Towards Probablistic Asset Management of Storm Surge Barriers Under Rapidly Changing Circumstances

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In the Netherlands, the asset management of its storm surge barriers is based on system performance. In support, highly detailed reliability models are applied to enable the efficient assessment of the consequences of (temporarily) system changes. Yet, this high level of detail comes at the cost of the transparency and adjustability. As a result, the risk models are less suitable to assess the effect of large system changes and strategies to improve the barrier's performance when needed. In this presentation we analyse how the high level of detail reduces the usability and explore how the models might be adjusted to minimize this effect.

Keywords: Asset management, storm surge barrier, risk assessment, system reliability, probabilistic maintenance.

1. Introduction

As the first line of coastal defence, storm surge barriers play a crucial role in the coastal flood safety system of the Netherlands. Under normal circumstances, the storm surge barriers are open to allow free flow of water and navigation. In storm conditions, however, the barriers are closed to ensure that the water body behind won't exceed unacceptable levels (Mooyaart & Jonkman, 2017).

The ability of the storm surge barrier to prevent unacceptable inner water levels depends mainly on its height, structural reliability and closure reliability (Mooyaart et al, 2022). In the Netherlands, probabilistic maintenance and operations is applied in order to continuously maintain the required closure reliability, while optimizing the maintenance costs (Webbers et al., 2008). A Performance-based Risk Analysis (PRA) helps the continuous monitoring of the closure reliability and search for improvements if necessary (Rijkswaterstaat, 2017).

The PRA is a highly detailed analysis that uses fault and event tree like techniques to address all relevant risks that might threaten the structure's performance. The high level of detail enables the efficient assessment of the consequences of (temporarily) changes like longer repair times, higher failure rates or a smaller operational team.

As a consequence of sea level rise, socio-economic changes and aging, discrepancies between desired and actual closure reliability occur more frequently and grow faster than previously. In order to anticipate these discrepancies more rigorous system adjustments are needed. Yet, the high level of detail that has proven so useful for probabilistic maintenance also reduces the transparency and adjustability of the risk models. This complicates the efficient exploration of large system adjustments.

2. Current model philosophy

The PRA is characterized by slight conservatism (i.e. pessimistic estimates of the performance parameters) and a high level of detail. The conservatism is applied such that new insights in the actual values of the parameters do not automatically lead to failure to comply with the performance requirements. The high level of detail is adopted to more accurately model redundancies and can support the assessment of the consequences of changes at component level.

Typically, the components are assumed to have a constant failure rate, i.e. to be in the central part of the 'bath tub curve'. That means that the period of 'infant mortality' with high failure rates is over and that the components are preventively replaced before age and wear kick in. Dependent on the component, periodic testing is applied to reduce the effect of dormant failures.

In case of small system changes or new model insights the risk analysis helps to assess the consequences for the overall reliability and to find ways for improvement if needed. In this way, the PRA helps to ensure that the right level of closure reliability is maintained in a cost effective way.

3. Drawbacks of current approach

The conservatism, the high level of detail and the strong focus on the actual performance level also bear some disadvantages when addressing more substantial system changes.

The strong focus on the actual performance and its wide communication may lead to anchoring. That means that the, in principle, conservative risk model may be increasingly perceived as a credible representation of the truth. As a consequence, when an increase in reliability is desired, it is likely that the possibility of reducing the model's conservatism might be ignored. In fact, the strong focus on complying with the desired reliability level may even encourage conservative bias. After all, a proposed measure is more likely to be granted when a model implies that the measure is necessary.

Also, the high level of detail and especially the aim to accurately model all possible redundancies may lead to additional conservatism and the ignorance of promising possibilities to increase the reliability. Obviously, more detail leads to more conservatism when model parameters are conservatively estimated.

Moreover, the more accurately and detailed all redundancies are modelled, the harder it gets to comprehend and adjust the model. This may create additional thresholds in modelling other potential factors that may affect the reliability.

Hence, as a consequence of anchoring and the lack of transparency and adjustability, numerous options to improve the modelled reliability remain largely unexplored.

4. Concluding remarks

In our analysis we show that the combination of slightly conservative estimates, a high level of detail and a strong focus on modelled reliability may lead to anchoring, to overly pessimistic reliability estimates and to the under-exploration of promising improvements. This becomes especially problematic when substantial improvements are desired.

To overcome these disadvantages, it seems logical to at least tackle two of the three characteristics of the current modelling approach. A promising first step could be to only allow conservatism as long the modelled threat is negligible and only allow high level of detail when this leads to substantially less conservative estimates. This simple adjustment of the modelling approach will drastically decrease the overall conservatism and increase the model's transparency and adjustability.

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