Working Together on Hydraulic Structures within the Dutch Flood Protection Programme: challenges and opportunities

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Abstract. Over 400 hydraulic structures are listed in the Dutch Flood Protection Programme (DFPP). That is a daunting task for the next 30 years, meaning that every three weeks one structure should be reinforced to meet the statutory standards. In an innovation project, the regional water authorities, Rijkswaterstaat, the Dutch Flood Protection Programme, research institutes and the consultancy agencies joint forces. In the past period, we have identified numerous obstacles, using the critical success factors framework, that hamper the reinforcement of these civil engineering structures. To tackle the barriers, we developed a roadmap that gives more insight in the steps for strengthening these structures. In addition, we incorporate the lessons learned from current strengthening projects, such as experience in draining centuries-old sluices, engaging with the local community and using new, sustainable material, to further optimize the overall programming of these structures within DFPP, and to enhance the knowledge transfer and uptake within the triple helix.

1 Introduction

Two-thirds of the Netherlands is below the current sea level, and this amount is likely to increase due to climate change. In the past, the Dutch responded reactively to floods. However, after the catastrophic floods of 1953, the Dutch took measures to prevent a similar disaster: a system of dike rings with flood protection levels was developed for flood risk management (Most, et al, 2014), and statutory standards were set out in the Flood Protection Act of 1996 to maintain this system. Those standards related to the primary flood defences: those on the coast, major rivers and lakes. In 2008, the second Delta Commission advised changes to take future uncertainties, such as climate change and land subsidence, into account in order to sustainably protect the Netherlands. The Dutch national government recently adopted a risk-based approach (Most, et al, 2014) for the Dutch flood risk management policy. This is based on new knowledge about the safety of dikes and the impact of serious floods as a result of the failure of dikes and/or other structures. This is a proactive approach, in which protection standards are based on both the probability and the impact of flooding in 2050, considering climate change and socio-economic developments. The Water Act (soon to be the Environment Act) sets out the statutory standards for the flood protection structures, such as dikes, dams, and other hydraulic structures. Every 12 years, the regional water authorities are required to conduct assessments to ensure that the flood defences still meet the statutory standards. Where the safety standards are not met, the responsible body can apply for funding from the

Dutch Flood Protection Programme (DFPP) (Jorissen et al., 2016). Over 1500 km of dikes and 400 hydraulic structures will have to be upgraded between now and 2050. Jonkman et al., (2018) highlighted two key challenges; (1) one of them being the renewal, adaptation or upgrade of these structures. Here, future requirements (e.g new safey standards) and other demands (increase of shipping traffic) must to be considered. The other challenge is the management and maintenance of the existing structures. Until recently, limited attention was raised for the hydraulic structures, let alone a systematic approach towards them. In this paper, we apply the learning-while-doing approach of the DFPP to these hydraulic structures and introduce the readers to our approach and experiences so far. So, we focus primarily on the hydraulic structures that often consist of a location-specific combination of components and materials and are required to perform other functions too. For these structures, multiple parties, with their own individual interests and responsibilities, play a role, and they seek to minimise trade-offs. This complexity further emphasises the importance of knowledge management and continuous learning around these structures. In addition, within the programme board of DFPP it is felt that these structures seem to get limited attention, whereas the investment needed to strengthen these structures to meet the statutory standards is high. The number of structures that are currently on the programme requires that every three weeks a structure is strengthened. This sense of urgency led the programme board, together with other parties, to initiate an innovation project dedicated only to these hydraulic structures to develop instruments. The paper is structured as follows: Section 2 presents the methods, looking at the Dutch Flood Protection Programme and specifically to the hydraulic structures, followed by a description of the methodology used in our study; in Section 3, we describe how the framework helped to identify challenges and opportunities, and how they are faced. Finally, Section 4 presents the discussion and conclusions of this paper.

2 Materials and methods

2.1 Dutch Flood Protection Programme: context

Currently, the DFPP faces the task to upgrade about 1500 km of dikes and about 400 hydraulic structures before 2050. The exact numbers depend on the results of the statutory assessment of flood defences by the regional water authorities; first round after the new implementation of the risk-based approach finishes in 2023. To ensure that the reinforcement task of DFPP is realized within time and available budget, they adopted a knowledge and innovation strategy. In Tromp et al. (2022) more information is available on this learning-while-doing strategy. In 2018, representatives of Rijkswaterstaat, the regional water authorities, knowledge institutes and consultancy agencies together underline the necessity to start an innovation project focused on the civil engineering structures that are part of the primary flood defence system in the Netherlands (DFPP, 2018). This includes locks, sluices, culverts, pumping stations and storm surge barriers. The DFPP uses the definition for hydraulic structures according to The Dutch Water Act (2016) : a construction that is part of a flood defence and, over a limited length, takes over all or part of the flood protection function of the body of land, but is constructed for the purpose of another (utilitarian) function that crosses the flood defence (such as draining and facilitating navigation). In connection with this utilitarian function, these hydraulic structures are usually equipped with one or more valves. For the DFPP, the stricter requirement is that the flow surface of the water retaining structure must be >0.5 m2 (DFPP, 2016).

