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Thesis:

Integrating Ecosystem and Infrastructure Services into a Multi-Actor Multi-Criteria analysis: A path towards improved assessment of Linking Opportunities in Dutch dike-strengthening projects

MSc Thesis Proposal – Construction Management and Engineering

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Executive summary

Developing integrated dike-strengthening projects that combine the flood protection agenda with other sectoral agendas is challenging. Additional public value may be realised when measures are included that aim at improving functionalities that lay outside the main objective of a dike-strengthening project. In this research, the inclusion of such measures is called the integration of a linking opportunity (LO). Numerous LOs exist in the context of dike-strengthening projects and the Flood Protection Program, largely financing these projects, advocates the need of assessing the suitability of LOs in the initiation and exploration phases of its projects. However, LO assessment is difficult as only limited assessment tools exist while the assessment itself encompasses a complex interconnection of both stakeholder interests and the provided services in the geographical project area. Additionally, the unique characteristics of individual dike-strengthening projects make it difficult to standardize the assessment, further challenging decision making. Hence, more extensive assessment tools are desired.

This research aims to design, test and validate an assessment method for assessing LOs in the initiation and exploration phase of Dutch dike-strengthening projects. Such a tool is required to: a) indicate the desirability of LO integration b) allow for trade-offs to be included in the assessment, c) enable comparisons between individual LOs, d) indicate the distribution of both positive and negative effects on different stakeholders following LO integration and e) indicate the cost-effectiveness of public value creation following LO integration.

In this research, an LO assessment tool is designed that uses ecosystem services, infrastructure services, and success criteria within a Multi Actor Multi Criteria Analysis (MAMCA). Here, the literature on ecosystem services is supplemented with services provided by infrastructure to develop a more comprehensive framework that describes the functionalities that are provided within the project areas of dike-strengthening projects. Success criteria describe the interests of the dike-strengthening project itself. Both the services and SC are incorporated within a MAMCA and provide identified LOs with scores based on an actor perceived importance, thereby indicating the amount of created public value following LO integration. Lastly, a cost-effectiveness analysis is adopted in the assessment that uses the scores obtained by the LOs in the MAMCA and combines these scores with the realisation costs of the LOs to demonstrate the cost-effectiveness of an LO regarding the provisioning of public value. Thereby linking the assessment to wider notions of economic welfare and economic efficiency.

The developed assessment tool has been validated using a test case and a validation session where three industry professionals were consulted. Here, the dike-strengthening project “Culemborgse Veer - Beatrixsluis” has been used as the test case as this project includes 7 diverse LOs for which sufficient documentation was available, meaning effect studies and cost calculations. In this rapport the realisation costs of the LOs in the test case are not disclosed considering the sensitive nature of this data. However, the results of the cost-effectiveness analysis, and the validation thereof, are described qualitatively. Using the developed assessment, the LOs in the test case have been assessed and the results have been discussed with industry experts in a validation session to reflect on the performance of the assessment. It was shown that the assessment tool provides insight by a) indicating the desirability of LO integration (indicated by a negative or positive LO score), b) allowing trade-offs in the assessment (as positive scores compensate negative scores), c) enabling comparisons between individual LOs (using comparable scores), d) indicating the desirability of an LO for individual stakeholders (showing scores per stakeholders), and e) indicating the cost-effectiveness of public value creation per LO. However, the assessment must not be leading in decision making but should be used as a supportive tool. Here it could prove valuable as a tool in communication and co-creation that clarifies and substantiates decisions.

Contents

Executive summary 1
1.0 Introduction 4
1.1 Background 4
1.2 Problem statement 5
1.3 Research objective 6
1.4 Research scope 6
1.5 Relevance 7
1.6 Report outline 8
2.0 Theoretical background 9
2.1 Linking opportunities 9
2.2 Public value 10
2.3 Ecosystem services and the absence of infrastructure services 10
2.4 Success criteria 11
2.5 Multi-actor multi-criteria analysis 12
2.6 Cost-effectiveness analysis 12
2.7 Synthesis 13
3.0 Method 14
3.1 The design cycle 14
3.2 Problem investigation 15
3.3 Treatment design 15
Multi-actor multi-criteria analysis and cost-effectiveness 16
Ecosystem services and infrastructure services in the assessment 16
Success criteria in the assessment 17
3.4 Application of the assessment: a case study 17
Case selection 17
LOs in the test case 17
3.5 Data collection and analysis in the application of the assessment 19
Validation session 20
Data collection and analysis 20
Sensitivity analysis 21
4.0 Results 23
4.1 Problem investigation 23
4.2 The designed assessment 24
Conceptual model 25
The selection of included services 25

The selection of included success criteria 27
The cost-effectiveness of provided services 28
Context of use 29
4.3 Application of the assessment: case study results 29
The actor-based evaluation of services 29
The actor-based evaluation of success criteria 30
Assessment of the linking opportunities 31
Cost-effectiveness analysis 34
Sensitivity analysis 34
4.4 Reflection and final design 37
Reflection on the assessment tool 37
Reflection on the context of use 38
Final design 38
5.0 Discussion 41
5.1 Reflection on key findings 41
Application of the assessment: discussion on case study findings 41
Ecosystem services and its relation to infrastructure services 42
Project success criteria and drivers for LO integration 42
Results of the cost-effectiveness analysis and sensitivity analysis 43
5.2 Reflection on the research approach and assessment method 44
Research methods and limitations 44
Improving the assessment 45
5.3 Generalizability of the assessment 45
6.0 Conclusions and recommendations 47
Conclusions 47
Recommendations for further research 47
Recommendations for practical applications and development 47
Acknowledgements 49
References 50
Appendices 55
A) Interview protocol for evaluating the infrastructure services and ecosystem services 56
B) Interview protocol for evaluating the project success criteria 61
C) Scoring of the linking opportunities in the test case 66
D) Validation session with industry professionals 97

1.0 Introduction

1.1 Background

With more than half the country susceptible to flooding, the Netherlands has a long history of dike construction and maintenance (Botzen & van den Bergh, 2008). To guarantee the desired water safety, continuous efforts are needed. This is emphasized by the change of the Water Act in 2017 where new safety norms were adopted resulting in the need for flood protection reinforcements (Tweede Kamer der Staten-Generaal, 2016). The Delta Program for 2015 has previously provided higher safety standards for over 200 dike sections (Werk aan de delta, 2014) and the Flood Protection Program predicts that around 1500km of dike will need strengthening before 2050 (HWBP, 2021).

The approach towards the provisioning of water safety is currently undergoing a transition. Following the flood disaster of 1953, water safety became a topic of national security where the application of predominantly technocratic and sectoral work methods has resulted in large-scale engineering solutions (Meijerink, 2005). These solutions and methods heavily focused on flood risk reduction, often leaving little room for other functions of Dutch waters. Change started following the ecological turn of the 1970s when growing recognition of landscape values and nature conservation emerged, leading to the first reference of integrated water resource management (IWRM) in the Netherlands in 1980 (Mostert, 2009). The concept of IWRM advocates a holistic perspective towards the management of water systems, including groundwater, quantity and quality issues and the effects of the water system on the environment. In the Netherlands, IWRM became a national policy in 1989 (Derde nota Waterhuishouding, 1989; Mostert, 2009).

The emphasis on integrated and collaborative approaches persists in the Dutch Flood Protection Program (in Dutch: Hoogwaterbeschermingsprogramma), this is an alliance of 21 regional water authorities and the national Ministry of Infrastructure and Water Management (Avoyan & Meijerink, 2020). The emphasis on integration is demonstrated by the program's explicit ambition to incorporate spatial planning, the functionalities of the system and the existing environment in their considerations (HWBP, 2017). Other important considerations are those of nature, sustainability, cultural history, landscape values, minimizing public costs and reducing environmental disturbances during the construction of the project. Construction work on dikes will inadvertently affect these points of consideration and the Flood Protection Program, therefore, allows initiatives that advance the aforementioned societal values to be included in the project scope. The opportunity to include initiatives aimed at improving functionalities that lay outside the main objective of a project is called a "Meekoppelkans" in the Dutch water management sector (Most, Heijden, & Knoeff, 2018) and translates to a "linkage opportunity" (LO).

A dike-strengthening project in the Flood Protection Program consist of multiple phases. It starts with the initiation phase where the goal and scope of the project are determined. In this phase, the identification of potential LOs begins. After the initiation phase, the exploration phase starts where the suitability of LOs is investigated further. The exploration phase is concluded with the documentation of a preferential design where a decision is made regarding which LOs are integrated into the project. This preferential design is thereafter further developed in the plan development phase, the last phase before the realization phase. The assessment of LOs thus takes place in the initiation and exploration phase of dike-strengthening projects. Here, LOs are included in projects to improve spatial development, aid IWRM, obtain synergies or more generally, to create public value.

Public value can be defined as “a reflection of what society believes are important values in the production of certain products or services and whose provision is the responsibility of the government” (Kuitert, Volker, & Hermans, 2019, p. 259). The governmental responsibilities in the context of water management have been shifting from flood risk reduction towards IWRM as political negotiations continuously redefine the place, meaning and importance of water (safety). The public values that emerge from these negotiations provide a normative consensus that essentially describes the collective objectives that are to be achieved (Correljé & Broekhans, 2015). The integration of LOs within dike-strengthening projects may promote a more cost-effective fulfilment of these collective objectives when the goals of different governmental organisations are combined, providing governments with an obligation to investigate LOs as part of the responsible allocation of resources. The Flood Protection Program recognizes that considerable overlap exists between their objectives and objectives in the vicinity of their projects. The program, therefore, advocates for the application of LOs to enhance the creation of public value and to improve the cost-effectiveness of deployed public resources (HWBP, 2017).

A direct link between an LO and the public value it provides is difficult to establish. An intermediate step that describes the actions, functions or services provided by an LO, followed by the consideration of how desirable these effects are, is needed to allow concrete evaluations. A substantial part of the services that can be provided is investigated by the literature on ecosystem services that describes the services provided by natural ecosystems (Millennium Ecosystem Assessment, 2003). Literature that describes the services provided by the built environment, or infrastructure, is also prevalent but less adapted to be used for assessment purposes.

1.2 Problem statement

The development and realization of integrated projects have, however, proven difficult as it remains challenging to combine the flood protection agenda with the agendas of other sectors and domains (Delta Programme, 2016). Leading some researchers to argue that current water safety arrangements, procedures and instruments are still characterized by a traditional and sectoral approach towards flood management (Avoyan & Meijerink, 2020).

Within the Flood Protection Program, coordination between sectors, domains, and stakeholders is of considerable importance in the initiation and exploration phase of a project where the objectives of the project are determined and where potential LOs are identified. Earlier research conducted at RoyalHaskoningDHV, that focuses on energy transition integration, has described the importance of a timely allocation of adequate financial means. It states that the successful integration of energy transition LOs is advanced by a timely cost distribution (de Vries, 2021). Thereby emphasizing the importance of considering LOs early in the projects (in the initiation and exploration phase of projects). However, LO assessment in these phases is difficult as only limited assessment tools exist while the assessment itself encompasses a complex interconnection of stakeholder interests and the geographical project area provides numerous services that need consideration. Additionally, the unique characteristics of individual dike-strengthening projects make it difficult to standardize the assessment, further challenging decision making by making the assessment labour intensive in a work environment where the availability of resources is limited and where more economic approaches are sought to realize upcoming projects.

The existing challenges in assessing LOs and in subsequent decision making may act as barriers for accurate decision making, possibly resulting in the integration of unsuitable LOs or in the rejection of desirable LOs. This process might make dike-strengthening projects needlessly sectoral as LOs are

discarded. The literature on project management describes how the objectives of a project are often defended against conflicting objectives from other projects or parties. Projects thus generally only satisfy the specific ambitions that have been defined in advance which results in situations where “the outcomes of projects are increasingly contradictory to other ambitions and goals” (Buuren, Buijs, & Teisman, 2010, p. 674). This illustrates the importance of integrating existing ambitions, demands or goals within the project scope to counteract developments that possibly constrain these objectives. Alternatively, inaccurate decision making regarding the integration of LOs may drive an inefficient use of resources as unsuitable LOs are advanced. Both pathways result in inefficient, or reduced, public value creation.

1.3 Research objective

The aim of this research is to design, test and validate an actor-weighted assessment method for assessing LOs in the initiation and exploration phase of a dike-strengthening project and to thereby support the decision making of project managers. This assessment will have to provide two distinct indications. Firstly, whether it is beneficial to integrate an identified LO, or whether it would be more efficient to realize the dike-strengthening and the LO as two separate projects. Because, knowing that a separate realization of the projects proves more effective will render the process of integration unnecessary. Secondly, the assessment needs to indicate the cost-effectiveness of integrating an LO. Additional requirements are found and described in the results of the problem investigation (chapter 4.1).

The assessment tool designed in this research is aimed at aiding industry professionals in deciding which LOs to integrate in a dike-strengthening project. These professionals are in a position where they are involved in decision making. Considering that the authority of deciding which LOs to integrate is placed with local water authorities, means that the tool is primarily developed for decision makers at local water authorities and for parties aiding the local water authorities such as consultancy firms.

To design an assessment tool a design cycle is used as described in Chapter 3, the following research questions guide the design and validation of the assessment tool:

(1) Which services can be fulfilled in the context of a dike-strengthening project?
(2) How are the services evaluated by the public stakeholders involved in a dike-strengthening project?
(3) How cost-effective are identified LOs at providing public value?

1.4 Research scope

This research focuses on assessing identified LOs with actor-weighted (ecosystem) services to indicate public value creation. The research thereby contributes to operationalizing ES and public value principles for decision making. While considering the evaluation of services in sub-question 2, this research is limited to the perspective of public parties considering the manageability of the data collection. However, the designed assessment method does not inherently exclude non-public parties. The accuracy of the assessment is expected to be improved as non-public parties are also included in the assessment. The focus of this research was furthermore applied specifically towards readily identified LOs in the initiation and exploration phase of dike-strengthening projects in the Flood Protection Program. Because in these phases, a decision is made on how the required water safety can be achieved, resulting in a preferred alternative being documented (HWBP, 2017).

The project phase in which the assessment can be used is expected to depend on the level of detail of the ES that are used in the assessment. The relatively broad formulations that the Millennium Ecosystem Assessment (2003) provides, make the assessment especially suitable for the earlier project phases where the available information regarding LOs is limited. Limited information makes it unfeasible to conduct a detailed assessment because the required information is unavailable. Figure 1 shows the conceptualization of the suitability range of the assessment.

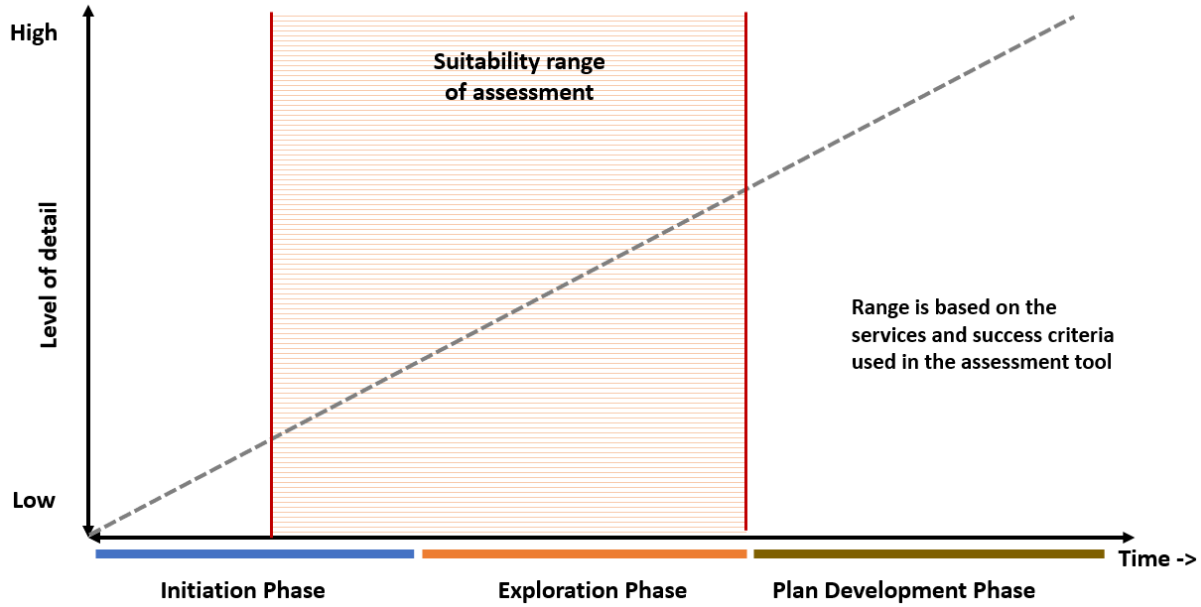

Figure 1: Suitability range of the assessment

The range as shown in Figure 1 is the range for which the current assessment has been developed. The validation session will indicate if the designed assessment is applicable within this range. The figure furthermore demonstrates the concept that the suitability range of the assessment is determined by the ES that are used in the assessment. Optimization of the assessment regarding a specific project phase is thus possible by altering the included services to better correspond to the required level of detail of the project phase.

1.5 Relevance

Limited tools exist for the assessment of LOs and the existing literature describing the trade-offs, challenges, and processes relating to LO integration is sparse. The most compatible literature that has been found describes the possible synergies between climate mitigation and adaptation, and proposes linking these objectives (Duguma, Minang, & van Noordwijk, 2014). In the context of Dutch dike-strengthening projects, the linking of objectives, providing incentives for LO integration, has received limited scientific attention. Grey literature suggests, however, that there are many LOs available in dike-strengthening projects as objectives for nature development (Rijkswaterstaat, 2020b), the energy transition (Planbureau voor de Leefomgeving, 2022), housing development (Ministerie BZK, 2022), and climate adaptation (Stichting CAS, 2021) are all extensively described and present near dikes. The insight that this research provides helps to better understand the current processes, challenges, and goals that influence the integration of LOs.

The practical relevance of this research is the development of an assessment tool that aids in a more effective, objective, and comparable assessment of LOs in dike-strengthening projects. This tool could be used by regional water authorities and consultancy firms that are in a position to accept or decline the integration of a proposed LO. Here the tool might aid in making the assessment cheaper as efficiency is improved and by integrating more desirable LOs. The inclusion of a cost-effectiveness analysis in the assessment furthermore allows for decision making that provides more public value on a macro scale as resources are deployed in a more cost-effective manner. Meaning that on the macro scale (e.g., the whole Netherlands) more services are provided using the same number of resources. The assessment tool thereby seeks to aid in the provisioning of additional public value.

1.6 Report outline

The report introduction, of which this is the concluding paragraph, has outlined the context and aim of the research. The next chapter provides the theoretical background that is used in this research. Chapter 3, thereafter, uses the concepts and information of the theoretical background to clarify the research method. The subsequent results are provided in Chapter 4. Followed by a discussion in Chapter five and the final conclusions in Chapter 6. Specific data and information collection approaches relating to the interviews can be found in Appendix A, B and D. The scoring results of individual LOs, including argumentation, can be found in Appendix C.

2.0 Theoretical background

Flood risk management in the Netherlands is dominated by a probability-reducing approach with a limited focus on spatial integration (Kaufmann, 2018). More integrative approaches are desired that facilitate the growing demands for landscape values, nature conversation, and recreational values near dikes (Van Loon-Steensma & Vellinga, 2019). The integration and combination of these different functionalities, such as recreation and nature conservation, are endorsed by national policy (Ministerie BZK, 2020), with the Flood Protection Program stating that LOs must be considered in their projects (HWBP, 2017). This chapter describes how the inclusion of LOs in dike-strengthening projects may provide public value and how the provisioning of this value can be assessed by adopting a multi-actor multi-criteria analysis (MAMCA) using both services and success criteria in the assessment. Therefore, the literature on synergies, co-developments, public value, ecosystem services, project success criteria, and cost-effectiveness analysis (CEA) is discussed in this chapter.

2.1 Linking opportunities

The Delta Program, overarching the Flood Protection Program, speaks of linking tasks and linkage opportunities when describing the possible implementation of measures that connect tasks and ambitions of various parties in the fields of water management and spatial planning (Delta Programme, 2016). In scientific literature, the added value of linking projects is frequently described by using the concept of synergies. Broadly speaking, the term synergy refers to the "combined, cooperative effects that arise from the relationships and interactions among various forces, particles, elements, parts, genomes, or individuals in a given context" (Corning, 2014, p. 187). A thorough analysis of synergies is provided by Duguma et al. (2014), stating that distinct types of synergies exist, namely additive and non-additive synergies. Additive synergies occur when the resulting effect is the sum of all the minor effects making up the total effect. Non-additive synergies occur when the resulting effect differs from the sum of minor effects. More generally the term "synergy" is used across the literature when the combined effect supersedes the sum of individual effects, resulting in a whole that is greater than the sum of its parts (D. Li & Bou-Zeid, 2013). This definition is not without criticism, as studies state that many types of synergies exist and that wholes are not necessarily greater than the sum of their parts, just different (Corning, 2014).

This research follows the colloquially used definition of synergy where synergy describes the increase of value (or positive effects) that results from the interaction of separate parts. In this way, a synergy describes solely the positive dimension of "linking" and omits to describe the adverse consequences or trade-offs that might result from linking (Kongsager, 2018). For the aims of this study, the term linking is therefore preferred.

