Workshop on
Life Cycle Management
27-29 October Rotterdam

Can a pipe safely cross a dike without huge costs? A life cycle analysis based on probabilities and consequences

Babette Lassing[1*], *Timo Schweckendiek*[2], *Henk Kruse*[2], and *Ton Vrouwenvelder*[1]

[1]Unit Buildings, Infrastucture and Maritime, TNO
[2]Unit Geo-Engineering, Deltares
*Corresponding author: babette.lassing@tno.nl

ABSTRACT:

The Netherlands are protected from flooding by thousands of kilometres of dikes. It is a densely populated country with a lot of above and underground infrastructure. Therefor it is inevitable that pipes such as gas and water pipelines cross the dikes. The safety of the dikes in the Netherlands is regulated by law. A pipe is only allowed to cross a dike if the safety of the dike is guaranteed. The probability of failure of the dike may not exceed the prescribed probability of failure taking into account all possible failure modes.

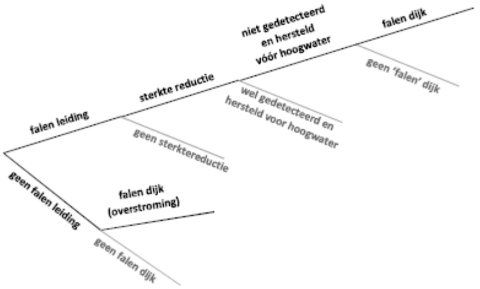

Fig. 1. *Safety framework for assessment of cables and pipes, 2018*

In a probabilistic flood risk approach the probability of flooding (failure of the dike) for a certain period is calculated as follows: *P(inundation) = P(failure pipe) P(failure dike | failure pie) P(high water before repair)*.
For the specific type of pipe the different failure scenarios are analysed given the specific dike situation.
In this paper the relationship between pipes crossing a dike and life cycle management is explained. This relationship is based on flood risks. It starts with coarse estimates, adding more detail and advanced probabilistic calculations if and when needed. Consequences of failure of the pipe will be modelled, probabilities of events for a year will be estimated and/or (semi-)probabilisticly calculated for the current situation as well as different designs or mitigating measures and a sensitivity analysis will be done (including analyses of changing water levels during the life of the dike and ageing of the pipe). In this way a substantiated decision based on safety of the hinterland against flooding can be taken, whether or not a pipe crossing of the dike is allowed with or without mitigating measures such as sheet piles. During the life of the dike it has to be shown every few years (based on the Dutch Water Law) that the dike with its pipe crossing still complies to the demanded flood risks now and for the next period.

References:

1. A.C.W.M. Vrouwenvelder, B.L. Lassing, S.H.J. van Es, J.F.M. Wessels, M. Visschedijk, H. Kruse, 2016. Methodiek "Falen waterkering als gevolg van falen pijpleiding", fase 1. TNO-Deltares report TNO 2016 R11806
2. S.H.J. van Es, B.L. Lassing, 2018. Literatuurstudie en interviews over vervangende waterkeringen voor de projectoverstijgende verkenning K&L. POV Kabels & Leidingen, TNO 2018 R11591
3. T. Schweckendiek, A. van der Meer, 2018. Faalkansanalyse bij dijkontwerp Zeeburgereiland met parallelle waterleiding. POV Kabels en Leidingen, Deltares 11202871-002.
4. T. Schweckendiek, A. van der Meer, 2018. WBI Veiligheidsraamwerk Kabels en Leidingen Generieke uitgangspunten als vertrekpunt voor nadere uitwerking in (pilot) projecten. Deltares 11202225-005

Workshop on
Life Cycle Management
27-29 October Rotterdam

Challenges and opportunities in Life Cycle Management for water Infrastructure

Frank den Heijer[1], *Wouter Jan* Klerk[2, *]

[1]Sustainable River Management, HAN University of Applied Sciences, Arnhem; Waterinfraworks, Kesteren.
[2]Section Hydraulic Engineering, faculty of Civil Engineering & Geosciences, Delft University of Technology, Delft; Deltares, Delft.
*Corresponding author: frank.denheijer@han.nl

ABSTRACT:

There is an increasing awareness of the aging of our water systems and water infrastructure as dikes, hydraulic structures and sewer systems. We distinguish three drivers that require improvements in life cycle management capabilities for water infrastructure. First, there are autonomous drivers such as increasing sea levels, soil subsidence in urban areas and deterioration of existing hydraulic structures. Secondly there are societal drivers, such as improving sustainability and transparency in decision making. Thirdly, there are professional drivers in the form of new possibilities, such as the improvement of IT capacity and capability.

