Risk-based asset management of a navigation network

Ad VAN DER TOORN Lecturer / Researcher Delft Technical University Delft, the Netherlands <u>a.vandertoorn@tudelft.nl</u>

Hans JANSSEN Sr. Advisor RWS, The Netherlands hans.janssen@rws.nl Wouter VAN DER WIEL Projectleader IV-Infra, Papendrecht, The Netherlands w.d.vanderwiel@iv-infra.nl

Dirk-Jan KILJAN Sr. Advisor RWS, The Netherlands <u>dirkjan.kiljan@rws.nl</u> Mario DE ROOIJ Sr. Researcher TNO Delft, The Netherlands *mario.derooij@tno.nl*

Summary

In the Netherlands the State Public Works is responsible for the main waterway network, where locks are mostly the decisive bottlenecks in the navigation corridors. In the last decade the State Public Works has changed from a technical oriented maintenance organization mainly focussed at the component and asset level to a user oriented service provider at the corridor and network level, while the more technical activities at the basis are brought to the market. This radical change will only be successful if the relations between the technical conditions of components at the basis can be linked to requirements at the network level in terms of availability, reliability, etc. To work this out a restricted amount of twenty locks are carefully inspected and bottom-up analysed to assess their present state and to find these vertical relations. Next a set of more generalized findings based on key performance indicators will be rolled out across the whole network in order to rank the risk of the different systems and prioritize inspection and maintenance activities.

Keywords: Waterway network; service provider; asset manager; risk based; inspection; maintenance; reassessment; availability; reliability; key performance indicators.



Fig. 1A and 1B: The Dutch waterway network

1. Introduction

The State Public Works in the Netherlands has to manage the main waterway network (~3.300 km) in which around 120 navigation locks are the dominant assets (see fig.1A and 1B). These locks are mostly serial links in minor waterways, but also parallel links in important waterway corridors, like the Meuse-corridor, the Amsterdam-Rhine- and Scheldt-Rhine-connection.

Up to now design, but also inspection and maintenance of these objects were all technically oriented, with the implicit belief that if all components are 'in the right technical order', the whole macro-system (waterway network) will be too. However this approach is often physically restricted by the problematic accessibility of 'hidden' (underwater or underground) components and also limited by the organisational capacity and budget limits (see fig. 2). So unreliability and unavailability at the (macro)system-level were more or less accidental and implicit results of all these technically oriented activities at the basis.

But in the last decade the State Public Works has transformed from a technically oriented organization where design, inspection and maintenance were mainly in house and stand-alone activities, towards a functionally oriented asset manager, where technical activities were left over to the private market. Now top requirements will explicitly be defined in terms of RAMS (reliability, availability, maintain-ability, safety), not just for a single new navigation lock (as the new giant lock in IJmuiden), but finally for complete existing waterway connections and not just based on what is technically achievable, but based on macro-economic evaluations (Costs versus Risk-reduction for transport).

This drastic transformation gives risks but also different challenges like:

- 1. Existing wet infrastructure has to be thoroughly inspected and reassessed to make not only their present condition, but also their implicit RAMS explicit and their relation as well.
- 2. But the amount of assets forces to be efficient with these in-depth inspections and reassess-ments, so for the network as a whole a more generic approach will be needed.
- 3. Contracts has to be transformed in terms of DBMFET-type, for periods of 10-30 years, with RAMS-specifications at a (macro)system-level.
- 4. Requirements at the (macro)system-level for new and existing infrastructure has to be derived from macro-economics.
- 5. Traditional market partners have to work together and reorganise their work in that new sense, at a bigger and more integrated scale and for much longer periods of time.
- 6. The traditional technically oriented State Public Works has to reinvent themselves as a qualified principle for other types of contracts, as a client friendly service provider, but also as an asset-manager, with still enough technical know-how!

Asset management (system levels and goals)



or ..'Not to much' loss of material importa

cross-sections?

or Budget-limits

∑ I&M-costs / year

Fig. 2: Different goals at different system-levels

preparation and/or realisation

by in-house a/o external teams

2. Risk based approach

Sheet piles, etc.

Unavailability and unreliability at the top of a system will most of the time originate from foreseen, but what is more worse also from unforeseen or still unknown (combinations of) basic events at the component level (see figure 3). There could be on-going ageing-processes like corrosion or fatigues of steel gates or doors, wear and tear of hydraulic plungers, cables and/or hinges, carbonation, alkali silica reaction (ASR) or chloride penetration of concrete lock heads, erosion of bottom protection, etc. All this could lead to loss of strength, but at the same time there could be a steady growth or even a sudden jump in loading conditions, by bigger vessels, more engine power, etc. There could be (hidden) human failures in design, during construction or in the operational stage; there could be unforeseen heavy natural boundary conditions or a certain unforeseen combination of all these basic events. If the time dependent basic events and their consequences for the behaviour of the structure were not recognized during inspection and following reassessment, so not repaired by preventive maintenance actions, they could lead to unforeseen failure at the component level and dependent of the build in redundancy also at the system or even macro-system level. Together with the time to repair in case of unplanned maintenance, this will result in certain unavailability. But if these basic events were known, well recognized during inspection and consequences for the behaviour of the structure may not be neglected, they could lead to

preventive maintenance actions and so to a certain planned unavailability of the subsystem or dependent of the redundancy even at the system or macro-system level (see fig. 3).



Fig. 3: Relations between events at the basis and performance at the top of the system

Although basic events stands at the basis of the failure tree, it is a hard job to physically model all relevant basic events for all components and next their possible effects on different subsystems, etc.