In this study, the word 'linking' is utilized as a key term, which means to 'join' or 'couple' individual parts (e.g., projects). The term "linking" is similarly used by others (Ayers & Huq, 2009; Kongsager, 2018; Martens, McEvoy, & Chang, 2009) but other terminology is also prevalent, especially in the scientific domain of climate adaptation and mitigation. Here, terms such as integration (Swart & Raes, 2015; Wilbanks & Sathaye, 2007), interaction (Warren, 2011), and also synergy (Duguma et al., 2014) are used to describe the same phenomenon as linking. The term "Linking Opportunity" as used in this study, describes that an opportunity towards linking is identified but that a decision on linking has not been made.

2.2 Public value

The integration of an LO in a dike-strengthening project should increase the amount of public value created. However, the production of public value is difficult to quantify and "scholars in the field refrain from a definition of public value that is explicit, clear, and univocal" (Correljé & Broekhans, 2015, p. 101). Thus, making public value a relatively general term that, as suggested by other scholars, is strongly associated with processes of collaborative negotiation where both public and private stakeholders jointly pursue solutions for public challenges (Brown, Cherney, & Warner, 2021), as is the case in dike-strengthening projects. This study adopts the definition as formulated by Kuitert et al. (2019, p. 258) where public value is defined as "a reflection of what society believes are important values in the production of certain products or services and whose provision is the responsibility of the government". This, however, raises questions about which values are important and how this value is provided. These questions are hard to answer objectively resulting in the statement that "the characteristics of public values complicate decision making as rational assessment often seems impossible"(Kuitert et al., 2019, p. 258). Here, the literature on ecosystem services may be used to indicate more objectively how public value is provided, making rational assessment more accessible and thereby aiding the assessment of LOs.

2.3 Ecosystem services and the absence of infrastructure services

The dependency of human societies on the services and value that nature provides has been discussed in scientific literature since the late 1960s. Here, the discussion started by recognizing that human economies are both supplied and constrained by the amount of natural capital (i.e., resources) available (Häyhä & Franzese, 2014). This aspect of providing natural capital was thereafter expanded by literature that describes the regulating, cultural and supporting functions that ecosystems provide, strengthening the conceptualization of services being provided by ecosystems (Gómez-Baggethun, de Groot, Lomas, & Montes, 2010). Since then, the publication of the Millennium Ecosystem Assessment (2003) has spread the notion of ecosystem services even further (Häyhä & Franzese, 2014). Ecosystem services (ES) are generally defined as "the benefits of nature to households, communities, and economies" (Boyd & Banzhaf, 2007). But diverging definitions are prevalent, so while the public value-providing capacities of ES are undisputed, scholars state that too much ambiguity exists around the concept of ES (La Notte et al., 2017) limiting its ability to indicate public value creation. Especially the literature on cultural ecosystem services is ambiguous, including services such as recreation, spiritual and religious values, educational values, and the provisioning of inspiration. Indicators for these services are severely limited, making it unclear when and where these services are provided (Hernández-Morcillo, Plieninger, & Bieling, 2013). Provisioning services, describing the products that can be obtained from ecosystems and regulating services such as climate regulation, water regulation, and pollination, are defined more clearly and possess better indicators (Millennium Ecosystem Assessment, 2003). Furthermore, many services provided by ecosystems can be enhanced by infrastructure. For example, the ecosystem services of food provisioning and water regulation are shaped considerably by existing infrastructure (Burdine & Taylor, 2018). Many services, defined in this research as "the benefits that the environment provides to households, communities, and economies", are thus a combination of ecosystem services and infrastructure services (IS). However, no scientific framework was found that elaborates on the services provided by infrastructure that is comparable to the framework of ES. The literature does describe concepts such as "built capital" and "the built environment" but lacks comprehensive descriptions of the services they provide (Hale et al., 2015). Furthermore, frameworks providing a synthesis between the concepts of ES and IS do not exist. The literature predominantly conceptualises ES and IS as distinct concepts or alternatively places the built

environment (IS) within a natural world superstructure (Coutts & Hahn, 2015). A synthesis of these concepts might prove valuable. In this research, individual papers describing individual infrastructure services were therefore combined with the literature on ecosystem services to develop an overarching and comprehensive framework describing the services provided by, on, and near dikes.

Literature suggests that there is an increasing recognition that "environmental" and "developmental" interests do not necessarily result in trade-offs but that synergistic "win-win" situations are possible where ecological, social, and economic benefits are obtained by integrating the concept of ES in spatial planning and decision making (de Groot, Alkemade, Braat, Hein, & Willemen, 2010). Other research shows that there is a growing body of evidence describing the positive influences of ES on the quality of human life (Gómez-Baggethun & Barton, 2013). Thereby providing an incentive to operationalise ES as a pathway towards public value provisioning. However, this remains challenging in practice. Knüppe, Pahl-Wostl, and Vinke-de Kruijf (2016, p. 70) state that "there is no simple or established way of integrating ES into policies and decision making" but acknowledges that "incorporating ecosystem services provides significant opportunities to […] increase synergies" and thus public value. Thereby articulating both the importance and challenge of including (ecosystem) services in decision making.

2.4 Success criteria

The integration of an LO influences both the services provided in a geographic area after project completion and the dike-strengthening project itself. Literature on project success criteria (SC) is investigated to better understand the resulting implications of LO integration on the interests of a dike-strengthening project. Songer and Molenaar (1997) investigated the project characteristics for successful public-sector design-built projects and defined six SC as shown in Table 1.

Table 1: Success criteria and definitions sourced from (Songer & Molenaar, 1997)

Success criteria	Definition
On budget	The project is completed at or under the contracted cost.
On Schedule	The project is completed on or before the construction finish date
Meets specifications	The completed project meets or exceeds all technical performance specifications provided by the owner
Conforms to user's specifications	The completed project meets or exceeds the user's envisioned functional goals (fitness for purpose).
High quality of workmanship	The completed project meets or exceeds the accepted standards of workmanship in all areas
Minimizes construction aggravation	The construction process does not unduly burden the owner's project management staff

The SC described in the table above strongly focus on the conformation to specifications that have been defined in advance. In a more recent study, Lamprou and Vagiona (2018) conducted a literature review and found a broader range of relevant SC. Including SC such as stakeholder satisfaction, environmental impact and user satisfaction. The inclusion of these criteria presents a broader definition of project success where not just the fulfilment of specifications, but also the interests of affected stakeholders, are considered. Illustrating the existence of different perspectives on what constitutes project success. The different definition of project success that can be used by project managers and the actors surrounding might considerably influence their view on the desirability of different LOs. The SC mentioned in this paragraph receive further attention in Chapter 3.3.

2.5 Multi-actor multi-criteria analysis

Different actors and stakeholders can provide unique, opposing or contradicting viewpoints (C. Macharis, De Witte, & Turcksin, 2010), with differences in the definition of "project success" being just one example. In a project environment where many stakeholders, interests and viewpoints are prevalent, such as in dike-strengthening projects, methods are desired that accommodate the viewpoints of different stakeholders. One such method is the multi-actor multi-criteria analysis (MAMCA) where the viewpoints of different stakeholders are explicitly considered. In a MAMCA, individual stakeholders provide their own perspective on the relative importance of the criteria that are used in a multi-criteria analysis (Cathy Macharis, de Witte, & Ampe, 2009). This provides assessment results for every individual stakeholder. These individual results can thereafter be compiled to provide a total assessment score. This method includes various stakeholders in the decision making process. Furthermore, the criteria of a MAMCA are not predetermined and can be adapted to the entity under assessment. Both services (ES and IS) and SC can thus be included in a MAMCA.

2.6 Cost-effectiveness analysis

A fundamental scarcity of resources drives the need for an efficient application of resources because a society that allocates its resources in an efficient manner is, by definition, more sustainable (Jena & Philipson, 2008). The process of measuring and maximizing public value creation in the most cost- or resource-effective manner could function as a guiding principle towards a better allocation of resources. Alternative methods of determining the desirability of an investment exist in the form of a cost-benefit analysis where both the costs and the benefits are monetized, thereby allowing for an evaluation and comparison of projects, programs or LOs (Mishan & Quah, 2020). However, it is often difficult or unwanted to monetize the benefits of an intervention. This is the case in the health sector where the monetization of a life saved is deemed undesirable (Murray, Evans, Acharya, & Baltussen, 2000). Cost-effectiveness analysis (CEA) is therefore commonly used in the healthcare sector to support decision making on the application of different medical treatments or programs (Cookson et al., 2017) and is also used in the domain of defence policy (Boardman, Greenberg, Vining, & Weimer, 2017). CEA works by adopting a single metric or unit and evaluates how efficiently, meaning at what cost, this metric can be provided by different interventions. This allows for the evaluation and comparison of different interventions. CEA has also been used in the domain of ecosystem management where a CEA was adopted in combination with an ecosystem service assessment to improve decision making on the desired layout of dikes (Boerema, Van Passel, & Meire, 2018).

The integration of an LO in a dike-strengthening project affects the services that are provided in a given geographic area. Different LOs, affecting services in different ways, may subsequently produce different amounts of public value for varying costs. Here, a CEA may be used as a tool in decision making for choosing among alternative LOs with the goal of maximizing the attainable public value with the resources available (Kaplan, 2014; Neumann & Sanders, 2017). For assessing LOs this research assumes that explicit calculations (e.g., a cost-benefit analysis) are undesirable or impossible due to the high degree of complexity resulting from the many services involved, and because many services cannot be adequately monetized. This makes the monetization of benefits impossible and therefore a CEA is preferred.

In this research, the cost-effectiveness of an LO is determined by dividing its MAMCA score by the monetary costs associated with realising the LO. The principle is shown in Equation 1 below:

$$Cost\text{-}effectiveness = \frac{Multi\ Actor\ Multi\ Criteria\ Analysis\ score}{Monetary\ costs}$$

Equation 1: The cost-effectiveness formula

The method used for determining the amount of public value that an LO provides is described in Chapter 4.2 where the designed assessment method is discussed. Chapter 4.3 shows an adapted version of Equation 1 where the units are provided.

2.7 Synthesis

LOs are included in dike-strengthening projects as a way of providing public value. It is however difficult to show or quantify public value creation. The effects of LO integration, and the desirability of these effects, need to be assessed before public value related statements can be made. To conceptualise the possible effects of LO integration, the literature on ES, IS, and SC can be used. This allows an objective quantification of the effects that follow from LO integration by indicating how the LO is expected to affect both services and SC. The provisioning of public value by services and SC is extensively documented in the literature and depends on the interests of stakeholders within the project scope. To incorporate the interests and viewpoints of different stakeholders, a MAMCA can be deployed using services and SC. Thereafter, the scores obtained in the MAMCA can be used in a CEA to include notions of economic efficiency within the assessment. The relation between the key concepts used in this research is shown in Figure 2.

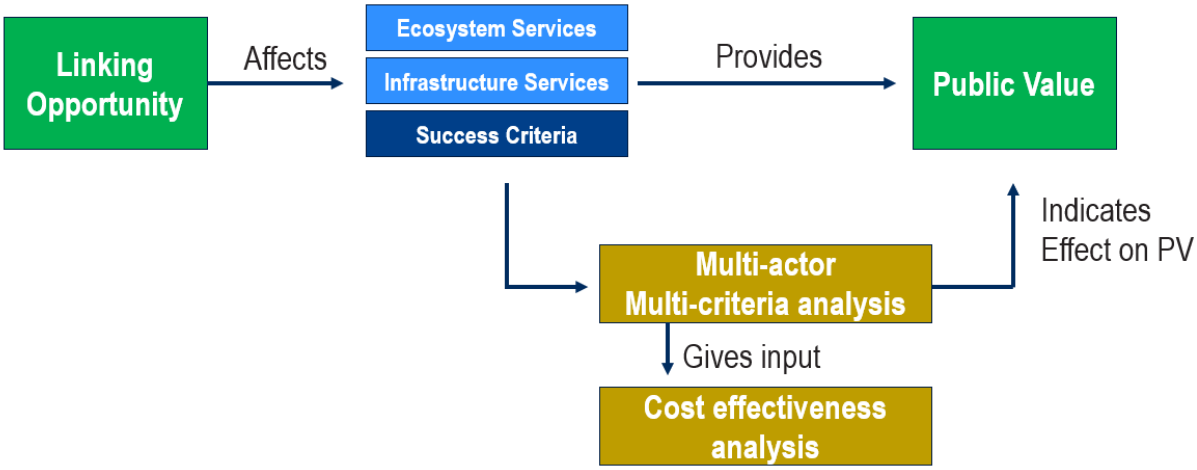

Figure 2: The relation between key concepts

3.0 Method

3.1 The design cycle

The research proposed in this study is design-oriented research that follows the design cycle, as formulated by Wieringa (2014), to provide an assessment method for assessing identified linking opportunities. The design cycle of Wieringa consists of three steps and provides a structured approach towards rational problem-solving. In this research, design steps two (design treatment) and three (validate treatment) of Wieringa have been combined in a single step as shown in Figure 3. Thereafter, the design cycle has been expanded with two additional steps that incorporate a test case and a final design. Additionally, the figure conceptualises the requirements for the treatment design resulting from the problem as an intermediate result.

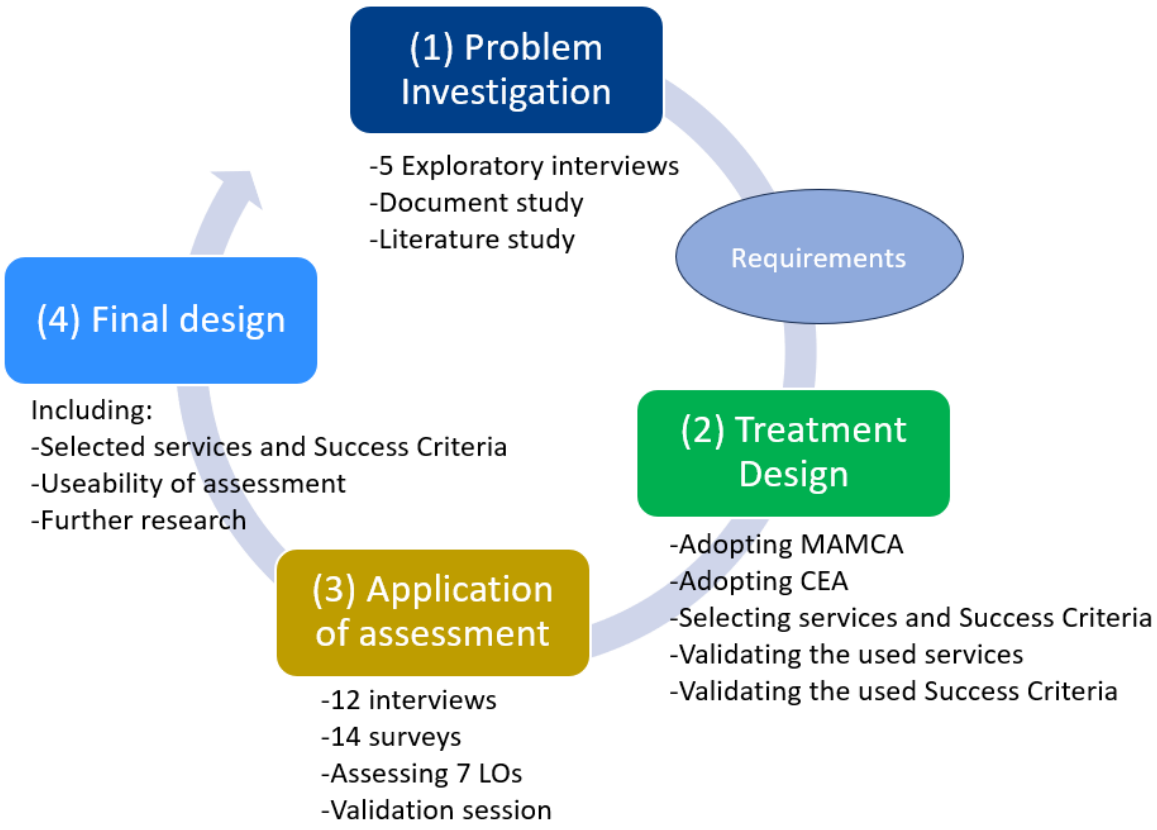

Figure 3: The design cycle followed in this research

The design cycle used in this research thus consists of the following steps:

(1) problem investigation: What phenomena must be improved? Why?
(2) Treatment design: Design one or more artefacts that could treat the problem. Would these designs treat the problem?
(3) Test case: How does the design function when applied to a test case? What can be improved?
(4) Final design: adapt the design following the results of step three.

3.2 Problem investigation

The problem investigation is the first step in the design cycle. The goal of the problem investigation is to prepare the design of the problem treatment by learning about the problem's characteristics and to investigate the availability of possible solutions provided by literature (Wieringa, 2014). For this research this constitutes an investigation of which assessment methods are currently deployed, where these methods prove insufficient, and what the requirements for an improved assessment would be. In this problem investigation the involved stakeholders, the goals of these stakeholders, and the occurring phenomena or mechanisms that affect these goals were studied by discussing the current work methods for LO integration with five industry professionals using semi-structured interviews, see Table 2. These industry professionals are potential users of the designed treatment. Here, an industry professional is defined as someone that works on dike-strengthening projects, has experience with the implementation of LOs in the context of dike-strengthening projects, and is familiar with the policy, goals, and aims of the Flood Protection Program.

Table 2: Industry professionals involved in the problem investigation

Organization	Function
RHDHV	Advisor flood risk
RHDHV	Senior advisor plan studies hydraulic engineering
RHDHV	Stakeholder manager
RHDHV	landscape architect (and LO manager for CUB)
HDSR	Stakeholder manager

In the exploratory interviews the stakeholders of a dike-strengthening project were considered. Here the exploratory interviews focused on the methods that are used to examine the goals and interests of the stakeholders and the methods used to integrate these goals and interest in the dike-strengthening projects were discussed. Grey literature is reviewed to better understand current work methods and policy (Delta Programme, 2016; HWBP, 2014, 2017; Ministerie BZK, 2020; Rijkswaterstaat, 2020a). This understanding was supplemented by the five exploratory interviews with industry professionals in which they explained their experiences with these work methods and policies. Given the exploratory nature of these consultations, no specific agenda or structure was used. The length of the consultations ranged from 30 to 90 minutes.

3.3 Treatment design

The treatment design is the second step in the design cycle. In this step a tool is designed that could treat the problem found in the problem investigation. In this research, the designed treatment constitutes an assessment tool that uses services to assess the created public value following LO integration. Project success criteria are included to evaluate the effects of LO integration on the interests of the dike-strengthening project itself. Both the services and SC are incorporated in a MAMCA that provides scores for the LOs. Lastly, a CEA is adopted in the assessment that uses the scores obtained by the LOs in the MAMCA and combines these scores with the realisation costs of the LOs to demonstrate the cost-effectiveness of an LO regarding the provisioning of public value. This paragraph explains how the services and SC that are adopted in the assessment were found and how the services and SC are used in the MAMCA and CEA.

Multi-actor multi-criteria analysis and cost-effectiveness

A MAMCA constitutes an evaluation method that allows different stakeholders to provide their own perspective on the relative importance of the criteria that are used in a multi-criteria analysis (Cathy Macharis et al., 2009). The assessment tool designed in this research consists of a MAMCA that adopts both services and SC as its criteria. The designed assessment requires, as input, that stakeholders in a dike-strengthening project provide their perceived importance of the criteria in the MAMCA. The assessment tool, using a MAMCA, thereafter evaluates LOs based on stakeholder-evaluated criteria to provide the LO with a final score per stakeholder. Combining the scores of all stakeholders, allowing for a difference in importance for the stakeholders involved, provides an LO with a final score that indicated how much services the LO provides. The inclusion of a CEA thereafter indicates how much service is provided per monetary unit. Thereby normalising the effects of the different realisation costs of different LOs.

Chapter 3.5, describing the method of data collection and data analysis, explains in more detail how the actor perceived importance is determined and how LOs are scored. The method regarding the selection of the services and SC that are included in the assessment tool is described in the two paragraphs below.

Ecosystem services and infrastructure services in the assessment

The literature on ES and IS was used to formulate the criteria incorporated in the assessment. Not all the services described in the literature were included. A selection was made based on relevance, usability, and minimizing overlap between services. Relevance relates to the inclusion of services that are provided near Dutch dikes and the exclusion of services that are not. Here, consultation with industry professionals and (grey) literature helped to establish the relevance of services. Usability concerns how well a service is defined and how understandable it is for industry professionals. Furthermore, the number of included services was minimized to improve the usability of the assessment and to minimize the overlap between services. Overlap is undesirable because this would result in double counting, making the assessment less accurate.

The services in the assessment are broadly formulated because the services must be usable in the assessment of various LOs. For the compilation of ES, the paper by Gómez-Baggethun and Barton (2013) was used as a starting point to describe relevant ES, to give a description of the service and to provide indicators of the service. Indicators are used in the assessment of LOs to enable a more objective assessment of LOs. However, not every service is supported by indicators of similar rigidity. Especially Cultural Ecosystem Services (CES) are poorly indicated, as described by the paper of Layke (2009). Both the data availability and the ability of indicators to convey information are limited in comparison to regulating and provisioning services. Furthermore, because the paper of Gómez-Baggethun and Barton (2013) was primarily focused on provisioning services and regulating services, additional ES literature was used to supplement the cultural services that ecosystems may provide.

Many of the services that ecosystems provide can be strengthened using infrastructure and some services such as mobility and housing are predominantly provided by infrastructure. The services that infrastructure provides are poorly conceptualised in the scientific literature and were therefore added based on grey literature and on the expert opinion of industry professionals. Upon completing the list of relevant services, the contents were discussed with an industry professional to investigate possible shortcomings or omitted services. Thereby validating the used services.