In 2021, Regional water Authority Hollands Noorderkwartier initiated the innovation project ‘Working jointly together on hydraulic structures’. This specific regional water authority already had experience with strengthening structures, as they carried out a pilot where seven sluices were strengthened. Aim was to gain more insight in the current sense of urgency for the hydraulic structures within the Dutch Flood Protection Programme. For the first phase, the core team identified four pillars: (1) Inventory on the overall reinforcement scope within DFPP, (2) Inventory on the challenges and opportunities when starting a reinforcement project , (3) Inventory on knowledge gaps around hydraulic structures, and (4) Identification of the current sense of urgency around these civil engineering structures, both at the administrative and executive level.

2.2 Methodology

The core team used the methodology and framework that was developed by the DFPP programme boar. To identify why the development of innovations stopped, the DFPP organisation used the critical success factors framework (Tromp et al., 2022) as derived from (Shrivastava et al., 1988; Van Staveren, 2006). From this framework (Figure 1) identifies six critical success factors (CSFs):

1. *People involved*: is sufficient knowledge and expertise available for the project team, and does the involved people have the required competences?
2. *Instruments*: are the knowledge and tools available to design the structures in its surroundings?
3. *Organisation*: is there political willingness to take risks, and what boundary conditions have been given to the project team?
4. *Governance*: how is decision-making organised, and how are organisations such as contractors and local stakeholders involved?
5. *Legislation*: how can the project comply with formal and informal regulations?
6. *Discourse*: is there enough support in society for strengthening the structures?

The three success factors on the lower row of Figure 1 are preconditions located outside the boundaries of influence of flood defence reinforcement projects. The remaining three success factors can be controlled by either the regional water authorities or the project team members. This framework helps the DFPP to formulate activities to enhance, and possibly steer, the development of knowledge and innovations. In the next section, we describe in more detail the scope and challenges for the hydraulic structures within the DFPP.

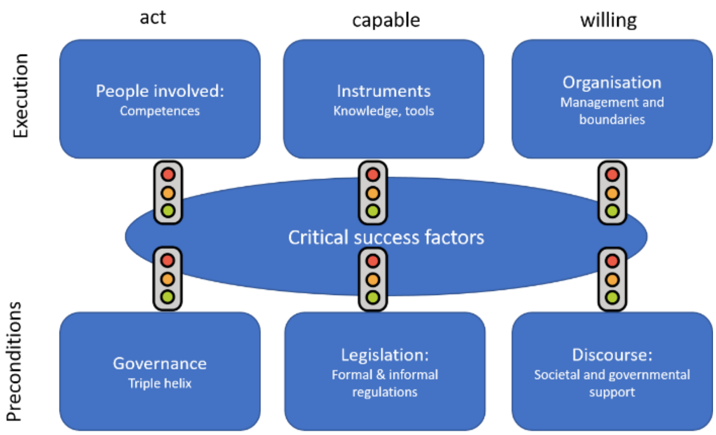

Figure 1: The six critical success factors framework (Tromp et al. (2022)

3 Results: opportunities and challenges

Within the DFPP project 'Working jointly together on hydraulic structures', further insight into the scope of the task, a uniform approach and available knowledge is gained. In this section we describe these results of the research

3.1 Scope of the hydraulic structures within DFPP

In the Netherlands a total of 1824 hydraulic structures are in the primary flood defence system, this includes culverts, sluices, storm surge barriers, movable barriers (see Figure 2). All regional water authorities and Rijkswaterstaat were approached to share information already available from their running statutory assessments. This was mostly mid-term information, because the organisations had not all finished. By summer 2021, about 40% had been assessed (total of 685). Of these, 547 structures were found to meet the specified lower limit of the safety requirement and 138 structures did not meet the lower limit. Of the 138 structures that failed the statutory assessment, the authorities have indicated a wish to include 91 in the

DFPP. Of the other remaining structures, this was unknown.

