



Working Together on Civil-Engineering Structures within the Dutch Flood Protection Programme: challenges and opportunities

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Abstract. Over 400 civil-engineering structures (e.g. sluices, pumping stations) 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, lessons learned from current strengthening projects on civil engineering structures are used 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 to sustainably protect the Netherlands. The Dutch national government 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 because 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 Environment Act sets out the statutory standards for the flood protection structures, such as dikes, dams, and other civil-engineering structures (e.g. locks, coupures, siphons). 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 civil-engineering structures will have to be upgraded between now and 2050.

In this paper, we focus primarily on the civil-engineering 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 DFPP programme board 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 civil-engineering structures to develop instruments. This paper aims to provide an overview of current activities to gain more attention to the DFPP-listed civil-engineering structures.

The paper is structured as follows: Sect. 2 presents the methods, looking at the Dutch Flood Protection Programme and specifically to the civil-engineering structures, followed by a description of the methodology used in our study; in Sect. 3, we describe how the framework helped to identify challenges and opportunities, and how they are faced. Finally, Sect. 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 civil-engineering 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. (2022b) 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 civil-engineering structures according to The Dutch Environment 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 $>0.5 \text{ m}^2$ (DFPP, 2016).

In 2021, Regional water Authority Hollands Noorderkwartier initiated the innovation project “Working jointly together on Civil-engineering 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 civil-engineering 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 board, as laid down in the knowledge and innovation strategy; more specifically the insights gained on knowledge management and the critical success framework, as shown in Tromp et al. (2022b). This framework (Fig. 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 Fig. 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. The traffic lights in Fig. 1 show that if one of the CSF's is at red or orange a project stagnates in its implementation. This specific framework helps the DFPP to formulate activities to enhance, and possibly steer, the development of knowledge and innovations.

While the focus in Tromp et al. (2022b) was on an enhanced understanding of which elements of the knowledge and innovation strategy work and others fail, the focus here was on finding out why regional water authorities do have not yet undertaken water retaining structures, using the CSF

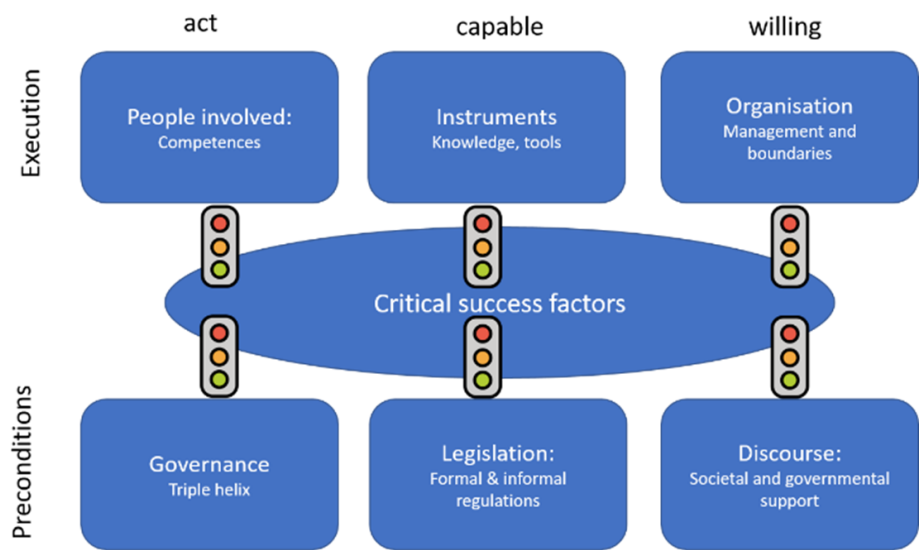


Figure 1. The six critical success factors framework (Tromp et al., 2022b).

framework. However, this framework has never been used from the onset of an (innovation) project to explore, for the different phases and at so many different organisations, at what factors caused, in this case the non-reinforcement of civil engineering structures within DFPP. With this approach, we illustrate how knowledge development, transfer and up-take can be enhanced by focusing on one or more CSFs in particular way.

In the next section, we describe in more detail the scope and challenges for the civil-engineering structures within the DFPP.