Success criteria in the assessment

The integration of an LO affects both the services provided in a geographic area after project completion and the project itself. Consultation with industry professionals in the preparation of this research has indicated that the expected effects of LO integration on the dike-strengthening project itself can be a strong incentive for both the inclusion and exclusion of LOs. To incorporate the interests of the dike-strengthening project, meaning for example the effect on the budget or project planning, project Success Criteria (SC) have been adopted into the assessment. These criteria have been based on the paper of Songer and Molenaar (1997) that describes the criteria of a successful public sector design-build project. The criteria have been supplemented by considering the paper of Lamprou and Vagiona (2018) which provides a literature review on SC. Not all the SC identified in the literature have been included. A selection was made based on relevance and a minimization of overlap similar to the followed procedure for the services as described in the paragraph above.

3.4 Application of the assessment: a case study

The third step of the design cycle by Wieringa (2014) includes the validation of the designed problem treatment. The designed assessment method was validated using a test case. This paragraph describes the selection process of the test case and explains which LOs are included in the test case.

Case selection

A suitable test case for this research must satisfy three conditions. Firstly, the case (i.e., dike-strengthening project) must be part of the Flood Protection Program; this provides a stable and well-documented context for which the policies are well known. Additionally, testing a project of the Flood Protection Program seems more relevant as there is a large work stock of future projects scheduled. Secondly, the case must encompass multiple LOs that preferably possess varying characteristics. Thirdly, the case must be past the initiation phase to guarantee that sufficient data is available on the identified LOs. Following these requirements resulted in advancing the dike-strengthening project “Culemborgse Veer - Beatrixsluis” (CUB) as the test case for this research.

The selected dike-strengthening project CUB is one of six projects that is part of an overarching program called the ‘Sterke Lekdijk’ with the goal of strengthening the Lekdijk over a total length of 55 kilometres as the dike currently does not comply with the safety norms. The dike section withing the CUB project encompasses a length of 10.8 kilometres and runs from the north side of the Lek from the Veerweg near the Culemborgse Veer towards the Beatrixsluis. The project is managed by the regional water authority “Hoogheemraadschap de Stichtse Rijnlanden” (HDSR). It includes seven LOs as HDSR has provided multiple partners with the possibility to integrate their project within the dike-strengthening project. The goal of which is to improve efficiency and to provide added public value. The LOs are desribed below.

LOs in the test case

Floodplain development Honswijkerwaard: In this LO the floodplains near the dike are redesigned with the goal of nature development. Development is important as the Department of Waterways and Public Works is responsible for realizing the goals as formulated in the European Water Framework Directive. Fulfilment of these goals is required by the European Union in 2027 and the redevelopment of the floodplains is a chance to improve both the water quality as required by the European directive and to improve nature development. Further nature-related goals are advanced by the Province of

Utrecht focusing on terrestrial nature development goals as advanced by Natuurnetwerk Nederland and Natura 2000. The State Forestry is also closely involved in this LO as the area manager of large areas of the floodplain. A further driver for integrating this LO is the opportunity to improve the efficiency (Dutch: werk met werk maken) of the project as it might be possible to reuse redundant soils of the floodplain within the dike-strengthening project. Three different variants are being designed for this floodplain. Three different variants of this LO have been proposed and all the variants are assessed in this test case.

The inlet sluice: The dike-strengthening project crosses the iconic area of the New Dutch Waterline. There are several LOs identified that are about strengthening and experiencing this military heritage. One of these projects is making the inlet sluice at Fort Honswijk visible and experienceable again. The inlet sluice was placed under the earthworks of the dike in 1985 as part of a dike reinforcement that was carried out at the time. This LO aims at making the inlet sluice visible and experienceable again. The municipality of Houten is the main party advancing this LO but receives support from both the province of Utrecht and HDSR. Four different variants of this LO have been proposed and all the variants are included in this test case.

The accessible and safe dike: The municipality of Houten is the main party driving the development of an LO called the 'accessible and safe Lekdijk'. The ambition of the municipality of Houten is to improve the traffic safety and accessibility of a part of the Lekdijk between the A27 and Fort Honswijk. The required road capacity is expected to increase in the future and therefore, a widening of the road is considered necessary.

Strengthening of the iconic area: Commissioned by the province, this LO is a collection of smaller individual measures that seek to make the iconic area near the Lek dike more accessible and open to being experienced. Aiming at more recreational use, enhancing the perception of both the landscape and the cultural history in the area. Some proposed measures in this LO include the realization of walking routes, the highlighting of historical objects and the realization of resting points. Thereby strengthening spatial quality in the area.

Mobility and recreation: The province of Utrecht has the ambition to display the dike as a recognizable and continuous element, that functions as a connection between the surrounding landscapes. Therefore, a uniform road layout is considered desirable, including the colour of the road surface and road furniture being used. This LO is in development for the whole of the Sterke Lekdijk, the overarching program that includes CUB.

Ecological dike: HDSR desires to develop a flowery Lekdijk. It has been concluded that the Lekdijk has great potential for developing a species-rich oat hay meadow as the soil structure is suitable in many areas and also because the outer slope is mainly oriented towards the south. A flowery dike is beneficial for biodiversity and contributes to the strength of the dike revetment.

Floodplain development in the Steenwaard: The LO is conceptually similar to the first LO but includes a different floodplain that is located further upstream in the river Lek. Integration of this LO is a chance to improve both the water quality as required by the European Water Framework Directive and to improve nature development.

3.5 Data collection and analysis in the application of the assessment

The paragraph on the treatment design above has explained the selection criteria for including ES, IS and SC in the assessment. But before the assessment is operational, values need to be assigned to the services and criteria that indicate their relative importance. This is done for five individual stakeholders and here a multi-actor multi-criteria analysis (MAMCA) is used. The evaluation of the services and SC in the MAMCA is actor-dependent. Therefore, multiple interviews with different actors are needed to provide the assessment with the required input. Only public parties have been interviewed here, as all the identified LOs have been proposed by public parties and because private parties were considered more accessible. In total 10 interviews (including 10 surveys) have been conducted for evaluating ES and IS involving 5 public parties, see Table 3. All the interviewees are involved in the dike-strengthening project of the test case (CUB) and are presumed capable of expressing the interest of their organizations within the dike-strengthening project. In the interviews, a survey was used to evaluate the services. In the surveys, points were divided among the services. The percentage of points that a service obtained corresponds to the perceived importance of the service as evaluated by the interviewees representing their organization. Every survey was concluded with the question of whether there were any services missing. The interviews were furthermore used to investigate the viewpoints of the interviewees regarding the methods of LO integration and to discuss points of attention forwarded by the interviewees. The interviews took between 30 and 60 minutes and were recorded and transcribed. The protocol of the interviews for the services can be found in Appendix A.

Table 3: The parties interviewed for valuing ES and IS, including the functions of interviewees

Party	Interview 1	Interview 2
Municipality Houten	Policy advisor	Strategic advisor spatial development
Province Utrecht	Project leader	Program manager and senior advisor
State forestry	Account manager	Project advisor
Department of Waterways and Public Works	Stakeholder manager	Licensing advisor
HDSR	Project manager	Stakeholder manager

The interviews and surveys investigating the perceived importance of the SC are conducted following the same approach as for the services. The limited differences can be found in Appendix B where the interview protocol for the SC is described. For evaluating the SC, 4 interviews (including 4 surveys) have been held with employees of HDSR, see Table 4. Every survey was concluded with the question of whether there were any success criteria missing. No additional parties are required for this evaluation as the project interests described by the SC solely influence the interests of HDSR. The interviewees have been selected on their ability to express the project-related interests of HDSR, requiring them to be aware of the goals and ambitions of their organization. Note that the project manager and stakeholder manager of HDSR have been interviewed, both for the evaluation of the services and the evaluation of the SC. For both interviewees the evaluation of the services and SC (including 2 surveys) were combined in a single interview. Therefore, 14 surveys have been conducted in 12 interviews with two interviewees filling in two surveys in a single interview. Furthermore, the program manager and alderman of the regional water authority have not been asked to evaluate the services for the CUB project because they lack in-depth knowledge of the local project characteristics.

Table 4: The functions of the interviewees evaluating the SC

HDSR Interview 1	Project manager	**HDSR Interview 3**	Program manager
HDSR Interview 2	Stakeholder manager	**HDSR Interview 4**	Alderman of regional water authority

After establishing the relative importance of the services and SC, the assessment can be used to assess the LOs in the test case: the CUB project. Here, grey literature and expert opinions are required to indicate the costs of integration and the effects that LO integration will have on the provided services in the geographical area and on the SC. Combining the expected effects on services and criteria with the actor-based valuations of individual services and effects results in comparative scores for the LOs.

Validation session

A validation session with three industry professionals was organized to investigate and discuss the assessment method that is designed in this research. This session took 90 minutes and started with a presentation that explains the assessment method and the results it provides. Thereafter, a fictional casus was given to the participants in which a fictional LO needs to be assessed in a fictional project environment (see Appendix D). Here, a fictional casus and project environment is considered more appropriate as this excludes possible biases and connotations that otherwise might influence the participants. In the casus the participants are asked to use the assessment method on the provided test case, providing the participants with a more in-depth understanding of the strengths and limitations of the assessment. The validation session is concluded with a reflection and discussion on the performance of the assessment. The given presentation and the provided casus are shown in Appendix D.

The data provided by the validation session consists of mostly qualitative information provided by the participants during the discussion and during the fictional casus. The participants were asked what they perceive to be the strong and weak points in the assessment and if they perceive the assessment tool to be sufficient for solving or mitigating the challenges found in the problem investigation. Additionally, the quantitative results obtained in the casus are used to interpret how the assessment is used by industry professionals. Providing insight into how the scoring method is adopted and applied by the target audience for whom the assessment is developed.

Data collection and analysis

In the interviews, a survey is filled in by the interviewees in which they scored the services and SC by allocating a number to every service and SC. The interviewees were requested to consider the relative importance of their scoring, meaning that scoring a single service two times higher than another service means that the former service is two times more important than the latter. Thereafter, a normalization of the scores is performed, describing the importance of the ES and IS with a percentage of the total score. The same procedure is performed for the SC.

The effects of LO integration are scored following the description as shown in Table 5. The numerical score corresponding to the description is multiplied by the actor-evaluated importance of the service or SC. The sum of all the effects, both negative and positive, provides the score of an LO. A 7-point scale, ranging from -3 towards 3 is chosen to convey additional information in the sum of the effects. By using this scoring scale, a net positive score for the LO indicates a total positive effect, while a net negative effect indicates a negative effect following LO integration. This calculation is performed for all

five stakeholders and for the seven LOs. The effects of LO integration on the SC are furthermore calculated separately per LO.

Table 5: Scoring criteria for the effects of LO integration

Score	Description
+3	LO integration has a strong positive effect on the service or SC
+2	LO integration has a positive effect on the service or SC
+1	LO integration may have a small positive effect on the service or SC
0	LO integration has no effect or a neutral effect or SC
-1	LO integration may have a small negative effect on the service or SC
-2	LO integration has a negative effect on the service or SC
-3	LO integration has a strong negative effect on the service or SC

Combining the net effects on the interests of the five public stakeholders results in a total score that indicates the desirability of LO integration. To account for a difference in realization costs for the different LOs, a CEA is performed that divides the final score of an LO with its realization costs. Thereby improving the comparability between LOs and enabling better decision making regarding the LOs that are most desirable.

Sensitivity analysis

Both the scoring of LOs and the cost estimates of realizing an LO, cause uncertainties to emerge in the obtained results. This can be caused by a change in macroeconomic conditions, a shift in the perception of public values, or inaccuracies in the judgements of stakeholders and industry professionals when evaluating services and the effects of LOs. Therefore, a sensitivity analysis is performed to indicate the robustness of the results by changing the values of key variables. This will provide an indication of how stable the obtained results are and show which key variables are the most influential for the stability of the obtained results. This rapport uses a one-way sensitivity analysis technique (Qian & Mahdi, 2020). This method works by changing one variable while holding the other variables constant. Three key variables will be investigated in this sensitivity analysis, the used scoring regime, the importance of the individual stakeholders, and the realisation costs for the LOs.

The scoring regime of the LOs relates to the numerical score that is attributed to an LO as described in Table 5. In the assessment, a scoring regime from -3 towards 3 is applied with incremented steps of 1 point. This makes a strong positive effect, which is attributed 3 points, 3 times more influential than a small positive score which is attributed 1 point. To allow for a bigger differentiation between minor and major effects, a variant will be analysed where the scoring regime ranges from -5 towards 5 with incremented steps of 2 (thus -5, -3, -1, 0, 1, 3, 5). Taking this principle a step further, another variant is analysed with a quadratic incremented step (meaning -10, -3, -1, 0, 1, 3, 10).

The second variable to be analysed in the sensitivity analyses regards the importance of individual stakeholders. As stakeholder importance is generally not uniformly distributed over the involved stakeholders, it becomes necessary to consider a difference in importance in the assessment. However, objectively differentiating between the importance of individual stakeholders is difficult and therefore all the stakeholders are considered equally important in the assessment. To investigate the influence of this assumption, all LOs have been assessed five more times while altering the importance of a single stakeholder each time.

The third investigated variable is the realisation costs of the LOs. This is investigated by assessing all the LOs two additional times, once while lowering the realisation costs towards 75% of the expected costs, and once while increasing the realisation costs towards 125% of the expected costs. The newly obtained scores will then be compared to the scores obtained by assessing the LOs for their expected realisation costs (the 100%). The results of this sensitivity test will show how many places an LO increases or decreases in ranking when assess for +-25% realisation costs. Here, large changes in ranking would indicate a large sensitivity towards realisation costs.

4.0 Results

This chapter presents the results of the problem investigation and describes the requirements for an assessment tool to solve or mitigate these problems. Then, the designed assessment is described followed by the results obtained by the application of the assessment on a test case. Including the results of the validation session with industry professionals.

4.1 Problem investigation

The exploratory interviews indicate that the initiation phase is crucial for identifying LOs. In the process of identification, the province often has an important role in gathering projects with overlapping timelines and interests. This is a first step in identifying LOs. Secondly, design ateliers (In Dutch: ontwerp ateliers) may be organized in which stakeholders come together to brainstorm about preferred designs for the dike-strengthening project and possible LOs (Rijkswaterstaat, 2020a). The use of design ateliers is advised by the Flood Protection Program and the linking of regional objectives with the dike-strengthening project is encouraged (Rijkswaterstaat, 2020a). The Flood Protection Program, however, does not provide financial means for the realization of LOs and has a reduced focus on spatial development in comparison to the Room for the River projects of the early 2000s, pressuring the resources available for LO assessments and integration. Tools and guidelines provided by grey literature (HWBP, 2014, 2017) are furthermore limited and primarily focus on the broad processes regarding a dike-strengthening project, and scarcely address the topic of individual LO assessment. (Ministerie BZK, 2020; Rijkswaterstaat, 2020a). The scientific literature on ES and public value reinforces these findings by stating that decision making based on (ecosystem) services and public value principles is considered difficult (Correljé & Broekhans, 2015; de Groot et al., 2010; La Notte et al., 2017)

The exploratory interviews furthermore show that available assessment tools for LOs do exist in the form of decision trees. Here, several closed questions must be answered whereafter the decision tree indicates if an LO can be integrated. While easy to use, this tool does come with limitations such as its inability to A) conceptualize trade-offs in decision making and B) objectively account for stakeholder interests in decision making. The closed questions in the decision tree, such as “Is LO integration socially desirable” do not provide objective criteria. It is furthermore not stated whether an LO is socially desirable when all affected stakeholders stand to benefit or if integration is also desirable when considered gains for some stakeholders exceed the limited losses of others. Because objective trade-offs are not available, the threshold of when an LO is socially desirable is ill-defined. The vague and subjective decision criteria furthermore prohibit the objective comparison of individual LOs, adding to the complexity of accurate decision making regarding the integration of LOs.

Other tools and methods, such as integrated work sessions with stakeholders, are subjected to comparable challenges. Here the primary focus is on investigating the feasibility of LO integration without a systematic method of establishing the desirability of LO integration for (different) stakeholders. The exploratory interviews indicated that the problems within the decision tree and integrated work sessions are emblematic for the overall LO assessment process. More focus on the desirability of LO integration and a structured insight into how individual LOs influence individual stakeholders could prove valuable in the assessment of LOs. The current focus on feasibility without a robust conceptualization of the trade-offs involved in LO integration and without specific definitions for decision criteria could result in unsatisfactory decision making. This could result in a suboptimal use of LOs and drive the sectoral realization of dike-strengthening projects, thereby causing an inefficient realization of public value in dike-strengthening projects. See the problem tree in Figure 4.

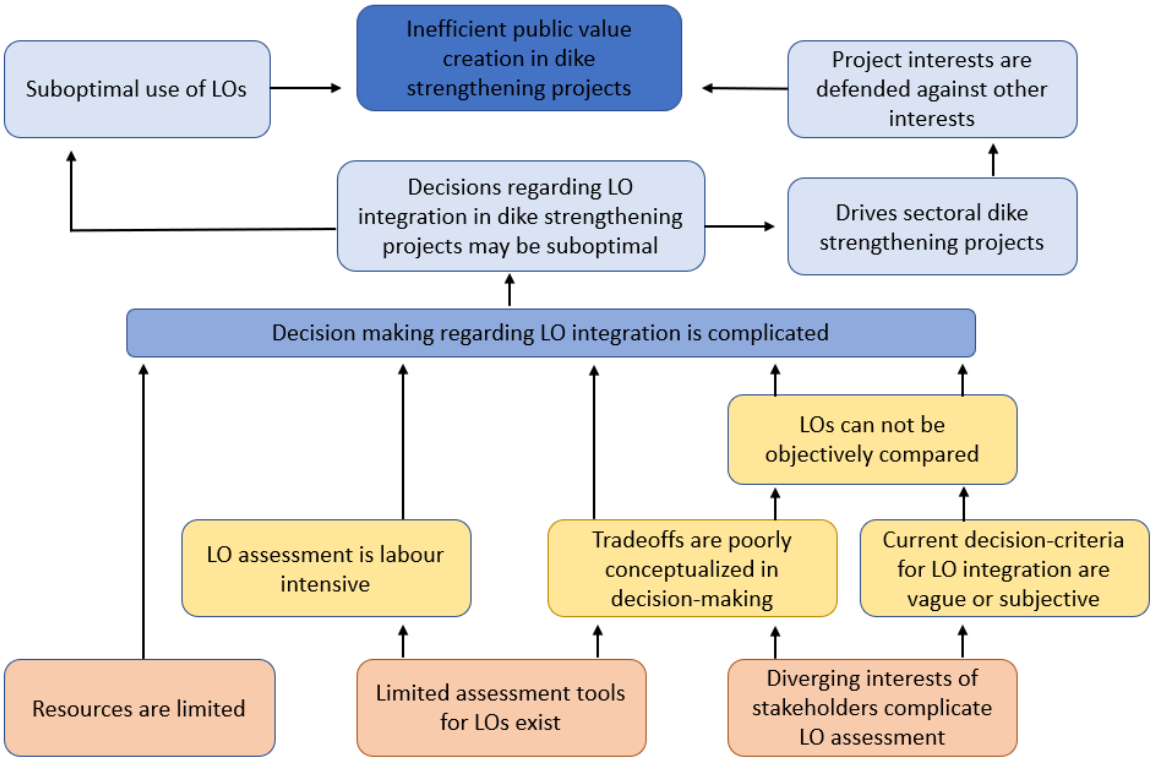

Figure 4: The problem tree

As described in the problem statement (Chapter 1.2), tools for assessing LOs are limited whilst the context of the required assessment is complicated by diverging interests of different stakeholders that value different services provided within the project scope. This, in combination with poorly conceptualized trade-offs and subjective decision criteria that disallow comparisons between LOs, results in an environment where decision making supporting efficient public value creation, is insufficiently enabled. The problem investigation, therefore, concludes that more extensive assessment tools, suitable for the initiation and exploration phase of dike-strengthening projects, are desired. The assessment tool designed in this research is thus required to:

A) Indicate the desirability of LO integration.
B) Allow for trade-offs to be included in the assessment.
C) Enable comparisons between individual LOs.
D) Indicate more objectively the distribution of both positive and adverse effects of integration for different stakeholders.
E) Indicate the cost-effectiveness of public value creation following LO integration.

4.2 The designed assessment

This paragraph describes the assessment tool that is designed for the assessment of LOs in the initiation and exploration phase of dike-strengthening projects of the Dutch Flood Protection Program. The working of the assessment is described using the conceptual model as shown in Figure 5. Thereafter the services and SC that are included in the MAMCA are discussed. The first sub-question of this research: “which services can be fulfilled in the context of a dike-strengthening project?” is answered by describing the services that are used in the assessment.

Conceptual model

The effects of LO integration are vaguely or subjectively assessed by current methods as described in the problem statement and the problem investigation. The integration of an LO does have an objectively verifiable effect on both the services that will be provided in the project area after project completion and on the project itself in terms of budget, planning, quality, and hindrance. The literature on services and SC is used to develop an assessment that A) is based on objectively verifiable indicators and B) allows for comparison between LOs, because the same assessment criteria are meant to be used for all LOs. Pursuing the use of these objectively verifiable effects in the assessment is expected to provide a more reliable indication of the public value created, and thus the degree of desirability that the integration of an LO provides. Thereby improving decision making. However, the effects on services and SC cannot be directly translated into a corresponding effect on public value as the valuation of services is actor dependent with different actors valuing services differently. Therefore, a multi-actor multi-criteria analysis (MAMCA) (Lode, Heuninckx, te Boveldt, Macharis, & Coosemans, 2022; Cathy Macharis et al., 2009) is conducted. Here the services and SC provide the criteria that are used in the MAMCA. By combining the objectively verifiable effects resulting from LO integration and the actor evaluated criteria, an indication of the effect of LO integration on public value creation can be provided, see Figure 5. This approach allows for:

A) The identification of desirable LOs based on positive MAMCA scores.
B) Trade-offs to be included in the assessment as a negative influence on one service can be compensated by a positive effect on another.
C) Individual LOs to be compared because the used assessment criteria are the same for all the assessed LOs.
D) Insight into the distribution of both the positive and adverse effects for different stakeholders enabled by using a MAMCA.
E) Indicated the cost-effectiveness of public value creation by adopting a CEA in the assessment.