Water infrastructure represents societal value. With the different drivers there is a continuous desire for life cycle approaches and techniques that enable us to deal efficiently with our infrastructure over longer times.

In the ROBAMCI programme, executed in the Netherlands during last years, 14 practical cases of life-cycle management of water infrastructure have been developed. From these cases the following challenges are recognized:

- Coping with scarcity of data, and/or poor data quality: typically, due to the change in type of questions (from singular decisions to life-cycle management strategies) the available data is not fit-for-purpose.
- Related to the above, new decision criteria such as adaptivity, resilience and robustness are pivotal in linking results from asset decision optimization models to practical and transparent decision making [1].
- An important trend is that more and more asset managers look at the performance of systems and networks of assets in time, rather than single objects. Due to this increase in scope, for instance maintenance optimization is about optimal maintenance of a portfolio of objects rather than a single object. This requires insight in the behaviour of objects in terms of system and network functionality. Also, due to the increased scope, operational short term decisions and strategic long term decisions become interdependent.

From the experiences with the cases within the ROBAMCI programme we see the following opportunities for tackling these challenges:

- The developments of computational power and intelligent mathematical and data-driven models offer new options for probabilistic planning of investments for asset management portfolio's. This can aid considerably in deriving more integral system-based maintenance and investment plans.
- The combination of decisions that are robust for a wide variety of situations and concepts such as the Value of Information to evaluate inspection and monitoring decisions can lead to efficient and adaptive strategies, also in cases where there is initially a scarce amount of quality data.

References:
1. Klerk, W.J.; Kanning, W.; van Veen, N.-J.; Kok, M. Influence of monitoring on investment planning of flood defence systems. In ISGSR2019; 2019.

LCM 2019 WORKSHOP
— iaLcce —

Workshop on
Life Cycle Management
27-29 October Rotterdam

InfraQuest
COMPETENCE CENTRE FOR ROADS & STRUCTURES

Stretching the boundaries of Infrastructure Asset Management – experience in large scale flood infrastructure asset management

Assela Pathirana[1], Mohanasundar Radhakrishnan[1], Tim Busker[1] and Richard Ashley[2]*

*Corresponding author: *a.pathirana@un-ihe.org

ABSTRACT:

Infrastructure Asset management (IAM) can be seen as a necessity that arose from the relative inability of traditional engineering to deal with resource-constrained situations. Since its broad introduction in ‘90s, many new ideas and methodologies have been developed to ensure that the IAM process is itself adaptable, and delivers the right assets that are adaptable for both existing and new infrastructure. Initially, IAM was developed as a response to the inability of traditional engineering approaches to deal with sustainable management of infrastructure assets. Over the last three decades, the process of IAM has itself faced a number of challenges that has led to a broadening in scope, as well as the integration of and with, new concepts, frameworks and techniques. Such expansion of scope poses a number of specific challenges to Life Cycle Costing (LCC) in IAM. Some of the current challenges faced by IAM are:

1. Flood infrastructure asset management – where climate adaptation needs to be incorporated as a mainstream consideration
2. Asset management of Nature-based solutions – where traditional models of asset aging and failure risk modelling are challenged by the use and operation of natural system assets.
3. Multi-functional assets (including 1 & 2 above) – where it is necessary to ensure appropriate valuation of multiple-benefits within the IAM process, including societal and ecosystem benefits.
4. Delivering IAM in extremely rapidly changing and uncertain physical and socio-economic environments (e.g. refugee movement, rapidly growing cities, sudden catastrophic events) – where dealing with (deep) uncertainty together with extreme urgency is needed.
5. IAM in a developing country context – where the status-quo is simply not satisfactory, so that there can friction between long-term sustainability ambitions of assets and an immediate need for improvement on the ground.

We describe these challenges and their implications on LCC with examples, and share some of the ideas that makes IAM more relevant in such challenging contexts.

LCM 2019 WORKSHOP
— iaLcce —

Workshop on
Life Cycle Management
27-29 October Rotterdam

InfraQuest
COMPETENCE CENTRE FOR ROADS & STRUCTURES

Practical approach for sustainability to achieve long-term value for money on (renovation) projects

Olga Brommet[1], *Gerard* File[2]

[1]Advisor Project- and Asset Management, Transport & Planning, Royal Haskoning DHV
[2]Cost- and Risk Engineer, Transport & Planning, Royal Haskoning DHV
*Corresponding author: olga.brommet @rhdhv.nl

ABSTRACT:

Keywords: Sustainability, life cycle costing, environmental cost indicators, value engineering, decision-making process

Nowadays, performance management of civil assets is characterized by the performance indicators reliability, availability, safety and sustainability. The challenge is to create maximum value by considering the performance versus the costs. The question remains how to quantify the performance, since the value can be different for every person and changes over time [1]. Practical evaluation of projects shows that most public sector organizations incorporate sustainability into their policy, but don't know how to quantify their sustainability performances and how to incorporate sustainability over the life time of a (renovation) project.

