) Adaptation, part of the Dutch Delta Program, contains agreements to make national vital and vulnerable functions such as electricity, telecom, drinking water and transport more resilient to flooding by 2050.

Therefore Rijkswaterstaat, the national highway operator, conducted a stress test of the highway network's resilience to climate change hazards including coastal, fluvial and pluvial flooding. The stress test identified weak spots in the network, which were investigated in more detail to determine the effectiveness and cost-benefit of potential measures. Based on the results the

Implementation Agenda for climate resilient networks and an interactive climate effect atlas were presented to the Dutch Parliament by the minister.

Recent research of a possible event in the western part of the Netherlands, with the same amount of extreme precipitation as in the south of the Netherlands in 2021, showed that highways should remain dry contrary to regional and municipal roads, as long as pumps are functioning properly. Pluvial flooding of highways may be prevented by intentional maintenance of water discharging systems and pumps.

In case of levee failures most roads in flood-prone areas in The Netherlands will be flooded though, in many cases with several meters of water. It will require major and costly investments to prevent this sort of flooding and it was concluded previously it is not possible or cost-effective to adapt the highways in such a way that it remains entirely available in flooded areas.

Therefore a new methodology for performing a cost-benefit analysis of measures in view of (regional) flooding has been developed.

The following conclusions can be drawn for The Netherlands, that will be evaluated to develop policy:

- For pluvial flooding standard design and maintenance standards are generally sufficient.
- For flooding due to failure of dunes and levees more drastic measures are cost-effective in specific regional cases, to be investigated with the newly developed cost-benefit assessment methodology.
- When physical measures on highways are not cost-effective there may well be compelling political and societal reasons to invest in flood-resilient highways. Examples are unacceptable loss of availability or vehicle loss hours due to flooding on certain network links.
- To support decisions in this regard also new risk evaluation methodologies are available in The Netherlands.