Figure 2: Artists impressions of hydraulic structures in the Dutch primary flood defence system (credit: Working jointly together on hydraulic structures', 2022)

The team (Iv-infra, 2021) made an extrapolation to gain insights how many structures could potentially be on the DFFP programme. This led to the insight that approximately 370 hydraulic structures, of which 50 large scale structures must be strengthened within the Dutch Flood Protection Programme. Most structures fail to meet two dominant safety requirements: sufficient height and a sufficiently reliable closure process; less dominant are piping and stability. In the study the team also distinguished between the different types, namely:

		# through extrapolation
Hydraulic structure does not comply with standard	138	~370
Lock	15	41
Flood lock	14	38
Coupure	37	100
Inlet/outlet pipe	37	127
Pumping station	9	24
Drainage sluice	16	43

This scoping should be updated in 2023 when all the results of the statutory assessment are available. This will undoubtedly lead to changes in the overall scoping.

3.2 Uniform approach: opportunities and challenges

For the uniform approach, we have created the so-called Hydraulic Roadmap (Figure 3). End users highlighted the need to visualise this process. This roadmap describes the three main phases taken during the life cycle of a hydraulic structure in a primary flood defence, namely: (1) Obligation to provide care on a *daily basis*, and when a hydraulic structure does not meet the statutory standard, a next step starts, namely (2) *Initiation*, to start planning for the upgrade, maintenance or renewal of a structure, which are carried out in (3) *(DFPP) Project*, which consists of multiple phases to reinforce the hydraulic structure. When this phase ends, the *daily maintenance* phase starts again. Regional water authority Hollands Noorderkwartier has worked on the pilot in which seven locks, predominantly have been strengthened in the past years. The knowledge gained (such as dealing with centuries-old locks, where the process of opening and closing is now done hydraulically instead of by hand while preserving historical value, as well as dealing with local residents) has been widely distributed to interested parties. This however does not guarantee the uptake of the knowledge by all water authorities having a task.

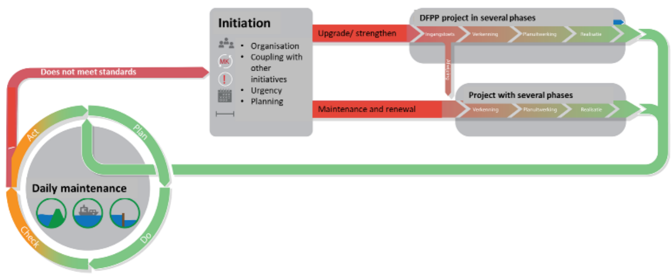

Figure 3: The Hydraulic Roadmap highlighting the different phases during the life cycle of a structure in a primary flood defence (Infram, 2021)

For each of these steps, we researched via semi-structured interviews and a desk study whether there were any points of attention and possible showstoppers leading to a delay in the reinforcement of a hydraulic structure (as well as maintenance (and replacement)). The respondents of the regional water authorities and Rijkswaterstaat indicated that, until now, they did not experience showstoppers.

However, points of attention did emerge within each phase of the roadmap. The raised concerns were classified by the six CSFs, as described earlier. This research (Infram, 2021) led to several key focus points, as shown in the next table.

CSF	Focus point(s)	Step
People	- Limited capacity and knowledge - Lack of instruments to deal with uncertainties - Overview of the task is lacking	- Obligation to care - Initiation - Project
Instruments	- Data is out of date, not of the appropriate level or unavailable - Need for an overview of all available knowledge and know-how on innovations - Knowledge gaps are not always clear	- Obligation to care - Initiation
Organisations	- A strong commissioner with adequate expertise daring to make decisions - No scenarios available (regarding the approach)	- Obligation to care - Initiation - Project
Governance	- Depending on knowledge of private parties - Unclear decision-making	- Obligation to care - Initiation - Project
Legislation	- No clear distinction between maintenance, replacement and reinforcement - Grant experiences	- Obligation to care - Initiation - Project
Discourse	- Attention to executive interest, urgency and action	Initiation

In several interviews with representatives of the private sector, regional water authorities, Rijkswaterstaat and other governmental organisations, we found that hydraulic structures still not get the required attention. Often, asset managers are unaware that these structures require a slightly different approach. In Dutch, the word for civil engineering structure is like the word that represents paintings and statues. So often a cognitive barrier (Tromp, 2019) occurs, thus hampering the knowledge uptake and transfer. The interviews highlighted that professionals at the water authorities sometimes lack insight in the available knowledge and how to use it. For this purpose, we analysed the available knowledge and highlighted relevant knowledge gaps for further research. We presented the available knowledge using the failure path approach (Tromp et al., 2022). A failure path is an entire chain of successive events that together lead to a flood according to the definition in the current Water Act. The failure path with the highest probability of occurrence for a specific flood defence structure strongly depends on the design and geometry of the structure and the environment in which it is located. In an in-depth analysis, a distinction is made between the events (i.e. processes of change from one condition to a new, successive condition) that, given a flood situation, may lead to flooding on the one hand, and the condition (based on scenarios) of parts of the flood defence prior to the flood situation on the other.