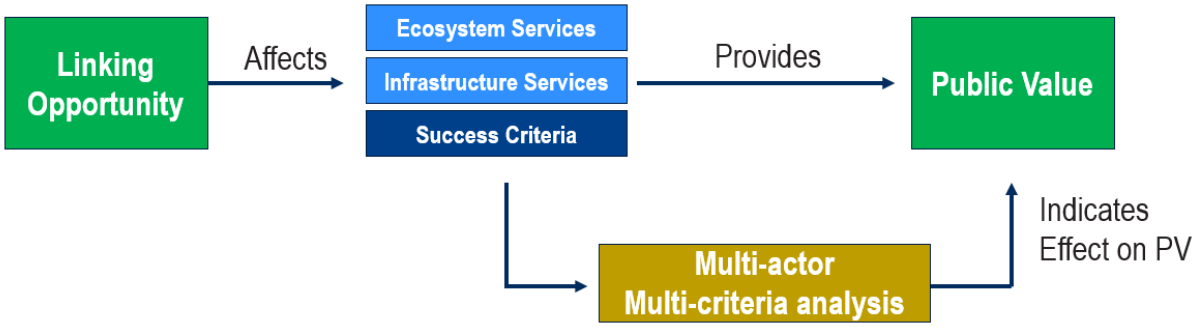

Figure 5: Conceptual model for the Linking Opportunity assessment

The selection of included services

The paper of Gómez-Baggethun and Barton (2013) was the starting point for the list of services. Two services were removed from their list: “moderation of environmental extremes” and “animal sighting”. The former was excluded from the assessment because it heavily focuses on storm and flood protection. This protection is a legal requirement for the dike-strengthening and is therefore never characterized as an LO but as the key objective. The latter was excluded because the value of sighting animals is readily captured in recreation and, in the case of culturally significant species, also in the cultural heritage service. For the useability of the assessment it is beneficial to limit the number of services included.

Many of the services that ecosystems provide can be strengthened using infrastructure. Many of the services used in the assessment method are therefore a combination of ES and IS, see Table 6. The literature on IS, however, is limited in comparison to the literature on ES. In conducting the literature review for the theoretical background of this research, no framework was found that describes the services that infrastructure provides in a systematic way that is comparable to ES.

Upon completing the list of relevant services, the contents of the table were discussed with an industry professional to investigate possible shortcomings or omitted services. No omitted services were suggested.

Table 6: Ecosystem services and infrastructure services in the assessment, adapted from (Gómez-Baggethun & Barton, 2013)

Service	Service of Type	Description	Examples	Indicators	Sources
Food provisioning	ES	The conversion of energy into edible plants by means of photosynthesis	Produced food	Production of food (tons yr−1)	(Altieri et al., 1999)
Water regulation	ES and IS	The timing and magnitude of runoff, flooding, and aquifer recharge	Soil and vegetation store water during heavy precipitation events	Soil infiltration capacity; % sealed relative to permeable surface (ha)	(Villarreal & Bengtsson, 2005)
Temperature regulation	ES	Photosynthesis, shadow, and evaporation.	Vegetation provides shade, creates humidity, and blocks wind	Leaf Area Index: Temperature decrease by tree cover×m2 of plot trees cover (°C)	(Bolund & Hunhammar, 1999)
Noise reduction	ES and IS	Absorption of sound waves	Absorption of sound waves by vegetation and objects	Leaf area (m2) and distance to roads (m); noise reduction dB(A)/vegetation unit (m)	(Kragh, 1981)
Purification of air	ES	Filtering of harmful gases and particles	Removal of pollutants by vegetation	O3, SO2, NO2, CO, and PM10 µm removal (tons yr−1) multiplied	(Chaparro & Terradas, 2009)
Water purification	ES	Removal or degradation of contaminated substances	The natural degradation of phosphorus, magnesium, and calcium carbonate	P, K, Mg and Ca in mgkg−1 compared to given soil/water quality standards	(Vauramo & Setala, 2011)
Climate regulation	ES	CO2 storage by photosynthesis	CO2 storage in biomass	CO2 sequestration by trees	(McPherson, 1998; Nowak, 1994)
Pollination and seed dispersal	ES	The distribution, abundance, and effectiveness of pollinators	Ecosystems provide habitat for birds, insects and pollinators	Species diversity and abundance of birds and bumble bees	(Andersson, Barthel, & Ahrne, 2007)
Recreation	ES and IS	The pleasure experienced as a result of services provided	Includes (eco)tourism, playgrounds, etc.	Number of visits (based on e.g., geolocated social media data), Revenue from tourism.	(Chiesura, 2004) (Hermes et al., 2018)
Erosion-prevention	ES and IS	The holding of soil and the prevention of landslides	Vegetation holding ground	t ha−1 yr−1	(Panagos et al., 2020)

Cultural heritage	ES	Cultural assets	Culturally important landscapes and objects	% of authentic land use/cover in cultural heritage landscape,	(Hølleland, Skrede, & Holmgaard, 2017) (Hernández-Morcillo et al., 2013)
Disease/pest regulation	ES	The reduction of unwanted species and/or diseases	The deterrence of pests and diseases	Estimated change in disease/pest burden as a result of changing ecosystems.	(Layke, 2009)
Educational services	ES and IS	The education provided or strengthened by the environment	Knowledge of nature, history, and surroundings	Number of educational programs, Local ecological knowledge	(Hernández-Morcillo et al., 2013)
Mobility	IS	The available transport infrastructure	Roads, waterways, cables, and pipes.	Traffic flow v/h, Navigability	(Astarita & Giofre, 2019)
Traffic safety	IS	Includes the safety of the available infrastructure	The separation of traffic types and the visibility in traffic	Expected collision energy, nr of accidents	(Astarita & Giofre, 2019)
Shelter	IS	The availability of accommodation	Accommodation Housing	Number of houses, m2 of housing, nr. of inhabitants, affordability of housing	(Boelhouwer, 2020)
Energy provisioning	ES	Providing energy	Energy out of biomass, wind and solar.	MWh	(Masum, Dwivedi, & Anderson, 2020)

The selection of included success criteria

The SC used in this research will be assessed for both positive and negative effects that can result from LO integration. During the problem investigation and the literature review it became apparent that negative and positive effects on a SC should not necessarily be assessed equally. The consequences of a negative effect on the budget (e.g., more costs) might be more severe than the positive effects on the budget (e.g., fewer costs), as the increase in required budget could result in the termination of the project while a decrease in the required budget might not result in effects of an equal magnitude. The list of included SC is shown in Table 7 and is based on the papers of Lamprou and Vagiona (2018) and Songer and Molenaar (1997). Both papers highlighted the importance of the budget and schedule as success criteria. Songer and Molenaar (1997) formulate four additional SC: 1) meets specifications, 2) conforms to user's specifications, 3) high quality of workmanship and 4) minimizes construction aggravation (the definitions of these SC can be seen in chapter 2.4). To prevent overlap between the SC, these four SC have been combined within a single SC named "quality". The SC advanced by Lamprou and Vagiona (2018), including stakeholder satisfaction, environmental impact, and user satisfaction, have been combined within the SC named "hindrance and satisfaction". This again reduces overlap and makes the assessment easier to use.

Table 7: Project success criteria in the assessment

Success Criteria	Description	Examples
On Budget	LO Integration has a positive influence on the required budget	> Less costs
	LO integration has a negative influence on the required budget	> More costs
On schedule	LO integration has a positive influence on the planning/schedule	Less time needed for: > Contracts > Procedures > Design phase > Realization phase
	LO integration has a negative influence on the planning/schedule	More time needed for: > Contracts > Procedures > Design phase > Realization phase
Quality	LO integration has a positive effect on the project quality	> Exceeds specifications > Improved maintainability > Extended lifetime
	LO integration has a negative effect on the project quality	> Decreased maintainability > Shortened lifetime
Hindrance and satisfaction	LO integration reduces hindrance and improves satisfaction	Less: > Road closures > Noise pollution > Scattered contact points > Business limitations And more support
	LO integration increases hindrance and reduces satisfaction	More: > Road closures > Noise pollution > Scattered contact points > Business limitations And less support

The cost-effectiveness of provided services

The designed assessment tool provides comparability between individual LOs because the use of a MAMCA provides all the services and SC with the same unit: a (numerical) actor perceived importance. Further comparability between LOs is provided by the inclusion of a CEA in the assessment tool that indicates how much service is provided per monetary unit, thereby normalising the effects of the different realisation costs of different LOs. The inclusion of this normalisation that the CEA provides allows for decision making that promotes more public value creation, as resources are deployed more cost-effectively. Meaning that more services are provided using the same number of resources. The inclusion of a CEA thus fulfils design requirement C and E as described in Chapter 4.1. The incorporation of the CEA in the assessment tool is conceptualised in Figure 6 below.

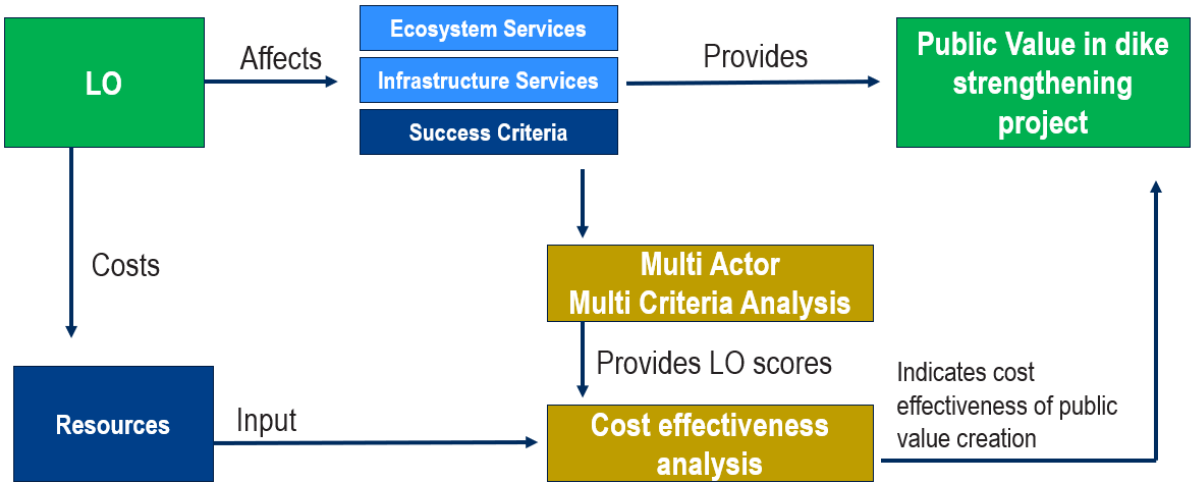

Figure 6: Conceptual model for the linking opportunity assessment including a cost-effectiveness analysis

Context of use

The assessment tool is designed to aid industry professionals with decision making regarding the integration of LOs. For optimal use of the tool, industry professionals are expected to update the tool with the required information during the duration of the project. This means updating the stakeholder-evaluated services and SC after a stakeholder has provided new information. For this, the current stakeholder engagement approaches and contact moment can still be applied. However, it would benefit the assessment if the services and SC as provided in this study are explicitly discussed with the stakeholder. For stakeholders that lack the required knowledge or resources to discuss the services, a stakeholder manager using the assessment tool might apply its expert judgement to represent the stakeholder. Furthermore, once effect studies and cost calculations become available for the identified LO, the assessment tool can be filled in further. The preliminary results that are provided by following this approach can motivate a further investigation of the effects of LO integration or the stakeholder-evaluated services and SC. Iterations of assessing, discussing preliminary results, and re-assessing are expected to benefit the assessment.

4.3 Application of the assessment: case study results

In this paragraph the test case results are described. This provides an answer to the second and third sub-question of this research by answering B) How the services are evaluated by the stakeholders involved in the dike-strengthening project and C) By providing the cost-effectiveness scores of the LOs.

The actor-based evaluation of services

The results of the interviews with the local water authority (HDSR), Rijkswaterstaat (RWS), the province of Utrecht (PU), the municipality of Houten (Houten), and the state forestry department (SBB) are shown in Table 8. The table shows the percentage of points that a service has received from each interviewee. Eight of the ten interviewees did consider the survey to encompass all the functions that the areas provide. However, as sand extraction does currently occur near the dike, the provisioning of sand was unduly excluded. As mentioned by two of the interviewees.

Table 8: The results of the surveys describing Ecosystem Services and Infrastructure Services

	Scored by										
Service	**HDSR 1**	**HDSR 2**	**RWS 1**	**RWS 2**	**PU 1**	**PU 2**	**Houten 1**	**Houten 2**	**SBB 1**	**SBB 2**	**Total**
Food provisioning	0%	10%	0%	4%	1%	1%	7%	1%	2%	2%	**4%**
Water regulation	18%	10%	18%	6%	4%	8%	7%	11%	19%	5%	**14%**
Temperature regulation	4%	0%	0%	9%	8%	5%	5%	1%	1%	2%	**5%**
Noise reduction	0%	0%	0%	1%	4%	2%	1%	4%	1%	2%	**2%**
Purification of air	5%	0%	0%	1%	4%	2%	8%	1%	1%	5%	**3%**
Water purification	7%	5%	4%	9%	4%	5%	3%	1%	2%	5%	**6%**
Climate regulation	4%	0%	0%	4%	5%	5%	7%	4%	1%	2%	**4%**
Pollination	9%	11%	18%	6%	8%	8%	6%	4%	4%	17%	**11%**
Recreation	5%	5%	0%	6%	10%	8%	9%	7%	9%	12%	**9%**
Erosion-prevention	14%	14%	18%	9%	1%	10%	2%	11%	19%	2%	**14%**
Cultural heritage	9%	11%	0%	9%	10%	10%	9%	7%	9%	17%	**11%**
Disease/pest regulation	4%	11%	18%	1%	7%	3%	3%	4%	1%	12%	**8%**
Educational services	9%	10%	4%	1%	9%	8%	8%	1%	9%	12%	**8%**
Mobility	4%	4%	18%	12%	9%	8%	7%	14%	19%	2%	**14%**
Traffic safety	0%	5%	0%	12%	9%	9%	7%	14%	1%	2%	**8%**
Shelter	0%	0%	0%	1%	4%	1%	7%	7%	1%	0%	**3%**
Energy provisioning	9%	4%	2%	9%	5%	5%	6%	4%	1%	2%	**6%**

As demonstrated by Table 8, the services of water regulation, erosion prevention and mobility are perceived as the most important in the geographical area encompassing the CUB project. Taken together, the cultural ES, including recreation, cultural heritage, and educational services, have also been perceived as important, together scoring 28% of the points in total. Services such as shelter (e.g., housing), climate regulation, noise reduction and food provisioning are considered the least important.

The actor-based evaluation of success criteria

Table 9 describes which success criteria are considered the most important in the assessment of LOs according to four representatives of the regional water authority (HDSR).

Table 9: The results of the surveys describing the project Success Criteria

	Scored by				
Success criteria	**Alderman of regional water authority**	**Program manager**	**Project manager**	**Stakeholder manager**	**Average**
Budget: positive effect	6%	13%	7%	9%	**8%**
Budget: negative effect	17%	13%	4%	11%	**11%**
Schedule positive effect	6%	9%	7%	9%	**8%**
Schedule negative effect	17%	9%	4%	23%	**13%**
Quality positive effect	28%	16%	18%	16%	**19%**
Quality negative effect	6%	16%	**no go**	9%	**10%**
Hindrance and satisfaction: positive effect	17%	13%	36%	16%	**20%**
Hindrance and satisfaction: negative effect	6%	13%	25%	7%	**12%**

The interview with the project manager of the CUB project gave a “no go” for a negative influence on the project quality. The project manager stated that a negative influence on the quality of the dike-strengthening project is unacceptable and referred thereby to the decision tree for LOs provided by the regional water authority that also states that integration is impossible when water safety is negatively influenced. The floodplain developments likely to be integrated do, however, negatively influence water safety, as wetter conditions near the dike enlarge the danger of piping under the dike. Mitigating measures are therefore required in combination with the floodplain development. Indicating that considerations are not as one-dimensional as the decision tree indicates. Discussing this observation with the project manager resulted in the acknowledgement that while mitigation is possible, the general principle stands. Other interviewees were less determined on this principle, agreeing that negative effects are permittable when water safety can still be guaranteed through mitigation of these negative effects.

Assessment of the linking opportunities

The actor-weighted services and SC have been used in the assessment of the LOs in the CUB project. In total, seven different LOs have been assessed. For two of the LOs, different variants of the LOs have been assessed, including three variants of the Honswijkerwaard floodplain development and the four variants of the inlet sluice. Detailed information regarding the expected effects following LO integration was gathered from the impact assessments that have been conducted for the LOs. A detailed description of the scores attributed to the LOs in the assessment can be found in Appendix C. The results of the LO assessment are shown in Table 10. This table shows, in the “effect on SC” row, for each LO the effect that it has on the success criteria of the CUB project. A positive score indicates a positive effect. Theoretically the maximum score is 300 which occurs if an LO is expected to have a strong positive effect on all the actor-weighted success criteria without any negative effects being foreseen. Likewise, the lowest possible score is -300. Furthermore, the table shows the LO services scores for every individual stakeholder. Here, the maximum score is again 300 and a positive score indicates that

the LO has a positive effect on the interests of the stakeholder. The total score represents the average score of the involved stakeholders.

The total score, including the scores of the five stakeholders, is positive for all the assessed LOs according to the assessment results. Only variant C of the Honswijkerwaard floodplain development and variant A of the inlet sluice have a negative effect on a stakeholder, namely the municipality of Houten. The assessment of the SC is positive for all the LOs and their variants, but with big differences between the LOs.

Looking at the variants of the Honswijkerwaard floodplain development, the assessment is not conclusive regarding the best variant. Variant A scores higher on the assessed services while variant B scores higher on the SC. The assessment does however indicate that the degree of positive effects of variants A and B are similar and preferable above variant C. When considering the cost-effectiveness of the measures variant B is preferred. The results on the variants of the inlet sluice are more conclusive, with variant D scoring the highest overall. Also, when considering the cost-effectiveness variant D remains the preferred solution.

Table 10: MAMCA scores for 7 Linking Opportunities including variants

	Honswaard A	Honswaard B	Honswaard C	Inlet sluice A	Inlet sluice B	Inlet sluice C	Inlet sluice D accessible road	Safe and Icon area	Mobility and recreation	Ecological dike	Steenwaard
Effect on SC	25,7	54,2	34,6	19,6	6,6	0,8	18,7	46,1	39,2	64,9	44,4	1,7
HDSR	79,1	70,6	42,7	10,6	51,6	27,6	51,6	-1,0	43,4	27,6	65,7	60,9
Department of Waterways and Public Works	51,3	58,6	57,0	-1,9	8,7	0,8	8,7	42,3	25,3	26,4	74,3	62,2
Province of Utrecht	69,7	59,5	4,6	0,7	58,6	32,8	58,6	23,4	57,3	35,8	48,4	52,9
State Forestry	87,8	74,8	13,8	2,8	71,2	39,0	71,2	9,2	62,8	34,5	67,6	62,8
Municipality Houten	51,1	39,6	-9,1	-5,5	34,3	17,5	34,3	36,3	50,7	35,4	34,7	25,3
Total	67,8	60,6	21,8	1,3	44,9	23,5	44,9	22,0	47,9	31,9	58,1	52,8

Cost-effectiveness analysis

The cost-effectiveness analysis in this research includes solely the realization costs of the LO, including the acquisition costs of land for some LOs. Maintenance costs have been excluded from the analysis because the temporal dimension in which services are provided has also been excluded in the MAMCA, meaning that the deterioration of services is not assessed. Table 11 below shows the ranking of the LOs, based on the obtained cost-effectiveness scores using Equation 2. Here, the MAMCA scores that are obtained in the assessment provide an indication of the amount of public value that an LO provides. The numerator thus represents a unitless representation of public value and the denominator is expressed in 100.000 euros. The names of the documents that contain the data on the construction costs are provided in Appendix C.

$$Cost\text{-}effectiveness = \frac{Multi\ Actor\ Multi\ Criteria\ Analysis\ score}{Monetary\ costs}$$

Equation 2: The cost-effectiveness calculation used in the assessment

Table 11 The ranking of LOs based on the cost-effectiveness scores in the assessment

Name of the linking opportunity	Rank
Inlet sluice D	1
Inlet sluice C	2
Inlet sluice B	3
Icon area	4
Honswijkerwaard B floodplain development	5
Inlet sluice A	6
Honswijkerwaard A floodplain development	7
Mobility and recreation	8
Safe and accessible road	9
Steenwaard floodplain development	10
Honswijkerwaard C floodplain development	11
Ecological dike	unavailable

Overall, the CEA indicates that variant D of the inlet sluice provides the most cost-effective public value. Followed by variant B and C of the inlet sluice, the Icon Area, and the Honswijkerwaard Floodplain Development. No investment cost was available for the Ecological Dike because this LO is still under development. Therefore, no cost-effectiveness score was obtained.