At this moment a direct and explicit relation between a specific basic event and the consequences at higher system-levels could only be modelled if there is one or there are just a few specific and dominant mechanism(s) like corrosion or fatigue, working at specific components of a system. Like this has been done for corrosion of sheet piling walls in the Port of Rotterdam, for fatigue of the welded joints of the Eastern Scheldt gates or for a few mechanisms that threaten the Dutch dikes.

In other more complex cases, a more generic approach is followed (see fig.4). So unavailability and unreliability at the subsystem-level (in the Dutch data system DISK so called IH-deel) are considered as the lowest detail level and the assumption will be that there are certain relations with a set of key performance indicators given by experts, partly based on experience and partly on theoretical models. These relations may be derived from the group of well inspected and reassessed assets (twenty locks).



Fig. 4: How economically based requirements meet technically based performance

These reassessments will give the relations between the present conditions at the component level and the performance at the sub-system or asset-level. There should also be an insight how this condition could change in time because of loss of strength by ageing-mechanisms in combination with (over)loading by ever growing amount or dimensions of passing vessels.

3. Application

A working group under the flag of 'InfraQuest' (a union of State Public Works, TNO and Delft University of Technology) is specific involved with the question how the in-depth inspection and assessment results of around twenty navigation locks (see fig. 5) can be used to estimate the performance of the remaining group of about hundred. And next how to predict the future performance of the group or even better sub-groups in specific corridors, in order to prioritize future inspection, reassessment and maintenance activities and so underpin budget allocation.

Three top failure trees for a navigation lock



(Princess Beatrix Lock / the Netherlands)

Fig. 5: Assessed relations between basic events and requirements at the top

To answer these questions a basic, but far from easy first step was to complete and update all relevant 'fixed' data of the involved assets (e.g. dimensions lock chamber, date of construction, type of doors, type and age of operating mechanism, etc.). The second step was to define a set of so called key performance indicators (KPI's), based on a mix of expert judgement plus well known ageing- and overloading-mechanisms, which could have a significant relation with the performance of the different subsystems of the locks and next with the lock as a whole in terms of unavailability, unreliability, etc.

Of course it will be a hell of a job to really fill in all these KPI's for all different lock subsystems. But for a restrictive well known group of around twenty locks some finger exercises have already been done to figure out which subsets of KPI's (or combination) may give strong relations with the performance of the subsystems of the locks. These strong relations may be used to estimate the present state of other less known subsystems of corresponding locks and on a higher system-level even of the corresponding navigation corridor. An estimate not only for the present state (see fig. 6), but also a prediction for the years ahead.



Fig. 6: Overall status waterway network

4. Update and completion of relevant data

The basic 'fixed' general data about the different navigation locks in the network, such as name, location, date of construction, original navigation class, main dimensions, main subsystems, etc. were mostly at hand in the nation-wide data-information-system DISK.

But more precise 'fixed' and 'variable' data, relevant for use in this prioritization-tool, such as 'age of moving mechanism', 'type of gearbox', 'last moment of renovation', 'depth restrictions', 'maximum head over a door', 'amount of leakage', etc., were much more spread over design documents or as build specs, inspection reports, experts knowledge, local operators or maintenance people.

Then the question arise what will be the effort to find it and how relevant will it be for this purpose. A first scan gives an impression about the effort and the expert sessions give a first indication about the relevance of the collected extra data. However the search for relevant relations could only be done if some data is already available. So it is more a matter of try-and-error than of brute force to fill in the 120 times 25 matrix.

5. Generalized findings

Although navigation locks are never completely identical, not in the same corridor or not even within the same complex (!), it should be possible (at least at the subsystem-level) to group them together in more or less homogeneous groups. For example with the same type and amount of users, the same type of doors or gates, the same operating mechanisms, steering and control systems, lock chambers, bottom protection, guiding works, etc.

For these kind of 'homogeneous' groups it may be possible to derive more generalized relations between a (combination of) KPI's and the performance of the specific type of subsystem. And so estimates could be given for less known subsystems and/or for other times (see fig. 7).



Fig. 7: Empirical relation for a moving mechanism between unavailability and age

6. Overall requirements

Of course a first estimate for the overall requirements at the asset or even better corridor level could be the summed up (from bottom to top) at hand existing availability, reliability, etc. In other words: 'what society needs is what there is', organically realised by the historically applied inspection regime, traditional maintenance actions and some upgrading throughout the years.

One step further could be a level described as: What is reasonable achievable for the present locks, with an optimized regime for inspection, maintenance actions and/or necessary upgrading's. But in fact the 'new' requirements should come top-down from a balance between the (extra) macro-economically benefits in case of a higher performance-level in terms of higher availability, reliability, etc. for navigation, so the transport of goods and the efforts to achieve that level. So a more advanced inspection and maintenance regime will be possible, balanced at higher system levels.

7. Present status project

The present status of this on-going project is that the data of all locks involved are cleaned up and enriched with relevant additional data from other sources. Though some empirical relations are already found (see fig.7), now the enriched data will be used to find even stronger relations, which may be used to roll out the new approach across the whole network.

8. Conclusions and Discussion

The radical change from technical oriented maintenance managers to service providers at the network level is not only a matter of renaming the organization and taking people into service with other skills, but it also gives a boost to a fundamental other way of asset management.

Scattered or even unknown data have to be collected and sorted. Some systems have to be inspected carefully to establish their present condition and (re)analysed thoroughly to establish missing links. More general findings will be spread out over the whole network to have a good prediction of the performance at the top of the network. Requirements at the top have to be defined and quantified.

The project is now in full swing and should be supported by a mix of theory and practice, but the organization is already in transition and people are on the move. 'Visionary captains' had slowly hove the organisational 'super tanker' to new and challenging targets behind the horizon, while the remaining experienced 'old sailors' still day-dream over the beloved land they left behind and 'younger sailors' try to set sail for a new course to reach that untrodden but promised land.