Two case studies show us how to transform policy into practice by using environmental cost indicators and life cycle costs or value engineering.
In the first case the LCC and environmental impact (expressed in costs) of possible alternatives for the reconstruction of canal banks are compared to determine the most favourable integrated solution, see figure 1. In practice we learned that it is important to define the scope of the interventions and the corresponding quantification on beforehand for a good weighing of the pros and cons. The study provided insight in the sensitivity of the applied materials and its corresponding prices over time. But this study did not give insight in the soft values of sustainability like construction nuisance, land use and climate adaption.
The second case considers a dyke reinforcement, whereby the philosophy of value engineering is applied to substantiate the preferred alternative. Functional and environmental aspects are determined by input from the relevant stakeholders. Value engineering supports the process for objectification and comparison, see figure 2. Only it is hard to explain the quantification of the soft values and the comparison of the alternatives in a simple way.

Proposition is to combine the methodologies to quantify the sustainability performance. The philosophy of value engineering, in combination with life cycle costs and environmental cost indicators provides fixed and tailored quantifiable criteria over the life time of an asset which gives a proper basis for making choices. The transparency of the decision-making process regarding the performance and costs over the lifetime results in a more broadly-based supported (renovation) project.

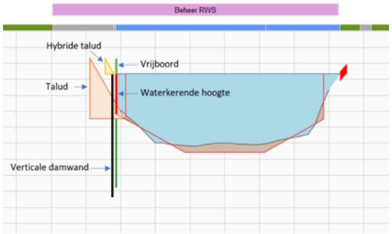

Figure 1 *Alternatives for the reconstruction of canal banks*

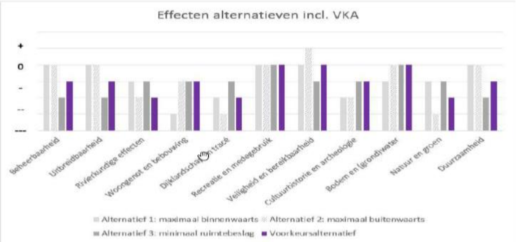

Figure 2 *functional and environmental aspects of a dyke reinforcement*

References:

5. de Ridder, H.A.J. (2013). *Dynamic Control of Projects: developing complex systems in a fast changing environment*. *Ecological Engineering.* Delft: TU Delft.

LCM 2019 WORKSHOP
— iaLcce —

Workshop on
Life Cycle Management
27-29 October Rotterdam

InfraQuest
COMPETENCE CENTRE FOR ROADS & STRUCTURES

Developing a resilient maintenance strategy for assets subject to changing conditions

Martijn de Jong[1,*]

[1]Rijkswaterstaat
*Corresponding author: martijn.de.jong@rws.nl

ABSTRACT:

Structures are gererally designed for a lifespan of 80+ years. Traditionally these structures are managed and maintained based on probalistic risk methods. This should be sufficient as long as these structures perform within the predefined limits.

But what if functional requirements change due to new insights coming aviailable? For instance: accelerated rise of the seawaterlevel. Or if views on risk manangement change? This may lead to structures coming to a (functional) end of life sooner than expected.

Changing conditions may lead to several fundamental questions. In case of storm surge barriers:
- Is closing the barrier more frequently acceptable? This has effects on the technical state of the barrier as well as an effect on the availability of a port or waterway behind the barrier.
- Do we accept higher risks?
- If we know assets will reach a functional or technical end of life sooner, how does this affect our current maintenance strategy. Should we invest in big replacement projects?

The aim of this abstract is to start a discussion on how to deal with uncertaincies in relation to (functional) end of life of structures. Results of the discussion should contribute to an answer to:

How can we develop a resilient maintenance strategy for assets which takes effects of changing conditions and uncertaincies in (functional) end of life scenarios into account and supports decision making processes?

Questions to be answered may be:
- What do we know already?
- What should we know? (What don't we know?)
- When should we know?
- Which scenarios should be investigated?

Possible scenarios to take into account (example storm surge barriers):
- Maintain current closing strategy.
- Raise functional requirements and accept higher risks.
- Raise functional requirements and take measurements elsewhere in the system (raise the dikes behind the barrier.)
- (evacuation plans)