Sensitivity analysis

All the LOs were assessed nine additional times to analyse the sensitivity of the assessment. Two additional assessments indicate the sensitivity of the scoring range, five additional assessments indicate the effect of varying stakeholder importance on the sensitivity, and two additional assessments indicate the sensitivity resulting from the realisation costs. The assessments regarding stakeholder importance only influence the services (ES and IS) in the assessment, because the SC are fully dependent on a single stakeholder: the regional water authority. Varying importance of stakeholder importance therefore does not influence the SC. Table 12 shows the results of the sensitivity analysis.

For each LO, the total score, constituting the average score of the stakeholders, is shown. In five iterations of the assessment, a single stakeholder is considered five times more important than the other stakeholders, here the total score is determined by multiplying the score of the "important" stakeholder by five, adding the scores of the other stakeholders and dividing by nine. Here a factor of 5 is chosen, as this is a large but still realistic difference in importance. In Table 12, the base variant describes the unaltered results of the assessment. The 1 3 5 and 1 3 10 variant describes the scores that were obtained using a different scoring regime.

Table 12: Results of the sensitivity analysis

ES and IS	Honswaard A	Honswaard B	Honswaard C	Inlet sluice A	Inlet sluice B	Inlet sluice C	Inlet sluice D	Safe and accessible road	Icon area	Mobility and recreation	Ecological dike	Steenwaard
Base variant	68	61	22	1	45	24	45	22	48	32	58	53
1 3 5 variant	74	77	22	1	77	42	77	47	73	39	86	60
1 3 10 variant	93	77	78	1	123	88	123	96	119	39	132	60
HDSR important	73	65	31	5	48	25	48	12	46	30	61	56
Rijkswaterstaat important	60	60	37	0	29	13	29	31	38	29	65	57
Province Utrecht important	69	60	14	1	51	28	51	23	52	34	54	53
State forestry important	77	67	18	2	57	30	57	16	55	33	62	57
Municipality Houten important	60	51	8	-2	40	21	40	28	49	33	48	41
Maximum change	**38%**	**27%**	**255%**	**306%**	**175%**	**273%**	**175%**	**336%**	**149%**	**23%**	**127%**	**-23%**
SC												
Base variant	26	54	35	20	7	1	19	46	39	65	44	2
1 3 5 variant	35	93	53	20	20	-2	38	85	59	104	63	9
1 3 10 variant	35	93	53	20	20	-2	38	183	59	202	63	9
Maximum change	**38%**	**71%**	**54%**	**0%**	**206%**	**-343%**	**105%**	**298%**	**50%**	**212%**	**42%**	**405%**

The sensitivity is indicated in Table 12 by determining the maximum change of the LO scores. Here, the scores of the base variant and the most diverging variant are used to calculate the maximum occurring change in percentages. This is done for each LO separately. For the services, the maximum change observed ranges from 23% towards 336%. For the SC, the maximum change ranges from 0% towards 405%. These large changes can be explained by two principles. Firstly, the inclusion of the "1 3 10 variant" substantially increases the scores that the LOs obtain because the overall scores of the LOs were already positive. Altering the scoring regime from (-3, -2, -1, 0, 1, 2, 3) towards (-10, -3, -1, 0, 1, 3, 10) therefore results in higher scores as the change disproportionately affects the positive scores, meaning that there are more changes from 2 and 3 towards 3 and 10 than that there are changes from -2 and -3 towards -3 and -10. The relatively large changes in the obtained score by using this scoring regime do not have to be influential as the meaning of the scores follow firstly from a total negative or total positive score, where a negative score indicates a negative effect, and a positive score indicates a positive effect following LO integration. Secondly, the meaning of the scores comes from the comparability they provide between the LOs. Table 12 illustrates that the use of different scoring regimes did not result in LO being assessed negatively, whereas they were previously assessed as positive. Different scoring regimes do however influence the ranking of the LOs, as it can be seen in Table 13 that the ranking of the LOs is considerably altered by using different scoring regimes.

Furthermore, the high maximum changes observed are partly caused by low-scoring LOs receiving a change that is relatively small in absolute terms but relatively big when described in percentages. This

makes the use of a maximum change described by a percentage less desirable as an indicator of sensitivity. More illustrative is the change in the ranking of the assessed LOs. If the ranking of the LOs is severely altered by a change in either the scoring regime or the importance of a stakeholder, then it could be stated that the assessment is sensitive to changes in this variable.

The ranking of the LOs is shown for all the iterations of the assessment in Table 13. Here it can clearly be seen that changing the scoring regime has a considerable impact on the ranking of the LOs. A change in the importance of a stakeholder has a relatively limited influence on the ranking. Together this indicates that the assessment is relatively sensitive to changes in the scoring regime and relatively insensitive to changes in stakeholder importance.

Table 13: Changes in rank following the sensitivity analysis

	Honswaard A	Honswaard B	Honswaard C	Inlet sluice A	Inlet sluice B	Inlet sluice C	Inlet sluice D	Safe and accessible road	Icon area	Mobility and recreation	Ecological dike	Steenwaard
Rank ES and IS												
Base variant	1	2	11	12	6	9	6	10	5	8	3	4
1 3 5 variant	5	4	11	12	2	9	2	8	6	10	1	7
1 3 10 variant	6	9	8	12	2	7	2	5	4	11	1	10
HDSR important	1	2	8	12	5	10	5	11	7	9	3	4
Rijkswaterstaat important	2	3	6	12	9	11	9	7	5	8	1	4
Province Utrecht important	1	2	11	12	6	9	6	10	5	8	3	4
State forestry important	1	2	10	12	5	9	5	11	7	8	3	4
Municipality Houten important	1	2	11	12	6	10	6	9	3	8	4	5
Change in rank ES and IS												
1 3 5 variant	4	2	0	0	4	0	4	2	1	2	2	3
1 3 10 variant	5	7	3	0	4	2	4	5	1	3	2	6
HDSR important	0	0	3	0	1	1	1	1	2	1	0	0
Rijkswaterstaat important	1	1	5	0	3	2	3	3	0	0	2	0
Province Utrecht important	0	0	0	0	0	0	0	0	0	0	0	0
State forestry important	0	0	1	0	1	0	1	1	2	0	0	0
Municipality Houten important	0	0	0	0	0	1	0	1	2	0	1	1
Rank SC												
Base variant	7	2	6	8	10	12	9	3	5	1	4	11
1 3 5 variant	8	2	6	10	9	12	7	3	5	1	4	11
1 3 10 variant	8	3	6	10	9	12	7	2	5	1	4	11
Change in rank SC												
1 3 5 variant	1	0	0	2	1	0	2	0	0	0	0	0
1 3 10 variant	1	1	0	2	1	0	2	1	0	0	0	0

To investigate how sensitive the assessment tool is towards changes in the realisation costs of an LO, reassessment has been undertaken with +-25% in the realisation costs. Table 14 shows that the resulting changes in ranking are relatively small in comparison to the changes in ranking after adopting alternative scoring regimes.

Table 14: changes in LO ranking following a +-25% change in realisation costs

Rank ES and IS	Honswaard A	Honswaard B	Honswaard C	Inlet sluice A	Inlet sluice B	Inlet sluice C	Inlet sluice D	Safe and accessible road	Icon area	Mobility and recreation	Ecological dike	Steenwaard
Ranking using calculated costs	7	5	11	6	3	2	1	9	4	8	NO	10
Rank when costs -25%	5	4	11	5	3	1	1	9	4	8	NO	9
Rank when costs +25%	7	7	11	7	3	2	2	10	4	8	NO	10
Change in ranking costs -25%	2	1	0	1	0	1	0	0	0	0	NO	1
Change in ranking costs +25%	0	2	0	1	0	0	1	1	0	0	NO	0

4.4 Reflection and final design

This paragraph reflects on the application of the assessment in the test case. A validation session with industry experts provided further insight into the usability of the assessment, including the context of use. Based on the insights this provided, improvements have been made to the final design of the assessment tool.

Reflection on the assessment tool

Using the assessment tool in a test case has shown that the assessment tool fulfils the requirements and provides insight by:

A) Indicating the desirability of LO integration based on stakeholder interests and project interests, by providing a negative or positive LO score.
B) Allowing trade-offs in the assessment, as positive scores can compensate for negative scores.
C) Enabling comparisons between individual LOs by providing comparable scores that are expressed in an amount of public value per monetary unit.
D) Indicating the desirability of an LO for individual stakeholders by showing assessment scores per individual stakeholder.
E) Indicating the cost-effectiveness of public value creation per LO.

The participants in the validation session agreed that the requirements are generally fulfilled but provided remarks, stating that they were unconvinced that the assessment could be used in the whole exploration phase and more specifically to indicate a preferred alternative in this phase. The assessment was perceived to be the most valuable in the early initiation phase up until halfway through the exploration phase, proving most valuable as a tool in communication that clarifies and substantiates decisions. Generally, the industry professionals argued that the assessment should not be leading in decision making but that it can be of supportive value in decision making. The participants also stated that in using a MAMCA, it is important to consider which representatives are interviewed. They furthermore agreed that a collective work session including multiple representatives from single parties could be a good method to circumvent individually held biases. An added benefit could come from aligning interpretations and creating understanding by collectively discussing the evaluation of services and SC. The Flood Protection Program does advance these collective meetings, called “design ateliers” and the participants agreed that the assessment method could be valuable in these meetings (Rijkswaterstaat, 2020a). Thereby obtaining a facilitating function.

Lastly, the test case and validation session have indicated that the used services and SC could be improved upon. The service “mobility” could be divided into waterborne mobility and road bound mobility and the service “cultural heritage” should be renamed into the “preservation of cultural heritage”. A service including the defence against pluvial flooding and a service regarding the provisioning of sand could be included.

Reflection on the context of use

The validation session with the industry professionals has demonstrated that the assessment method, i.e., using services and SC in a MAMCA to enhance decision making, is considered promising. Especially in the initiation and exploration phase, the assessment method could assist in structuring the available information and provide insight by coupling the functional demands of stakeholders and the expected effects resulting LO integration. Thereby indicating the desirability of the effects for individual stakeholders. The participants in the validation session stated that they perceive the assessment tool to be the most valuable in communication and facilitation, to comprehensively communicate which LOs are included in the project and why. Here, the industry professionals stated that improvements could be made to present the results of the assessment more graphicly to strengthen its communicative value. Secondly, the tool is perceived to be of value in facilitating sessions to clarify the project scope such as investigation sessions, brainstorming sessions, and sessions comparable to the design atelier advanced by the Flood Protection Program (Rijkswaterstaat, 2020a). Here, collectively discussing the perceived importance of different services and assessing the expected effects following LO integration could improve the mutual understanding between actors and stakeholders. The assessment tool assists in this process by structuring the information (i.e., perceived importance and assessed LOs) and by indicating the resulting effects. The scenario building that the assessment tool thereby provides may further the understanding of what is desirable by providing insight into how the actor-weighted services could be affected. The assessment is thus perceived by industry professionals in the validation session to be most valuable in supporting decision making, as opposed to determining a preferred solution based on the assessment results.

Final design

This final design section of the rapport includes an adapted framework describing the ecosystem services and infrastructure services used in the assessment, see Table 15. The assessment approach, shown in the conceptual model (chapter 4.2) remains unchanged. The framework describing the SC is also unchanged. However, improvements on the overall design are possible and chapter 6 describes areas of further research that would benefit the assessment.

Table 15: Ecosystem services and infrastructure services in the assessment, adapted from (Gómez-Baggethun & Barton, 2013)

Service	Service of Type	Description	Examples	Indicators	Sources
Food provisioning	ES	The conversion of energy into edible plants by means of photosynthesis	Produced food	Production of food (tons/yr−1)	(Altieri et al., 1999)
Soil and sediment provisioning	ES	The decomposition of rock-like materials into soil and sediment	Soil and sediment production	Production of soil and sediment (tons/yr-1)	(L. Li et al., 2020)

Water regulation	ES and IS	The timing and magnitude of rainfall, flooding, and aquifer recharge	The natural water cycle	Mm of rainfall per year, aquifer recharge (m3/yr-1)	(Villarreal & Bengtsson, 2005)
Pluvial flooding protection	ES and IS	Dampening rainwater runoff, storing rainwater	Soil and vegetation store water during heavy precipitation events	Soil infiltration capacity; % sealed relative to permeable surface (ha)	(Villarreal & Bengtsson, 2005)
Temperature regulation	ES	Photosynthesis, shadow, and evaporation.	Vegetation provides shade, creates humidity, and blocks wind	Leaf Area Index: Temperature decrease by tree cover×m2 of plot trees cover (°C)	(Bolund & Hunhammar, 1999)
Noise reduction	ES and IS	Absorption of sound waves	Absorption of sound waves by vegetation and objects	Leaf area (m2) and distance to roads (m); noise reduction dB(A)/vegetation unit (m)	(Kragh, 1981)
Purification of air	ES	Filtering of harmful gases and particles	Removal of pollutants by vegetation	O3, SO2, NO2, CO, and PM10 µm removal (tons yr−1) multiplied	(Chaparro & Terradas, 2009)
Water purification	ES	Removal or degradation of contaminated substances	The natural degradation of phosphorus, magnesium, and calcium carbonate	P, K, Mg and Ca in mgkg−1 compared to given soil/water quality standards	(Vauramo & Setala, 2011)
Climate regulation	ES	CO2 storage by photosynthesis	CO2 storage in biomass	CO2 sequestration by trees	(McPherson, 1998; Nowak, 1994)
Pollination and seed dispersal	ES	The distribution, abundance, and effectiveness of pollinators	Ecosystems provide habitat for birds, insects and pollinators	Species diversity and abundance of birds and bumble bees	(Andersson et al., 2007)
Recreation	ES and IS	The pleasure experienced as a result of services provided	Includes (eco)tourism, playgrounds, etc.	Number of visits (based on e.g., geolocated social media data), Revenue from tourism.	(Chiesura, 2004) (Hermes et al., 2018)
Erosion-prevention	ES and IS	The holding of soil and the prevention of landslides	Vegetation holding ground	t ha−1 yr−1	(Panagos et al., 2020)
Preservation of cultural heritage	ES	Cultural assets	Culturally important landscapes and objects	% of authentic land use/cover in cultural heritage landscape,	(Hølleland et al., 2017) (Hernández-Morcillo et al., 2013)
Disease/pest regulation	ES	The reduction of unwanted species and/or diseases	The deterrence of pests and diseases	Estimated change in disease/pest burden as a result of changing ecosystems.	(Layke, 2009)
Educational services	ES and IS	The education provided or strengthened by the environment	Knowledge of nature, history, and surroundings	Number of educational programs, Local ecological knowledge	(Hernández-Morcillo et al., 2013)

Mobility	IS	The available transport infrastructure	Roads, cables, and pipes.	Traffic flow v/h, Navigability	(Astarita & Giofre, 2019)
Waterborne mobility	ES and IS	The available infrastructure for transportation over water	Waterways, rivers, canals	Traffic flow v/h, Navigability	(Jonkeren & Rietveld, 2016)
Traffic safety	IS	Includes the safety of the available infrastructure	The separation of traffic types and the visibility in traffic	Expected collision energy, nr of accidents	(Astarita & Giofre, 2019)
Shelter	IS	The availability of accommodation	Accommodation Housing	Number of houses, m2 of housing, nr. of inhabitants, affordability of housing	(Boelhouwer, 2020)
Energy provisioning	ES	Providing energy	Energy out of biomass, wind and solar.	MWh	(Masum et al., 2020)

5.0 Discussion

This section provides a discussion about the results of the research including the problem investigation, the designed assessment tool, conducted interviews, a test case, and the validations session.

5.1 Reflection on key findings

While existing as individual areas of research, the concepts of LOs, ES, IS, SC, Public value, MAMCA, and CEA have not previously been integrated. This research shows that the integration of these concepts is possible, and that integration could provide insights that were previously unavailable. However, considering the large number of concepts that this study seeks to integrate, some connections between individual concepts would benefit from further research (as described in chapter 6). The development of the assessment tool in this research is a first step in laying the foundation for combining ES and IS in a single framework. The application of this framework within a MAMCA approach, expanded with a CEA, constitutes an innovative way of aiding decision making. The following paragraphs will reflect on the key findings of this research.

Application of the assessment: discussion on case study findings

In this research interviewees, representing public stakeholders, have been asked to assess the relative importance of services and SC. Differences in the attributed scores between representatives of the same stakeholder are prevalent and can largely be explained by varying interpretations of the services. The different evaluations on the topic of soil erosion provided by the two representatives of the state forestry illustrate this point. Here, the first interviewee allocated 19% of the points to erosion prevention, elaborating that biodiversity and erosion prevention are related, because more biodiverse dikes are more resilient to soil erosion. The provisioning of erosion prevention is thus related to a key interest of the State Forestry. The second interviewee stated, however, that the erosion of soil is desirable within floodplains as this provides ecological development and therefore only allocated 2% of the points to the prevention of erosion. The importance of a service is thus dependent on where this service is provided, in geographical terms, as illustrated by a representative of the province when elaborating that the provisioning of food is very desirable in the inner dike area but not in the outer dike floodplains.

In the case study, the process of evaluation itself has been considered useful by the interviewees. Especially the evaluation of the SC provided comparability and vocabulary to discuss priorities in a dike-strengthening project among representatives of the regional water authority. But evaluation has also been considered difficult by multiple interviewees. The main reason being the challenge of interpreting the boundaries of a service, e.g., where does cultural heritage stop, and recreation begin. Or when does the perceived value of water regulation become inflated, as positive cascading effects, such as increased water safety and more resilient food production become associated with it? Further difficulties stem from the fact that the required knowledge for adequately assessing the services encompasses many disciplines, ranging from water safety to mobility, cultural heritage, and ecology. Making it difficult for a single interviewee to possess all the required expertise. This results in some interviewees commenting that other departments within the same organization might assess the services differently. Some interviewees are furthermore drawn towards associations of concrete physical entities to better conceptualize the implications that measures have on the services being provided, using this to better determine the importance of the services. This, however, conflicts with the methodology of the assessment approach as it is meant to first determine the services that are

desired and only thereafter assess the suitability of a proposed measure. Using the desirability of measures (e.g., LOs) to determine the importance of the corresponding services that the measures provide, defeats the purpose of using services as a tool to assess LOs.

Lastly, some services, especially those related to ecology have been more difficult to assess as interviewees sought ways to translate the goals and ambitions of their organization to the corresponding services. Ecology, not a service, is stated by many interviewees to be high on the agenda of their organization. Determining the importance of services that are only partly related to ecology or that only partly represent the significance of ecology was deemed difficult by interviewees. This leads to another comment, independently provided by two interviewees, stating that the value of nature exceeds the domain of provided functionalities. Both interviewees argued that nature possesses values outside the realm of providing humanitarian functions.

Ecosystem services and its relation to infrastructure services

Literature describing the close relationship between dikes and natural ecosystems (van Loon-Steensma, Schelfhout, & Vellinga, 2014), has suggested that the literature on ES could prove valuable in the assessment and was therefore included to partially describe the services that are provided in the project areas of dike-strengthening projects. Consultation with industry professionals has demonstrated that the literature on ES is not conclusive in describing the services that are provided or strengthened by dike-strengthening projects. To supplement this list of services, IS were included in the assessment. However, no framework was found that describes the services that infrastructure provides in a systematic way that is comparable to the literature on ES. Studies that synthesize the concepts of natural environments and built environments have generally placed the built environment within the sphere of a natural environment, stating that "the natural environment should always be considered the superstructure on which the built environment is dependent (Coutts & Hahn, 2015, p. 9770)". This conceptualization is reflected in the scientific literature on ES and IS where a predominant focus is placed on services provided by ecosystems. However, as described in Chapter 4.2, many ES are enhanced by infrastructure, making the provided services near dikes the result of an interplay of both manmade infrastructure and natural ecosystems. But comprehensive descriptions of the services provided by infrastructure are lacking. A framework that conceptualizes IS through the services they provides could help to better understand the relationship between natural ecosystems, the built environment, and the services they provide. The service framework advanced in this study attempts to achieve this and has been appreciated by the interviewees and industry professionals involved in this research. Using this framework in an assessment method promotes the identification of synergetic effects in dike-strengthening projects. This is reinforced by Plepys, Heiskanen, and Mont (2015), stating that shifting the focus from material products towards the services they provide can make public value creation more efficient by reducing the required resources and by providing environmental benefits. The compiled list of services in this research is a first attempt at aligning the provided services by natural ecosystems and manmade infrastructure in the context of dikes. This has been considered useful throughout the research, with interviewees appreciating the vocabulary it provides and with industry professionals stating that the compiled list can prove valuable in communication, conceptualisation, and the formulation of key objectives.

Project success criteria and drivers for LO integration

The interviews conducted in the application of the assessment have demonstrated that the local water authority is motivated to integrate LOs. This is demonstrated by the surveys that were conducted to

investigate the drivers to include or exclude an LO. In total, 58% of the points have been attributed to positive effects resulting from LO integration and 42% to the negative effects. This indicates that the potential gains are a stronger driver for LO integration than that potential losses are a deterrent. This is not consistent with the scientific literature that frequently describes the water safety sector as sectoral and construction projects as protective towards their interests (Avoyan & Meijerink, 2020; Buuren et al., 2010). A defensive perspective towards the integration of LOs, where an absence of negative effects is required before an LO is integrated, could therefore be anticipated. However, the interviews and surveys suggest that the pursuit of positive effects is a more substantial driver for LO integration than the absence of negative effects. It is similarly notable that the following SC: "budget" and "schedule" only received 37% of the points combined. Whereas the topics of "quality" and "hindrance and satisfaction" received 63% of the points, suggesting that more traditional priorities in a construction project, planning and budget (Lamprou & Vagiona, 2018), are not the main drivers for LO integration.