3 Results: opportunities and challenges

Within the DFPP project “Working jointly together on Civil-engineering 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 civil-engineering structures within DFPP

In the Netherlands a total of 1824 civil-engineering structures are in the primary flood defence system, this includes culverts, sluices, storm surge barriers, movable barriers (see Fig. 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

Type of civil-engineering structure



Figure 2. Artists impressions of civil-engineering structures in the primary flood defence system of the Netherlands (credit: project Working jointly together on Civil-engineering structures).

a wish to include 91 in the DFPP. Of the other remaining structures, this was unknown.

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 civil-engineering 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 sta-

Table 1. Overview of civil-engineering structures that do not comply with the Dutch statutory standard.

Type of civil-engineering structure	# of structures that does not comply with standard	# through extrapolation
Lock	15	41
Flood lock	14	38
Coupure	37	100
Inlet/outlet pipe	47	127
Pumping station	9	24
Drainage sluice	16	43
Civil engineering structure does not comply with standard	138	~ 370

bility. In the study the team also distinguished between the different types, as shown in Table 1.

This scoping should be updated in 2024 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 Civil-engineering Roadmap (Fig. 3). This roadmap describes the set of steps taken during the life cycle of a Civil-engineering structure in a primary flood defence. Previous analyses and discussions revealed the need to visualise this process. The drafted roadmap distinguishes the following three steps: (1) Obligation to provide care on a daily basis, (2) Initiation; and (3) (DFPP) Project.

For each of these steps, we researched via semi-structured interviews and desk study whether there were any points of attention and possible showstoppers leading to a delay in the reinforcement of a civil engineering 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 step of the roadmap. The raised concerns were classified by the six critical success factors, as described earlier. This research (INFRAM, 2021) led to several key focus points for each critical success factor, as shown in the Table 2.

In several interviews with representatives of the private sector, regional water authorities, Rijkswaterstaat and other governmental organisations, we found that civil-engineering 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 similar to 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 fur-

ther research. We presented the available knowledge using the failure path approach (Tromp et al., 2022a). 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.

For the failure paths, we used the four distinctive failure mechanisms used for civil-engineering structures in BOI as input, 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.

This overview (Tromp et al., 2022a) 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 Civil-engineering structures’ project, has provided insights that civil-engineering structures do not yet always get the attention they deserve. This not only affects the stability of the DFPP programme, but also the projects themselves. An update on the scope and number of civil-engineering structures

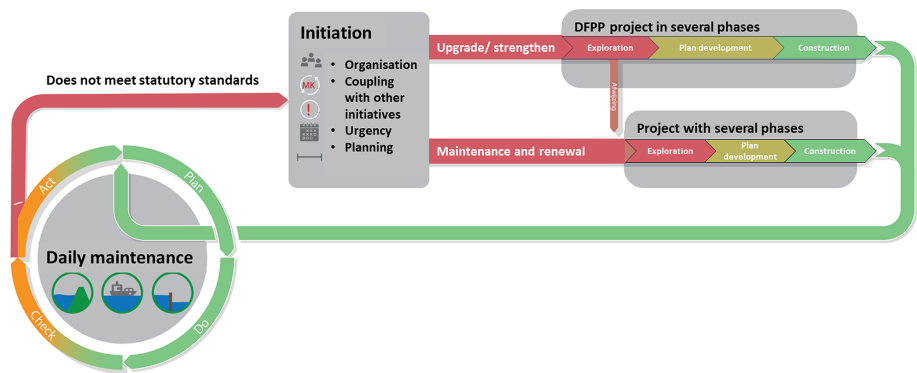


Figure 3. The Civil-engineering roadmap highlighting the different steps during the life cycle of a structure in a primary flood defence (INFRAM, 2021).

Table 2. Key focus points for each Critical Success factor with link to step in the Civil-Engineering roadmap (INFRAM, 2021).

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



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

in DFPP is required in the second phase. The regional water authorities need handholds to help them get started with civil engineering structure.

Fortunately, some projects have already been taken up within the DFPP. 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 has been disseminated in several meetings, but still requires further knowledge transfer to all water authorities having a task (Fig. 4).

In the second phase, allowing knowledge to flow is key. Projects such as those carried out at Regional water authority Hollands Noorderkwartier must actively share their knowledge with similar reinforcement projects on flood defence structure to prevent the traffic lights turning red or orange.

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.

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