In the Dutch statutory assessment of hydraulic structures, four failure mechanisms are considered, namely:

- Reliability of closure process of the structure, probability of non-closure per closure demand
- Height of hydraulic structure, probability of excessive wave overtopping and/or overflow
- Piping at structure, probability of insufficient resistance to piping
- Structural strength and stability, probability of structural failure

These four failure mechanisms were used for the failure paths. This overview (Tromp et al., 2022) provides insights where additional knowledge is required and steers the knowledge agendas of the Ministry of Infrastructure and Water Management, Rijkswaterstaat and the research institutes.

4 Discussion and conclusions

The first phase of the ‘Working jointly together on hydraulic structures’ project, has provided insights that hydraulic structures often do not get the attention they deserve. This affects the stability of the DFPP programme, but also the projects themselves. An update on the scope and number of hydraulic structures in DFPP is required in the second phase. The regional water authorities need handholds to help them get started with hydraulic structure. The lessons learned from the pilot at the regional water authority Hollands Noorderkwartier showed the effort undertaken to share knowledge. This however does not guarantee the uptake of the knowledge by all water authorities having a task.

Figure 4: Several meetings, held by Hollands Noorderkwartier to transfer and uptake knowledge around seven sluices (Photocredit: Regional Water Authority Hollands Noorderkwartier, 2022)

Therefore, projects such as those carried out at Regional water authority Hollands Noorderkwartier must actively share their knowledge with other projects. The innovation project will make the available knowledge accessible via a knowledge repository, but will also organise frequent meetings, each focusing on a different step and experience of the civil engineering roadmap. A wealth of information and knowledge needs has already been identified from the interviews held. As knowledge is situated and socially constructed, this knowledge must be actively shared and restated after each change in the group of participants. At the same time, a constant awareness of the impact of change on the programme's implementation will be required, as well as additional knowledge. This could also affect how knowledge is shared and absorbed in the future.

5 References

DFPP. Memo waterkerende kunstwerken binnen het HWBP: een definitie (in Dutch only), 2016

DFPP. Startnotitie POS Kunstwerken (in Dutch only), report. 2018.

INFRAM, Hydraulic structures roadmap), (in Dutch only) report, Project number: 21i861, 2 december 2021.

IV Infra, Inventory scope hydraulic structures). (In Dutch only) Reference INFR210556-R02. 23 December 2021.

Jonkman, S.N, Voortman, H.G., Klerk W.J., van Vuren, S. Developments in the management of flood defences and hydraulic infrastructure in the Netherlands, *Structure and Infrastructure Engineering* **2018,** *14*, *7*.

Jorissen, R.; Kraaij, E.; Tromp, E. Dutch flood protection policy and measures based on risk assessment. In *Proceedings of the 3rd European Conference on Flood Risk Management*, Lyon, France, 17–21 October 2016.

Most, H.; van der Tánczos, I.; Bruijn, K.M.; de Wagenaar, D. New Risk-based standards for flood protection in the Netherlands. In *Proceedings of the 6th International Conference on Flood Management*, Sao Paulo, Brazil, 16–18 September 2014.

Shrivastava, P.; Mitroff, I.I.; Miller, D.; Miglani, A. Understanding industrial crises. *J. Manag. Stud*. **1988**, 25, 283–303.

Tromp, E. *Enhancing Knowledge Transfer and Uptake in the Design Processes of Flood Defences*. Ph.D. Thesis, Delft University of Technology, Delft, The Netherlands, 11 November 2019.

Tromp, E., Verdijck, N., Breedeveld, J., Rode Draad Waterkerende Kunstwerken. Ontwikkeling kennis en kunde voor overstromingskansanalyse waterkerende kunstwerken (in Dutch only), September 2022

Tromp, E.; te Nijenhuis, A.; Knoeff, H. The Dutch Flood Protection Programme: Taking Innovations to the Next Level. *Water* **2022**, *14*, 1460.

Van Staveren, M. *Uncertainty and Ground Conditions, A Risk Management Approach*, 1st ed.; Butterworth-Heinemann Elsevier Ltd.: Oxford, UK, 2006.