Furthermore, combining the stakeholder interests in both the negative and positive effects, shows that the success criteria "budget" is considered the least important with only 19% of the attributed points, whereas "hindrance and satisfaction" is considered the most important with 32% of the attributed points. This is unexpected considering that earlier research at RoyalHaskoningDHV has shown that the timely distribution of construction and development costs is a major influence in the integration of LOs (de Vries, 2021). This previously conducted research indicates that "budget" is of considerable importance as a success criterion for the overall project. The results obtained in this study would, however, suggest that, although financial clarity promotes LO integration, the financial implications for a dike-strengthening project following LO integration are not the main motivation or deterrent for LO integration. This view, however, is based on the results of a single case study and might not be representative of other local water authorities.

Results of the cost-effectiveness analysis and sensitivity analysis

The sensitivity analysis found that the assessment method is especially sensitive to differences in the scoring regime used for assessing the LOs. The difference in importance of the stakeholders had a relatively small effect on the assessment results. This could be explained by the fact that the stakeholders included in the test case of the assessment have a relatively wide interest in different services. It could be expected that many private stakeholders, or one-issue organizations, have a bigger effect on the assessment results when they are perceived as the most important stakeholder in the assessment. The sensitivity of the assessment to changes in realisation costs is also relatively small when compared to the scoring regime. When reassessing the LOs in the CEA with +-25% differences in realisation costs, the maximum change in ranking the LOs was determined to be 2 places.

The inclusion of a CEA in the assessment tool is valuable because it makes the results of the assessment more comprehensive as it promotes an effective use of resources. Many services are desired, and the inclusion of the CEA can aid decision making that allows for a maximalisation of the provided ecosystem services and infrastructure services. The coupling between services and CEA, where the number of realised services constitutes the effectiveness that a CEA evaluates, can be considered a useful tool for comparing LOs and promoting a maximization of service creation.

5.2 Reflection on the research approach and assessment method

The interviewees involved in this research found it difficult to interpret the demarcations of the used services. This can partly be attributed to the absence of a framework describing IS, but a more substantial factor is the different terminology used in the work field, including terms such as ecology and biodiversity, which do not directly translate to a single service. Here, despite difficulties experienced by industry professionals, it might be valuable to describe an abstract term as "ecology" by the actual functions it provides. This may provide more accurate terminology to discuss which ecological developments are desirable and why. This may also provide more support for the measure, as the benefits can be communicated more concretely.

The same difficulty regarding the demarcation of services occurred in relation to the assessment of the LOs in the test case. For example, in assessing the LO describing the renovation of a historical inlet sluice, it is difficult to objectively differentiate between scores that recreation and cultural heritage should receive. Caused by the limited indicators that exist for these cultural ecosystem services, Hernández-Morcillo et al. (2013, p. 434) state that "Most of the cultural services indicators were deficient concerning their clarity of definitions, purposes and understanding of the processes to be measured". The assessment method proposed by this research would benefit from the development of more precise indicators. Another pathway towards more accurate assessment could follow from building a database of precedented assessments where the previous assessment scores for individual services could be used as a guiding instrument.

Research methods and limitations

The assessment itself and the research methods applied to design and validate the assessment are constrained by multiple limitations that are described in this paragraph. Firstly, the temporal dimension is only scarcely accounted for. Little consideration is given to the timespan for which services are provided. The number of years that a service is provided for could however significantly influence the desirability of an LO and, while not being included now, influences the cost-effectiveness of LO integration. The inclusion of life cycle costs and life cycle performance in the assessment could provide more accurate results and counteract possible tendencies towards short-term-based decision making. This, however, would increase the required amount of data for conducting the assessment, translating in more costs for data collection and data analysis when performing the assessment.

A further limitation regards the involved interviewees in the test case of this research. Only representatives from public parties were interviewed and here, no specific attention was given to interviewing representatives from all the different departments of the organization. This approach may cause certain viewpoints to be excluded from the assessment as different departments might have different interests and priorities. However, by establishing the actor-weighted evaluations in integrated work sessions where representatives from different departments are present, the exclusion of viewpoints could be negated. Furthermore, the viewpoints of private parties could partially be included in the same manner as public parties when the involved private parties possess the capabilities to evaluate the services. The viewpoints of private parties that are either insufficiently knowledgeable or unwilling to evaluate the services could still be included by having a stakeholder manager evaluate the services instead of the private party. This, as expressed by the industry professionals in the validation session, falls within the capabilities of a stakeholder manager as stakeholder managers currently already assess and convey the interests and viewpoints of various stakeholders.

Another limitation in this research regards the assessment of the LOs in the test case. While aided by extensive project documentation and consultation with an industry professional, the scoring of the LOs

has been performed by the researcher of this study. It is probable that someone else would assess the LOs differently. However, in determining the feasibility of the assessment method proposed by this research it was considered acceptable to illustrate the performance of the assessment in this manner. Focusing on the viability of the assessment method above the assessment results of a specific case.

Improving the assessment

A stronger link between the included services in the assessment and the terminology used by industry professionals could be established. Adopting terms such as spatial quality, biodiversity, and ecology more concretely in the assessment, would make it more interpretable for industry professionals. This relates to a key observation in the validation session, stating that the usability and interpretability of the assessment could be improved to make the assessment more applicable as a tool in communication.

To improve the comparability of LOs, it would be beneficial to develop a more comprehensive standardization of scoring LOs. As the sensitivity analysis has indicated, scoring from -3 towards 3 or alternatively from -5 to 5 considerably influences the assessment results. An approach where service indicators correspond to the score that an LO obtains might make the assessment more objective and allow for better comparisons between LOs. Furthermore, a temporal dimension could be established within the assessment where the duration of the provided services is considered. This is relevant because an LO that provides services for a longer time period provides more public value than an LO that provides the same services for a shorter duration. Additionally, a stronger connection between the services in the assessment and the SC "quality" could be established. This follows from the fact that the quality of the project is related to the effects that the project has on the services that are provided. An improved provisioning of services could constitute a higher quality of the project. In the current assessment, this link is missing. Lastly, the assessment could be subdivided into different geographical areas. Because, as stated by multiple interviewees, the services that are desirable in the inner and outer dike areas are sometimes different. For example, some services are only considered desirable in the outer dike areas. Evaluating the services for the inner and outer dike areas separately could thus improve the assessment.

5.3 Generalizability of the assessment

The assessment method, using a MAMCA with services and criteria, could be used in project types other than dike-strengthening projects. Big (infrastructure) projects that influence many stakeholders and effects varying services could be assessed using the same methodology. Especially rail and road projects face comparable challenges to dike-strengthening projects and are generally developed in a "Multi-Year Programme for Infrastructure, Spatial Planning, and Transport" (MIRT) (Ministry of I&W, 2018). These programs follow the same project phases as dike-strengthening projects, starting with an initiation phase followed by an exploration, plan development, and realization phase. Using the assessment method in these projects would require other services to be included in the assessment and would therefore require further research. Furthermore, it is expected that the assessment method could also be used in other countries as cultural differences and preferences can be accommodated within the process of re-establishing the actor-weighted importance of services and SC within the assessment. Especially counties with dense concentrations of stakeholders and a desire to safeguard stakeholder interests may benefit from adopting the assessment tool.

The services and criteria used in the developed assessment are chosen to fit the context of dike-strengthening projects in the Dutch Flood Protection Program with the aim of being applicable for all the dike-strengthening projects within the program. The actor-based evaluations in the test case have, however, been specifically provided for the context of a specific dike-strengthening project: "Culemborgse Veer - Beatrixsluis" (CUB). Considering that the evaluation of services could strongly vary between different geographic areas, it is expected that the services and SC included in the MAMCA require re-evaluation in each individual dike-strengthening project. Furthermore, the specific characteristics of other geographical project areas could also require the inclusion of additional services in the assessment when specific functions are provided in the project area. The interview results of the SC might be more generalizable as these results are not geographically dependent. However, these results have been obtained by interviewing representatives of a single local water authority that might not be representative of other local water authorities. So, while the assessment method might be more generally applicable, the contents of the assessment, meaning the services and SC, are expected to be strongly project dependent and would therefore require renewed attention when used for another project.

6.0 Conclusions and recommendations

Conclusions

This research has developed an assessment method for Linking Opportunities (LO) in Dutch dike-strengthening projects, using project success criteria, ecosystem services and infrastructure services in a multi-actor multi-criteria analysis (MAMCA). Thereby, the research demonstrated that ecosystem services and infrastructure services can effectively be integrated to operationalise public value creation for purposes of decision making. Multiple interviewees and industry professionals that were involved in this research have stated that the service framework used in this research, composed of ecosystem services and infrastructure services, provided a helpful vocabulary to discuss priorities, convey viewpoints, and assess LOs. Secondly, this research showed the advantages of using a MAMCA to indicate the distribution of adverse and beneficial effects for individual stakeholders. Here, stakeholder management approaches may be supported by the insight of which stakeholders might take a defensive stance following the adverse effects on their interests after LO integration. Additionally, this insight might promote decision making that promotes a fairer distribution of adverse and beneficial effects. Thirdly, the assessment tool provides, previously unavailable, comparability between LOs by adopting a CEA in the assessment that uses the actor-weighted MAMCA scores and the realisation costs of LOs. This comparability allows for decision making that promotes a more cost-effective allocation of resources, thereby stimulating additional public value creation in comparison to less cost-effective alternatives.

Recommendations for further research

The robustness of the assessment results could benefit from a future development of more objectively verifiable indicators for the used services and SC. Additionally, a standardized relation between the effect on a service and the score attributed to an LO would make the scoring more consistent, thereby also improving the results of the cost-effectiveness analysis, as the assessment results become better adapted to comparatively assess bigger and smaller LOs without over- or undervaluing larger LOs that are more expensive. Further benefits to the accuracy and usability of the assessment could result from the development of a framework that conceptualizes IS through the services it provides. A closer connection between the services provided by ecosystems and infrastructure, in combination with improved indicators, could improve the assessment. Additionally, the interpretability of the assessment could be advanced further by investigating the terminology in the grey literature and to better accommodate the currently used terminology in the assessment.

Furthermore, little consideration is given to the timespan for which services are provided. The number of years that a service is provided for could however significantly influence the desirability of an LO. Additional research would have to incorporate temporal considerations in the assessment. Lastly, using the assessment method in other types of infrastructure projects is expected to be possible but this could require other services to be included in the assessment.

Recommendations for practical applications and development

The application of the designed assessment in a test case and the validation session that reflected on the results has indicated that the designed assessment could prove most applicable as a tool in communication that clarifies and substantiates decisions. It was stated that the assessment should not be leading in decision making, but that it can be of supportive value in making decisions. The facilitating

benefits that the assessment provides were not a specific goal in the design of the assessment but were identified as a useful side effect. The functioning of the assessment in this regard can be significantly improved by becoming more user-friendly and visually oriented, thereby focussing on the communicative and facilitating functions it could fulfil. Additionally, the further development of the communicative and facilitating characteristics of the assessment could provide a pathway towards a more accurate assessment tool for decision making as the tool becomes more firmly embedded in the context where it is used.

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Appendices

A) Interview protocol for evaluating the infrastructure services and ecosystem services.
B) Interview protocol for evaluating the project Success Criteria
C) Scoring of the Linking Opportunities in the assessment
D) Validation session with industry professionals

A) Interview protocol for evaluating the infrastructure services and ecosystem services

Introduction

This rapport is made in preparation of ten interviews that are conducted in this research.

The research has defined services that are provided in the context of Dutch dike-strengthening projects. This rapport provides the protocol of the conducted interviews and shows the survey that has been used in the interviews to investigate the perceived importance of the services.

Before the description of the interview protocol and surveys, there is an introductory text provided in this rapport which is sent to the interviewees, and which was recited at the start of the interviews to inform the interviewees of the scope and goal of the research and interview. Standardization on this introduction is required to prevent the diversification of the interview results as an effect of different introductions (i.e., different priming of interviewees). The interview format does allow the interviewees to ask questions during to survey the guide the interpretation of the items in the survey.

The surveys as presented in this research have been formulate in English and were translated into Dutch to improve the understandability of the survey for the interviewees.

This appendix consists of two parts:

A) A written introduction for the interviewees
B) Interview protocol

Written introduction for interviewees [Dutch]

This introduction is written to be sent to the interviewees before the interviews. The contents of this introduction are also discussed in the introduction of the interviews. The aim of this part of the document is thus to clarify for the interviewees what is required from them and what their input will be used for.

Interview protocol

The protocol of the interview is described. This part is in English, but the survey as provided to the interviewees in the interview is described in Dutch as it is also presented in Dutch during the interview.

Written introduction for interviewees

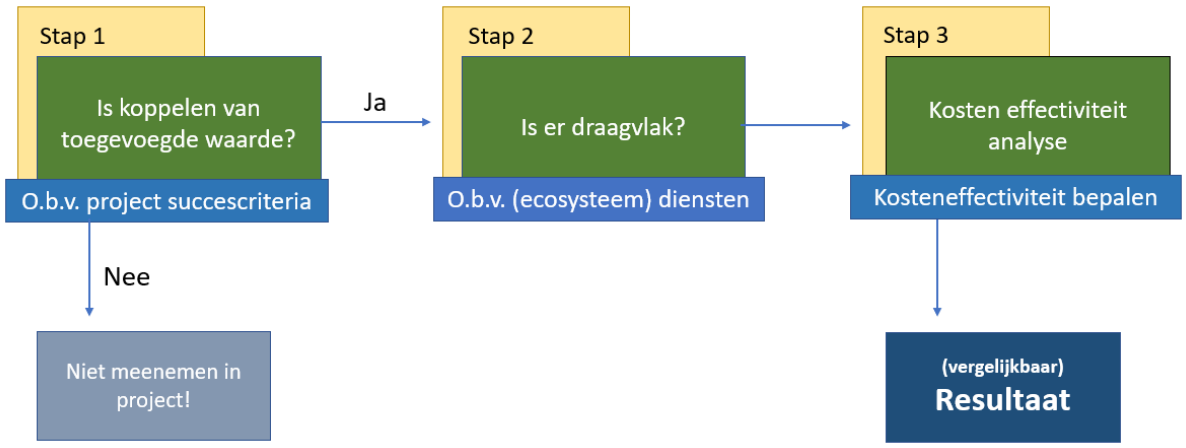
Algemene informatie

Dit onderzoek wordt uitgevoerd door Max Wingens, masterstudent bij de Universiteit Twente en afstudeerstagiair bij RoyalHaskoningDHV onder begeleiding van:

Joanne Vinke-de Kruijf	Universiteit Twente
Athanasios Votsis	Universiteit Twente
Beau Warbroek	Universiteit Twente
Idwer de Vries	RoyalHaskoningDHV
Luc Jenniskens	RoyalHaskoningDHV

Toelichting op het onderzoek

Dit onderzoek ontwerpt en test een afwegingskader om geïdentificeerde meekoppelkansen te beoordelen op draagvlak, maatschappelijke meerwaarde en synergiën. Dit gebeurt in drie stappen zoals weergegeven in Figuur 1.



Figuur 1: Conceptuele weergave van het onderzoek

In stap 1 zal het afwegingskader een indicatie geven of het meekoppelproject en het dijkversterkingsproject profijt hebben van een koppeling of dat beide projecten efficiënter verlopen als separate projecten. De afweging vindt hier plaats aan de hand van een viertal indicatoren die de succescriteria van een project beschrijven.

In stap 2 zal het afwegingskader een indicatie geven betreffende het draagvlak van een meekoppelkans. Het beginpunt is vaststellen welke diensten (of functies) in het gebied worden geleverd (of vervuld). Vervolgens wordt bekeken hoe deze diensten door een meekoppelkans worden beïnvloed. Twee soorten diensten worden bekeken: “ecosysteemdiensten” en “infrastructuurdiensten”. Ecosysteemdiensten beschrijven de voordelen die mensen uit de (natuurlijke) omgeving halen zoals

recreatie en (verbeterde) luchtkwaliteit. Infrastructuurdiensten omvatten o.a. mobiliteit en verkeersveiligheid. In stap 2 zal de meekoppelkans worden getoetst op de beïnvloeding van deze diensten en hier komt een score uit die een indicatie geeft van de maatschappelijke meerwaarde en de hoeveelheid draagvlak.

In stap 3 wordt er een kosteneffectiviteitsanalyse uitgevoerd met de score van de meekoppelkans uit stap 2 en met de verwachte kosten om de meekoppelkans te realiseren. Zo wordt de score van een meekoppelkans gecorrigeerd voor een verschil in kostprijs, dit geeft vergelijkbaarheid tussen de verschillende koppelkansen.

Het interview

Het doel van het interview is om een waardering te verbinden aan de verschillende diensten, zowel infrastructuur diensten als ecosysteem diensten, die in een gebied geleverd kunnen worden. Het interview bestaat uit een vragenlijst waarin punten verdeeld worden over deze diensten, zoals recreatie, water regulatie en mobiliteit. De resultaten van deze vragenlijst worden vervolgens gebruikt in het afwegingskader.

Geïnformeerde toestemming

Bij de start van het interview zal u mondeling gevraagd worden of het interview opgenomen mag worden en of de verkregen informatie voor onderzoeksdoeleinden gebruikt mag worden. De resultaten en geluidsopnames van de interviews zullen anoniem worden verwerkt. De informatie zal veilig en volgens de AVG-richtlijnen worden bewaard. Daarbij kunt u zich altijd terugtrekken uit dit onderzoek, de informatie zal dan worden verwijderd.

Interview protocol

1: Introduction of the research 5min

Introducing the research project: the interviewer gives a short description of the research. Including the aim of the research and the role of the interviews within the research. This information will also be sent to the interviewees by e-mail before the interview.

2: Explanation of the survey method 10min

The interviewer explains how the survey works. (That the items in the survey must be scored and that the relative height in scoring determines the perceived importance)

The interviewer explains the required perspective for filling in the survey. (Meaning that the interviewee fills in the survey from the perspective of the party that they represent)

The interviewer stresses that it is important that the surveys are filled in from the perspective of the project area (this is the scope) included in this case-study (So for CUB and not for a dike-strengthening project in general).

The interviewer stresses the importance of a distinctly separated assessment (where seemingly similar services, such as water regulation and high-water protection, must be valued separately according to the definitions and characteristics given in the survey.)

4: The survey 20min

The interviewer and interviewee go through the 17 (ecosystem) services in the survey (Table 1). The interviewer explains the contents of the services. Thereafter the interviewee fills in the second survey. To conclude the survey, the interviewer asks the interviewee if there might be items missing in the survey.

Table 1: Survey ecosystem services and infrastructure services in Dutch

Dienst	Omschrijving	Voorbeelden	Score:
Voedselvoorziening	Het omzetten van energie in eetbare planten d.m.v. fotosynthese	Verbouwd voedsel	
Water regulatie en afvoer mitigatie	Filtratie en afvoerregulatie van (regen)water	Bodem en vegetatie bergen water tijdens zware neerslag gebeurtenissen	
Temperatuur regulatie	Fotosynthese, schaduw, en verdamping	Vegetatie zorgt voor schaduw, creëert vochtigheid en blokkeert wind	
Geluidsdemping	Absorptie van geluidsgolven	Absorptie van geluidsgolven door vegetatie en objecten	

Zuivering van lucht	Filtering van schadelijke gassen en deeltjes	Verwijdering van verontreinigende stoffen door vegetatie	
(Water) zuivering	Verwijdering of afbraak van verontreinigde stoffen	De natuurlijke afbraak van o.a. fosfor, magnesium en calciumcarbonaat	
Klimaat regulering	CO2 opslag door middel van fotosynthese	CO2 opslag in biomassa	
Bestuiving en zaadverspreiding	Verspreiding van genetisch materiaal	Ecosystemen bieden leefgebied voor vogels, insecten en bestuivers	
Recreatie	Het plezier waarmee de omgeving wordt ervaren	Omvat (eco)toerisme, speeltuinen, etc.	
Erosie preventie	Het vasthouden van grond en het voorkomen van aardverschuiving	Aardverschuiving Vasthouden grond	
Cultureel erfgoed	Cultureel waardevolle attributen	Cultureel belangrijke landschappen en objecten	
De regulatie van ziektes, plagen	De afnamen van ongewenste soorten en/of ziektes	Het voorkomen of remmen van plagen en ziektes	
Educatieve waarde	De educatie die geleverd of versterkt wordt door het gebied	Kennis over natuur, geschiedenis en omgeving	
Mobiliteit	De beschikbare infrastructuur voor transportatie	Wegen, KenL, etc.	
Verkeersveiligheid	Omvat de veiligheid van de beschikbare infrastructuur	De scheiding van verkeerstypes en de zichtbaarheid	
Onderdak	De beschikbaarheid van onderdak	Woongelegenheid	
Energiebron	Het leveren van energie	Biomassa, wind en zon	

4: concluding the interview 5min

The interviewer asks the interviewee if they want to receive the research results and if there are questions.

B) Interview protocol for evaluating the project success criteria

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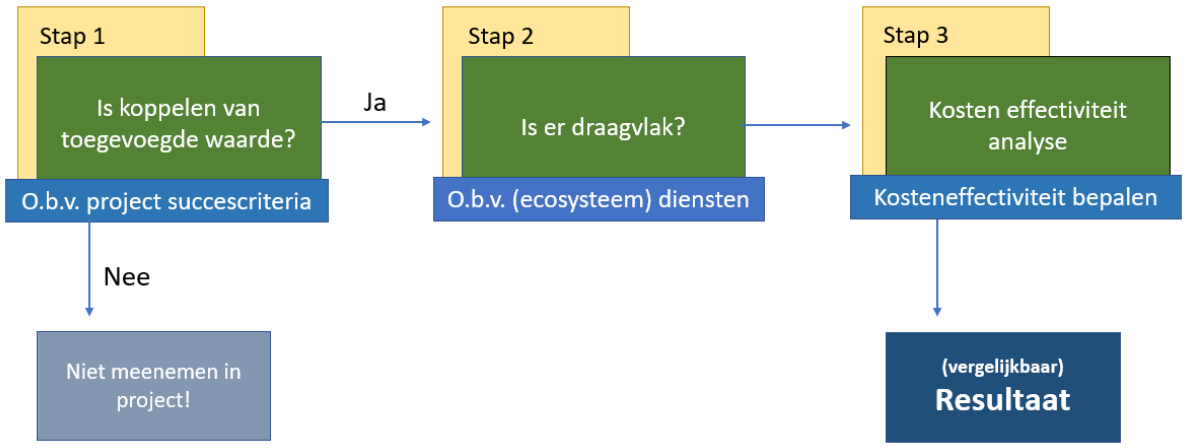

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Bij de start van het interview zal u mondeling gevraagd worden of het interview opgenomen mag worden en of de verkregen informatie voor onderzoeksdoeleinden gebruikt mag worden. De resultaten en geluidsopnames van de interviews zullen anoniem worden verwerkt. De informatie zal veilig en volgens de AVG-richtlijnen worden bewaard. Daarbij kunt u zich altijd terugtrekken uit dit onderzoek, de informatie zal dan worden verwijderd.

Interview protocol

1: Introduction of the research 5min

Introducing the research project: the interviewer gives a short description of the research. Including the aim of the research and the role of the interviews within the research. This information will also be sent to the interviewees by e-mail before the interview.

2: Explanation of the survey method 10min

The interviewer explains how the survey works. (That the items in the survey must be scored and that the relative height in scoring determines the perceived importance)

The interviewer explains the required perspective for filling in the survey. (Meaning that the interviewee fills in the survey from the perspective of the party that they represent)

The interviewer stresses that it is important that the surveys are filled in from the perspective of the project area (this is the scope) included in this case-study (So for CUB and not for a dike-strengthening project in general).

The interviewer stresses the importance of a distinctly separated assessment (where seemingly similar services, such as water regulation and high-water protection, must be valued separately according to the definitions and characteristics given in the survey.)

4: The survey 20min

The interviewer and interviewee go through the 17 (ecosystem) services in the survey (Table 1

). The interviewer explains the contents of the services. Thereafter the interviewee fills in the second survey. To conclude the survey, the interviewer asks the interviewee if there might be items missing in the survey.

Table 1: Survey project success criteria in Dutch

Project succescriteria	Definitie	Karakteristieken	Score:
Budget	Een positieve invloed van MKK integratie op het budget	> Minder kosten	
	Een negatieve invloed van MKK integratie op het budget	> Meer kosten	
Project planning	De positieve invloed van MKK integratie op de planning	Minder benodigde tijd voor: > Contracten > Procedures > Ontwerp > Uitvoering	

	De negatieve invloed van MKK integratie op de planning	Meer benodigde tijd voor: > Contracten > Procedures > Ontwerp > Uitvoering	
Kwaliteit	De positieve invloed van MKK integratie op de kwaliteit	> Overtreft specificaties > Betere onderhoudbaarheid > Verlengde levensduur	
	De negatieve invloed van MKK integratie op de kwaliteit	> Verminderde onderhoudbaarheid > Verminderde levensduur	
Overlast	De positieve invloed van MKK integratie op de overlast voor stakeholders	Minder: > Wegafsluitingen > Geluidsoverlast > Aantal aanspreekpunten > Beperkte bedrijfsvoering > Draagvlak	
	De negatieve invloed van MKK integratie op de overlast voor stakeholders	Meer: > Wegafsluitingen > Geluidsoverlast > aanspreekpunten > Beperkte bedrijfsvoering > Draagvlak	

4: concluding the interview 5min

The interviewer asks the interviewee if they want to receive the research results and if there are questions.

C) Scoring of the linking opportunities in the test case

This appendix provides the motivation for the scoring of the LOs. In this research the following LOs have been scored:

1	**Floodplain development Honswijkerwaard**	**(3 variants)**
2	**The inlet sluice**	**(4 variants)**
3	**The accessible and safe dike**	
4	**Strengthening of the iconic area**	
5	**Mobility and recreation**	
6	**The ecological dike**	
7	**Floodplain development in the Steenwaard**	

The sources used in the scoring of the LOs are internal documents used in the CUB dike-strengthening project and are mostly unpublished.

Floodplain development Honswijkerwaard

In this LO the floodplains near the dike are redesigned with the goal of nature development. Development is important as the Department of Waterways and Public Works is responsible for realizing the goals as formulated in the European Water Framework Directive. Fulfilment of these goals is required by the European Union in 2027 and the redevelopment of the floodplains is a chance to improve both the water quality as required by the European directive and to improve nature development. Three different variants of this LO have been proposed and all the variants are included in this test case.

Sources:

Rapport variantenstudie Honswijkerwaard

SSK-BI3499_Honswijkerewaard varianten_V01 (Contains costs calculations)

Variant A: Optimising the existing water system in the floodplain.

For variant A, the existing qualities regarding nature and cultural history are retained and further enhanced. The preservation of the polder function means that no direct connection with the southern Honswijkerplas and the river will be realised. In this variant, the current water system operation is largely maintained through the existing ditch system. The polder level will be slightly raised with the aim of marsh development.

Service	LO Score:	Clarification
Food provisioning	0	Variant A has no (or a very limited) impact on the ground levels in the inner dike area. Therefore, the effects on food provisioning is assessed as neutral.
Water regulation	0	The water level lowering effects are greater than the local water rising effects. For variant A, a local increase in seepage is expected.
Temperature regulation	0	No significant increase in tree cover. No wetter conditions under heat stress/droughts.
Noise reduction	0	
Purification of air	0	
Water purification	0	The soil quality of the floodplains is thus far unknown.
Climate regulation	1	More room for permanent vegetation may have a small positive effect on the storage of CO2.

Pollination	2	This variant contributes somewhat to the WFD objectives. The application of the river wood in the Honswijkerwaard yields some quality gains for macro-fauna and fish, as does the connection of the lakes in the riparian zone with the Lek. This means that there is some expansion of ecologically relevant acreage. In addition, suitable habitat is created for protected species that have not yet been found, such as the large loach and burbot. In and around the Honswijkerplas, biodiversity will increase through the application of river wood, which will benefit macrofauna and fish.
Recreation	2	The habitat of species near the Honswijkerplas (hawk, bats, beaver, stone and pine marten) remains unchanged In and around the Honswijkerplas, biodiversity will increase through the application of river wood, which will benefit macrofauna and fish. Historic clay pits along the dike will be restored or made more visible, making this part of the dike history easier to experience. This variant offers opportunities to make the existing recreational opportunities and [walking] routes around Honswijkerwaard more visible and experienceable.
Erosion-prevention	1	Calculations show that the flow velocity differences at high discharges are very small compared to the reference situation. The siltation potential is therefore relatively small. For all variants, the siltation potential is in the order of magnitude of 150-250m3 per year. This negative effect is therefore very limited. More biodiversity and rewetting have a potentially positive effect in combating erosion.
Cultural heritage	2	By strengthening the existing and potential values, a quality impulse is given to the essential characteristics and values of the area. The existing gradient is enhanced from permanently open water, to a swamp zone, flood grasslands towards glossy oat haylands on the higher ridges. Variant A contributes to the quality of the landscape by reducing structures (clay pits) or making existing structures more visible through a higher water level. Historic clay pits along the dike will be restored or made more visible, making this part of the dike history easier to experience.
Disease/pest regulation	1	This variant provides additional living space for wanted species, thereby increasing biodiversity which is expected to positively influence the ability of the system to counteract/prevent pests.
Educational services	1	Variant A contributes to the quality of the landscape by reducing structures (clay pits) or making existing structures more visible through a higher water level. This may have a small positive effect on educational services.

Mobility	-1	"The crossflow peak sees an increase. In absolute terms, the crossflow velocities of these peaks are higher than is considered acceptable in the RBK, so that a further increase is not desirable." [undesirable effect on shipping] The little infrastructure [K&L] that is present is not of vital value and relatively easy to install/remove and does not form an obstacle for one of the variants.
Traffic safety	0	
Shelter	0	Variant A has virtually no impact on the groundwater levels inside the dike. No homes will be additionally affected by seepage as a result of this variant.
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-1	The water-level lowering effects are much greater than the negative local impoundment effect, so that this impoundment will not cause any obstacles to the granting of permits. However, more work is likely to be required to obtain the permits.
Quality (+)	1	Assuming that the floodplain will be developed regardless LO integration, it will have a positive effect on the quality of the environment that the development of the floodplain is prepared alongside the development/design of the dike-strengthening.
Quality (-)	-2	Increase in the number of kilometres of forage paths in the floodplain that must be mowed (5 km more than B and C) River wood: periodic checks and replacement
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant. The effect however is limited because the dike will not need to be strengthened along the whole of the floodplain. The area affected by the project will thus increase significantly. Work in this variant, however, is more limited in scope than the needed works for variant C. Thereby reducing hinder.
Hindrance and satisfaction (-)	0	

Variant B: Connecting the floodplain to the river Lek.

Variant B assumes the abandonment of the dammed polder water level as a basis. The floodplain thus comes under the free influence of the water levels in the Lek. In this way, the floodplain can provide space for the implementation of nature objectives of both water-oriented and terrestrial nature based on WFD and NNN objectives. The existing height differences in the Honswijkerwaard will remain as they are in this variant as much as possible and offer space for a variation of nature types.

Service	LO Score:	Clarification
Food provisioning	-1	In variant B, relatively large rewetting [outside the dike] of the phreatic groundwater level is calculated (locally more than one meter) and a slightly more limited rewetting of the hydraulic head (predominantly 10 to 25 centimetres). A rise in the groundwater levels is not favourable for parts of the area that are now in agricultural use.
Water regulation	1	In a low-water scenario, wetting takes place (5 to 10 centimetres), which can potentially have a positive effect (potential occurrence of highly desiccated conditions in a dry year). For variant B, the polder level outside the dikes will be released, so that the regulated water system with the pumping station will no longer apply. This is estimated as a positive effect.
Temperature regulation	1	A wetter environment provides more cooling.
Noise reduction	0	
Purification of air	0	
Water purification	0	The environmental hygiene soil quality in the floodplains is currently unknown.
Climate regulation	1	More room for permanent vegetation may have a small positive effect on the storage of CO2
Pollination	2	Due to the expansion in surface area of relevant area and the expansion in quality of the area through more space for growing places for fish, macrofauna and aquatic plants, this variant meets the objective of WFD. More habitat for various (protected) species contributes to this service. The installation of shallow riparian zones and river wood in the Honswijkerplas contributes to the ecologically relevant area for macrofauna, fish and aquatic plants. In this variant the habitat of the species near the Honswijkerplas is also preserved. Due to the construction of the open water, which is in open connection with the Honswijkerplas and Lek, the habitat of the pond frog, moor frog and probably also the flat disc horn will be lost.
Recreation	2	IIn this variant, a bridge or wide culvert is provided to maintain the walking routes. This construction makes it possible to make the routes through the floodplain more visible, and also offers a view of the wet nature to be created. This makes it possible to enhance the experience of the Honswijkerwaard.

Erosion-prevention	1	Calculations show that the flow velocity differences at high discharges are very small compared to the reference situation. The siltation potential is therefore relatively small. For all variants, the siltation potential is in the order of magnitude of 150-250m3 per year. This negative effect is therefore very limited. More biodiversity and rewetting have a potentially positive effect in combating erosion.
Cultural heritage	1	By strengthening the existing and potential values, a quality impulse is given to the essential characteristics and values of the area. The existing gradient is enhanced from permanently open water to a marsh zone and from flood grasslands to glossy oat hay lands on the higher ridges Together variant 2 makes a small contribution to the quality of the landscape. By filling in the ditches, a historical structure is lost, but the addition of hedges maintains a reference to this structure in a form that historically fits this location. Together, in variant 2, a historic landscape structure, the ditch pattern, is removed but restored by putting back hedges in the same structure. This creates a neutral effect.
Disease/pest regulation	1	This variant provides additional living space for wanted species, thereby increasing biodiversity which is expected to positively influence the ability of the system to counteract/prevent pests.
Educational services	0	
Mobility	-1	The crossflow peak sees an increase. In an absolute sense, the crossflow velocities of these peaks are higher than considered acceptable in the RBK, which means that a further increase is not desirable. [undesirable effect on shipping] The little infrastructure [K&L] that is present is not of vital value and relatively easy to install/remove and does not form an obstacle for one of the variants.
Traffic safety	0	
Shelter	-1	For variant 2, small effects on the groundwater level are calculated (maximum 10 centimetres), because of which a risk of wetting at homes and the inner toe of the dike is expected. Mitigation is possible here, so that the assessment is given a small-scale negative effect
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-1	The water-level lowering effects are much greater than the negative local impoundment effect, so that this impoundment will not create any obstacles for permits, although additional work is expected to be required to obtain the permits.

Quality (+)	2	Removing the need to drain the polder leads to a reduction in management and maintenance effort Assuming that the floodplain development will take place anyway, it has a strong positive effect to prepare the design at the same time
Quality (-)	-1	Increase in the number of kilometers of foraging paths in the floodplain that must be mowed River wood: periodic checks and replacement Extra: Periodic maintenance of the footbridge
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant. The effect however is limited because the dike will not need to be strengthened along the whole of the floodplain. The area affected by the project will thus increase significantly. Work in this variant however is more limited in scope than the needed works for variant C.
Hindrance and satisfaction (-)	0	

Variant C: connecting to the river and wetting of the floodplain.

This variant is aimed at achieving as much river dynamics as possible by designing a large part of the floodplain as a one-sided branched channel, which links up with existing developments to make the Honswijkerplas shallower. The development of new, less dynamic water contributes to increasing the habitat for fish, macrofauna and aquatic plants. There is less room in this area for the development of shallow marshes and floodplains.

Service	LO Score:	Clarification
Food provisioning	-1	In variant C, relatively large rewetting [Outside the dike] of the phreatic groundwater level is calculated (locally more than one meter) and a slightly more limited rewetting of the hydraulic head (mainly 10 to 25 centimeters). A rise in the groundwater levels is not favorable for parts of the area that are now in agricultural use.
Water regulation	2	In a low water scenario, rewetting takes place (More than in scenario B), which can potentially have a positive effect (potential occurrence of highly desiccated conditions in a dry year). For variant C, the polder level outside the dikes will be released, so that the regulated water system with the pumping station will no longer apply. This is considered a positive effect.
Temperature regulation	1	A wetter environment provides more cooling
Noise reduction	0	
Purification of air	0	
Water purification	0	The environmental hygiene soil quality in the floodplains is currently unknown.
Climate regulation	1	More room for permanent vegetation may have a small positive effect on the storage of CO2
Pollination	3	There is a major expansion of the area of relevant area, this variant exceeds the WFD objectives to a limited extent. There is an improvement in quality through better utilization of the present graduating gradients. There is a large expansion of the relevant area [for WFD] (more than with 1A and 1B) The expansion of the floodplain forest along the Honswijkerplas has a positive effect on tree-dwelling species such as goshawks, bats and also the stone and pine marten. The quality of the beaver's habitat will also benefit. However, the habitat of the pool frog, moor frog and flat hornbill is being lost and within the current design it is not easy to mitigate this.
Recreation	-2	In variant C, a large part of the Honswijkerwaard will be permanently flooded. The northern quay will be completely broken through, and this recreational route will no longer be used

Erosion-prevention	1	Calculations show that the flow velocity differences at high discharges are very small compared to the reference situation. The siltation potential is therefore relatively small. For all variants, the siltation potential is in the order of magnitude of 150-250m3 per year. This negative effect is therefore very limited. More biodiversity and rewetting have a potentially positive effect in combating erosion.
Cultural heritage	-2	Due to the large-scale excavations, two quays designated as protected small landscape elements are affected. This is formally required to compensate. However, the quays cannot simply be realized elsewhere because they are linked to cultural-historical structures Variant C affects the quality of the landscape. It is true that elements that belong in a floodplain such as the Honswijkerwaard are being brought back, but the large-scale interventions required for this damage other existing historical structures. In particular, the loss of the plot pattern of the old-hoofed land and the adjustments to the historically created geomorphological relief of the floodplain are detrimental to the area. Variant C involves large-scale excavations in undisturbed soil. This means a significant damage to archaeological values.
Disease/pest regulation	1	This variant provides additional living space for wanted species, thereby increasing biodiversity which is expected to possibly influence the ability of the system to counteract/prevent pests.
Educational services	0	
Mobility	-1	"The crossflow peak sees an increase. In absolute terms, the crossflow velocities of these peaks are higher than is considered acceptable in the RBK, which means that a further increase is not desirable." [undesirable effect on shipping] The little infrastructure [K&L] that is present is not of vital value and relatively easy to install/remove and does not hinder any of the variants.
Traffic safety	0	
Shelter	-2	In the high-water scenario, a significant increase in the hydraulic head is calculated (25 centimeters), which causes an increasing seepage flow towards the inner-dike polder system. The hydraulic head here is significantly higher than in scenario B, so the risk of flooding at houses inside the dike is therefore also greater.
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	

On schedule (-)	-1	The water-level lowering effects are much greater than the negative local impoundment effect, which means that this impoundment will not cause any obstacles to the granting of permits Due to the large-scale excavations, two quays designated as protected small landscape elements are affected. This is formally compensable. However, the quays cannot simply be realized elsewhere because they are linked to cultural-historical structures.
Quality (+)	2	Removing the need to drain the polder leads to a reduction in management and maintenance effort
Quality (-)	-1	Increase in the number of kilometers of foraging paths in the floodplain that must be mowed (less than with variants A and B) River wood: periodic checks and replacement
Hindrance and satisfaction (+)	1	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant. The effect however is limited because the dike will not need to be strengthened along the whole of the floodplain. The area affected by the project will thus increase significantly. Work in this variant however is bigger in scope than the needed works for variants A and B.
Hindrance and satisfaction (-)	0	

The inlet sluice

The dike-strengthening project CUB is crossed by the iconic area of the New Dutch Waterline. There are several LOs identified that are about strengthening and experiencing this military heritage. One of these projects is making the inlet sluice at Fort Honswijk visible and experienceable again. The inlet sluice was placed under the earthworks of the dike in 1985 as part of a dike reinforcement that was carried out at the time. This LO aims at making the inlet sluice visible and experienceable again. Four different variants of this LO have been proposed and all the variants are included in this research.

Sources:

Eindversie Notitie Variantenstudie inlaatsluis

Inlaatsluis variant 2 (Contains costs calculations)

Inlaatsluis variant 3 (Contains costs calculations)

Inlaatsluis variant 4 (Contains costs calculations)

Variant A: the current situation complimented by artwork.

In variant A the current situation is maintained: the inlet sluice remains hidden under the current flood defense. Depicting the story of the inlet sluice is done exclusively with art and routing around the dike and the hidden inlet sluice, such as: the location and operation of the sluice, the role of the sluice and that the Fort was realized at the time to keep the hinterland relatively easily under water. water.

Service	LO Score:	Clarification
Food provisioning	0	Since the groundwater level at the location of the agricultural plots is (expectedly) dominated by rainwater, it is expected that there will be minor effects on the water absorption of the crop. All variants therefore score neutral (0 score).

Water regulation	0	Variant A scores neutral for the 'surface water system' criterion Variant A scores neutral for the 'groundwater system' criterion
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	
Pollination	1	At the level of the spatial intervention, nature management type L02.01 applies to all four variants: Fort terrain. This includes the systems of ramparts and vegetation. It is expected that for all 4 variants the system of ramparts, planting, etc. will be strengthened and green management will be continued.
Recreation	-1	Variant 1 makes the location of the former lock visible by means of art.
Erosion-prevention	0	
Cultural heritage	1	Variant A leaves the ground untouched, and therefore has no impact on archaeology. In variant A, the inlet sluice is not 'literally' made visible, and the inlet sluice is only made to be experienced with art.
Disease/pest regulation	0	
Educational services	0	Variant A scores neutral for the criterion 'legibility of the landscape', because in this alternative only a work of art is placed, and it is comparable to the reference situation.
Mobility	-1	Variant A scores neutral for the criterion 'cables and pipelines', because in this alternative only a structure is placed, and it is comparable to the reference situation.
Traffic safety	0	
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	0	
Quality (+)	0	No/little primary raw materials required.
Quality (-)	0	Since there are no changes to the current dike profile for variant A, nothing will change in terms of manageability compared to the current situation.
Hindrance and satisfaction (+)	1	Installing the art during the dike-strengthening project may have a minor positive influence on the experienced hindrance in comparison to a separate installment.
Hindrance and satisfaction (-)	0	

Variant B: Making the two lock chambers accessible.

In variant B, next to the inlet sluice on the outer side of the dike, a diaphragm wall is installed in the flood defense, making it possible to make the inlet sluice visible again inside the dike. The diaphragm wall acts as a water barrier. The soil inside the dike can be removed and the walls of the two lock chambers become visible again. Art is added to make the inlet sluice more pleasant to experience. What this art will look like will be worked out at a later stage.

Service	LO Score:	Clarification
Food provisioning	0	Since the groundwater level at the location of the agricultural plots is (expectedly) dominated by rainwater, it is expected that there will be minor effects on the water absorption of the crop. All variants therefore score neutral (0 score).
Water regulation	-1	The stretch of the diaphragm wall is relatively limited. Nevertheless, variant B is judged slightly negative because a barrier effect [for groundwater flow] cannot be ruled out here.
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	It is expected that 1 tree will need to be felled in the project area
Pollination	1	At the level of the spatial intervention, nature management type L02.01 applies to all four variants: Fort terrain. This includes the systems of ramparts and vegetation. It is expected that for all 4 variants the system of ramparts, planting, etc. will be strengthened and green management will be continued.
Recreation	2	By making the inlet sluice visible inside the dike, variants B and D make the relationship between the inlet sluice and the other elements of the ensemble more visible. In variants B and D, the lock is made visible on the inside and can be experienced. In variant B, the 'green dike' is partly interrupted because the lock inside the dike is released and a construction is placed outside the dike.
Erosion-prevention	0	

Cultural heritage	3	In variant B, a vertical construction is placed deep into the ground at the height of the current crown of the dike, which entails a small risk of damage to archaeological values in the easternmost tip. For this reason, a slightly negative score has been given. By making the inlet sluice visible inside the dike, variants B and D make the relationship between the inlet sluice and the other elements of the ensemble more visible. In variant B, the inside dike part of the inlet sluice (walls) becomes visible. In this variant, a diaphragm wall is placed next to the inlet lock, so that it cannot be made fully visible.
Disease/pest regulation	0	
Educational services	2	By making the inlet sluice inside the dike and the construction outside the dike visible, it becomes clear that water could previously be let in at this location for inundation. From the inlet sluice, the water inside and outside the dike is clearly visible/experienceable.
Mobility	-1	Variants B, C and D have a direct interface with a distribution water pipeline from Vitens and a medium voltage cable from Stedin. When an intervention takes place, the relevant cables must be moved.
Traffic safety	0	
Shelter	0	
Energy provisioning	0	

Succes criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	-1	More calculation costs are expected.
On schedule (+)	0	
On schedule (-)	-2	For variant B, a structure is installed in the ground, which entails considerable implementation-technical risks. Making a diaphragm wall requires heavy equipment and also necessary additional material. The crown of the dike where work has to be done is very narrow, so that a work platform outside the dike is required. Variant B scores negatively due to the high output complexity.
Quality (+)	2	The diaphragm wall construction in variant B scores positively on manageability. Because the diaphragm wall is a type 1 construction that is independently water-resistant. Variant B scores positively on inspect ability, because this is an independent water-retaining structure designed for the normative conditions and therefore requires minimal inspection.

Quality (-)	-1	Variant B is based on a continuous concrete self-retaining water-retaining structure, which means that this variant scores very negatively on expandability. The structure is designed for a lifespan of 100 years, which also limits the need to expand. Lots of primary raw materials needed.
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant.
Hindrance and satisfaction (-)	-2	Variant B requires a very deep and complex structure to be installed in a very complex environment, which entails significant safety risks. Constructions are used in variants B and D. The placement of structures generally results in more noise production. However, the maximum current value is not exceeded when carrying out the necessary work for this.

Variant C: moving the dike.

In variant C, the flood defense at the inlet sluice is moved outside the dike (approx. 20-25 meters), and the inlet sluice is dug free. Part of the harbor outside the dike must be filled in for this, which has consequences for its use. Art is added to make the inlet sluice more pleasant to experience. What this art will look like will be worked out at a later stage.

Service	LO Score:	Clarification
Food provisioning	0	Since the groundwater level at the location of the agricultural plots is (expectedly) dominated by rainwater, it is expected that there will be minor effects on the water absorption of the crop. All variants therefore score neutral (0 score).
Water regulation	-1	Without performing calculations, the estimate is that an axial shift over a short distance at this location near the fort will also have only a small uplift effect, reinforced by the location in the lee of the flow paths in this part of the Lek. Nevertheless, variants C and D are both judged to be slightly negative because fluvial effects could occur here and cannot be ruled out
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	It is expected that 1 tree will need to be felled in the project area.
Pollination	1	At the level of the spatial intervention, nature management type L02.01 applies to all four variants: Fort terrain. This includes the systems of ramparts and vegetation. It is expected that for all 4 variants the system of ramparts, planting, etc. will be strengthened and green management will be continued.
Recreation	1	For variant C, the inlet lock is made fully experienceable. Due to the relocation of the dike, the relationship between the sluice and the water inside and outside the dike, and thus the position of the inlet sluice in the water system, is less visible. The infantry banquet on the outer dike side of the dike will also be difficult to repair (autonomous development) if the 'new dike' is given a place here. Variant C includes a considerable relocation of the dike towards the river. This seriously affects the continuity of the dike
Erosion-prevention	0	
Cultural heritage	3	For variant C, the entire inlet lock, both inside and outside the dike, is made visible. For this reason, variant C scores very positively.

Disease/pest regulation	0	
Educational services	0	In variant C, the legibility of the landscape is significantly affected. This is mainly because the dike and the inlet sluice are located at a distance from each other, which means that the relationship between the inlet sluice and the water inside and outside the dike is not easily recognizable.
Mobility	-1	Variants B C and D have a direct interface with a distribution water pipeline from Vitens and a medium voltage cable from Stedin. When an intervention takes place, the relevant cables must be moved.
Traffic safety	0	
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-2	In variant C, underwater earthworks (and possibly dredging away of soft soil) and stone revetment are applied. The variant requires a lot of work but is otherwise relatively easy to implement. Only variant C shows a decrease in the area relevant for WFD targets fish, macrofauna and aquatic plants. This concerns the destruction of a small area, for which compensation must take place.
Quality (+)	1	A circular implementation is possible.
Quality (-)	-2	In variant C there is an increase in management. In addition, the management of the harbor filling and rock dumping is more complex than just the management of a green dike. Variant C scores very negatively. Variants C and D include a relocation of the flood defense outside the dikes, which reduces the options for expansion in the future. However, the flood defense itself can still be expanded, which means that these variants have a limited negative score.
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant.
Hindrance and satisfaction (-)	-1	In variant C it is necessary to carry out 'water work', which entails risks. Variant C therefore scores negative.

Variant D: Widening of the dike.

variant D is a hybrid form of variants B and C. In this variant the dike is widened on the outside by applying soil in the form of a wide verge. In theory, the flood defenses (including crown) will be relocated outside the dike, without filling in the harbor. To make the inlet lock more perceptible, art will be added, for which an assignment formulation for an art assignment will be issued.

Service	LO Score:	Clarification
Food provisioning	0	Since the groundwater level at the location of the agricultural plots is (expectedly) dominated by rainwater, it is expected that there will be minor effects on the water absorption of the crop. All variants therefore score neutral (0 score).
Water regulation	-1	Without performing calculations, the estimate is that an ash shift over a short distance at this location near the fort will also have only a small uplift effect, reinforced by the location in the lee of the flow paths in this part of the Lek. Nevertheless, variants C and D are both assessed as slightly negative because river-related effects could occur here and cannot be ruled out
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	It is expected that 1 tree will need to be felled in the project area
Pollination	1	At the level of the spatial intervention, nature management type L02.01 applies to all four variants: Fort terrain. This includes the systems of ramparts and vegetation. It is expected that for all 4 variants the system of ramparts, planting, etc. will be strengthened and green management will be continued.
Recreation	2	By making the inlet sluice visible inside the dike, variants B and D make the relationship between the inlet sluice and the other elements of the ensemble more visible.
Erosion-prevention	0	
Cultural heritage	3	In variant D, just like in variant B, only the inside dike part of the inlet sluice is made visible. In variants B and D, the lock is made visible on the inside and can be experienced. "
Disease/pest regulation	0	

Educational services	2	In variant D, the landscape becomes more readable by making the inlet sluice inside the dike and earthworks outside the dike visible. The intervention makes two 'time layers' visible: the presence of the inlet sluice and of the flood defense that was added to the area later.
Mobility	-1	Variants B C and D have a direct interface with a distribution water pipeline from Vitens and a medium voltage cable from Stedin. When an intervention takes place, the relevant cables must be moved.
Traffic safety	0	
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	-1	More calculation costs are expected.
On schedule (+)	0	
On schedule (-)	0	
Quality (+)	0	
Quality (-)	-1	Variant D results in a small increase in management effort, because the existing sheet pile wall along the harbor will now form part of the primary flood defense. As a result, this sheet pile wall including anchoring will have to be maintained periodically. Variants C and D assume a relocation of the flood defense outside the dikes, which reduces the options for expansion in the future. However, the flood defense itself can still be expanded, which means that these variants have a limited negative score.
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant.
Hindrance and satisfaction (-)	0	Finally, for variant D, the work related to the construction is slightly less complex, making it safer to carry out Constructions are used in variants B and D. The placement of structures generally produces more noise. However, the maximum current value is not exceeded when carrying out the necessary work for this.

The accessible and safe dike:

The municipality of Houten is the main party driving the development of an LO called the 'accessible and safe Lekdijk'. The ambition of the municipality of Houten is to improve the traffic safety and accessibility of a part of the Lekdijk between the A27 and Fort Honswijk. The required road capacity is expected to increase in the future and therefore, a widening of the road is considered necessary.

Sources:

MEMO onderbouwing wegverbreding

Notitie kosten 460m + bijlage (Contains costs calculations)

Service	LO Score:	Clarification
Food provisioning	0	
Water regulation	0	
Temperature regulation	0	
Noise reduction	0	
Purification of air	-1	Potential degradation in air quality due to additional traffic
Water purification	0	
Climate regulation	0	
Pollination	-1	Outside the dike are floodplains with nature as a function. [widening of the road may therefore reduce the m2 available for natural areas]
Recreation	-1	There are many different landowners inside the dike, which means that there is more uncertainty as to whether the same crown width is possible along the entire route. Outside the dike are floodplains with the function of a recreation area. [may result in a varying dike profile, negatively affect aesthetic values]
Erosion-prevention	0	
Cultural heritage	0	
Disease/pest regulation	0	

Educational services	0	
Mobility	3	Capacity is expected to increase in the future
Traffic safety	2	Safety is expected to increase
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-1	There are many different landowners inside the dike, which means that there is more uncertainty as to whether the same crown width is possible along the entire route. This can then only be expropriated as land. Outside the dike are floodplains with the function of nature or recreation area. Outside the dike, wood stands are present along the dike. Land must be purchased, and a land acquisition procedure must be initiated for this purpose.
Quality (+)	0	
Quality (-)	0	
Hindrance and satisfaction (+)	3	Nuisance is significantly less with a combined implementation. Nuisance/work pressure for residents is also reduced in the land purchase procedures with a combined approach.
Hindrance and satisfaction (-)	0	

Strengthening of the iconic area:

Commissioned by the province, this LO is a collection of smaller individual measures that seek to make the iconic area near the Lek dike more accessible and open to being experienced. Aiming at more recreational use, enhancing the perception of both the landscape and the cultural history in the area. Some proposed measures in this LO include the realization of walking routes, the highlighting of historical objects and the realization of resting points. Thereby strengthening spatial quality in the area.

Source:

Meekoppelkansen CUB uitwerking schetsontwerpen - geen bijlage - v2.0 LQ

Service	LO Score:	Clarification
Food provisioning	0	
Water regulation	0	
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	
Pollination	0	
Recreation	2	With the linkage opportunity, Lekdijk and the floodplains are more strongly connected to the area. The ultimate goal is to create a coherent network of transfer points, routes and attractions in the area and to strengthen recreation and tourism in the area. The users of the various locations that are part of the icon area are mainly cyclists and walkers. Efforts have been made to facilitate these holidaymakers as well and safely as possible.
Erosion-prevention	0	

Cultural heritage	3	The battery [near Noordelijke Lekdijk] will be subtly restored with attention to the original design and use in relation to the flood defense. With the linkage opportunity, Lekdijk and the floodplains are more strongly connected to the area. The ultimate goal is to create a coherent network of transfer points, routes, and attractions in the area and to strengthen the landscape qualities [including the many cultural elements] of the area. The main goal is that the valuable cultural-historical heritage, as elements and as an entire network or structure, is expressed and can be experienced. The sketch designs were created with this in mind.
Disease/pest regulation	0	
Educational services	0	These historical elements are better connected with each other and with the fort [Fort Honswijk], so that their historical function emerges more clearly.
Mobility	0	
Traffic safety	1	The users of the various locations that are part of the icon area are mainly cyclists and walkers. Efforts have been made to facilitate these holidaymakers as well and safely as possible. The area on the dike [Near Kazemat-Vreeswijk Oost] is bounded by two speed bumps to slow down motorized traffic. To guarantee the safety of the crossing walker [Near the Wielen and the Waalse Bos], a speed bump has been chosen at the crossing point. In addition, the footpath connects at right angles to the road to make the crossing as safe as possible.
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	0	
Quality (+)	0	
Quality (-)	0	
Hindrance and satisfaction (+)	2	A simultaneous realization of this LO and the dike-strengthening project will positively influence the amount of hindrance experienced. Especially when combined with other LOs such as the road widening.
Hindrance and satisfaction (-)	0	

Mobility and recreation:

The province of Utrecht has the ambition to display the dike as a recognizable and continuous element, that functions as a connection between the surrounding landscapes. Therefore, a uniform road layout is considered desirable, including the colour of the road surface and road furniture being used. This LO is in development for the whole of the Sterke Lekdijk, the overarching program that includes CUB.

Sources:

Visie Mobiliteit en Recreatie Lekdijk - Versie 1.1 Print

Financiele onderbouwing beeldkwaliteitsplan mobiliteit en recreatie (Contains costs calculations)

Service	LO Score:	Clarification
Food provisioning	0	
Water regulation	0	
Temperature regulation	0	
Noise reduction	1	A new road surface may positively influence noise reduction
Purification of air	0	
Water purification	0	
Climate regulation	0	
Pollination	0	
Recreation	2	The "visie mobiliteit and recreatie Lekdijk" speaks of increased recreational value as a result of a more continuous dike profile.
Erosion-prevention	1	A new road surface with grass concrete tiles in the roadside will reduce erosion on the dike.
Cultural heritage	0	
Disease/pest regulation	0	
Educational services	0	
Mobility	0	The widening of the road is part of another LO and in this assessment the widening is credited for providing additional mobility capacity. The surface renewal as included in this LO is judged not to provide a significant amount of additional mobility to be credited with a positive score.

Traffic safety	1	The new road surface (especially when including ribbed road surface) may have a positive effect on traffic safety.
Shelter	0	
Energy provisioning	0	

Success criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-1	LO covers the entire Lekdijk, so it is difficult to get all municipalities on the same page (7 municipalities and 7 budgets)
Quality (+)	1	Realizing this LO after the dike-strengthening may damage the dike and/or require mitigation measures when realizing the LO at a later time.
Quality (-)	0	
Hindrance and satisfaction (+)	3	A simultaneous realization of this LO and the dike-strengthening project will positively influence the amount of hindrance experienced. Especially when combined with LO 3: the road widening.
Hindrance and satisfaction (-)	0	

The ecological dike:

HDSR desires to develop a flowery Lekdijk. It has been concluded that the Lekdijk has great potential for developing a species-rich oat hay meadow as the soil structure is suitable in many areas and because the outer slope is mainly oriented towards the south. A flowery dike is beneficial for biodiversity and contributes to the strength of the dike revetment.

Sources:

Bloemrijke dijken rapport

Workshop bloemrijke dijken 14 april 2022

Service	LO Score:	Clarification
Food provisioning	-1	If the clippings are to be used as animal feed, ragwort should be avoided as much as possible. [Could still have a negative effect on food provisioning]
Water regulation	0	
Temperature regulation	0	
Noise reduction	0	
Purification of air	0	
Water purification	0	
Climate regulation	0	
Pollination	3	It has recently been shown that the creation of flower strips not only leads to an increase in bee species richness in the flower strips themselves, but also in the surrounding landscape (Dr. T. Bukovinszky, 2016).
Recreation	1	The recreational value of a flowery dike is greater than that of a grass dike.
Erosion-prevention	2	A wide variety of root depths ensure a well-rooted top layer, which contributes to preventing soil erosion.
Cultural heritage	0	
Disease/pest regulation	1	[A flower rich dike might both increase the around of wanted and unwanted species] unwanted species (e.g., ragwort, thistle). [The abundance of desired species is expected to increase significantly more]
Educational services	0	

Mobility	0	
Traffic safety	0	
Shelter	0	
Energy provisioning	0	

Succes criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-1	The realization of this LO needs to happen in specific time periods of the year. Realization will furthermore take multiple seasons. Both aspects might make the planning for realizing the dike-strengthening harder.
Quality (+)	2	More erosion-resistant thanks to biodiversity and less frequent mowing
Quality (-)	0	
Hindrance and satisfaction (+)	1	A simultaneous realization of this LO and the dike-strengthening project might positively influence the amount of hindrance experienced. The positive effect is expected to be small since the hindrance of realizing this LO is small and can only partly be combined with the dike-strengthening.
Hindrance and satisfaction (-)	0	

Floodplain development in the Steenwaard:

This LO is conceptually similar to the Honswijkerwaard floodplain development but includes a different floodplain that is located further upstream in the river Lek. Integration of this LO is a chance to improve both the water quality as required by the European Water Framework Directive and to improve nature development.

Sources:

Rapport variantenstudie Steenwaard

SSK-BI3499_steenwaard varianten_V01

Service	LO Score:	Clarification
Food provisioning	-1	A small-scale negative effect results with 25 centimeters of rewetting near the inner toe to 5 centimeters of rewetting in the hinterland) A significant increase in seepage pressure is expected. A significant increase as an effect is equivalent to an increase of more than 2% extra seepage pressure (m3) on a monitoring area. In this LO, groundwater levels are rising at the plots along the dike, which can cause rewetting in regular situations. Too much wetting can make it difficult to work the land with machines and hinder crop growth. On the other hand, in situations with low water, these variants can ensure a higher groundwater level for longer, which can reduce drought problems.
Water regulation	0	LO results in more impoundment in combination with few upstream water level lowering effects) Resulting in an increase in the groundwater level outside the dike of 5 to 20 centimeters and up to 25 centimeters rewetting inside the dike near the inner toe and up to 5 centimeters rewetting in the hinterland) Depending on which scenario is considered, there will be a positive (wetting during drought) or negative (wetting in an average or high water scenario) effect on the groundwater level outside the dikes. No significant effect (<5 centimeters) is calculated for the high-water scenario.
Temperature regulation	1	A wetter (and greener) environment provides more cooling
Noise reduction	0	

Purification of air	0	
Water purification	1	Throughout the area, efforts are being made to expand or improve the quality of nature management types.
Climate regulation	1	More room for permanent vegetation may have a small positive effect on the storage of CO2
Pollination	2	This variant includes more measures to strengthen the WFD tasking and meets the prioritized objective of connecting the river and adjacent lake. In the case of a scenario with low water, a clear rewetting is calculated outside the dike, so it is expected that the floodplain outside the dike will get a wetter groundwater regime. This can potentially have a beneficial effect on nature in the floodplains. LO will lead to loss of habitat for the amphibians, especially the great crested newt
Recreation	1	Throughout the area, efforts are being made to expand or improve the quality of nature management types. Recreational routes and opportunities in the floodplain will be preserved. On the edge of the floodplain, the foraging path on the outer dike toe of the Lekdijk will be reinforced. This offers a small contribution to the recreational routes.
Erosion-prevention	1	More biodiversity and rewetting have a potentially positive effect in combating erosion.
Cultural heritage	0	Restoring the old brick pits and the weakening of the banks of the ponds contributes to the identity of the area. Together, this LO contributes to the quality of the landscape by restoring structures (clay pits, riparian forest) and river dynamics, and removing an element that does not fit (the raised ground). In conclusion, this LO does not affect archaeological values. Due to the planting of riparian forest in the west of the Steenwaard, some shelters of the Werk aan de Groeneweg will be surrounded by forest, so that their historical location with an open field of fire will no longer be done justice. This is an impairment of the amenity value of this part of the New Dutch Waterline
Disease/pest regulation	1	This variant provides additional living space for wanted species, thereby increasing biodiversity which is expected to positively influence the ability of the system to counteract/prevent pests.
Educational services	1	Deepening the clay pits ensures that these historical landscape structures become visible again and the story of the construction of the dike becomes more legible in the landscape.
Mobility	0	In the reference situation, the area around the Steenwaard is not very sensitive to cross currents, there is no significant effect on shipping.
Traffic safety	0	

Shelter	-2	A small-scale negative effect results with 25 centimeters of re-wetting near the inside toe to 5 centimeters of re-wetting in the hinterland. A significant increase in seepage pressure is expected. A significant increase as an effect is equivalent to an increase of more than 2% extra seepage pressure (m3) on a monitoring area. In this LO, the low quay around the agricultural plot that surrounds the house is excavated. As a result, situations occur more often in which high water surrounds the house on 3 sides. At the moment this only occurs once in about 10 homes along the dike can experience wetting of their garden or higher groundwater levels under the home, which can lead to nuisance. years before when the lower quay floods. Soon this will happen about once a year. This can lead to a slight decrease in the enjoyment of living. The house remains accessible in all situations via the ferry road.
Energy provisioning	0	

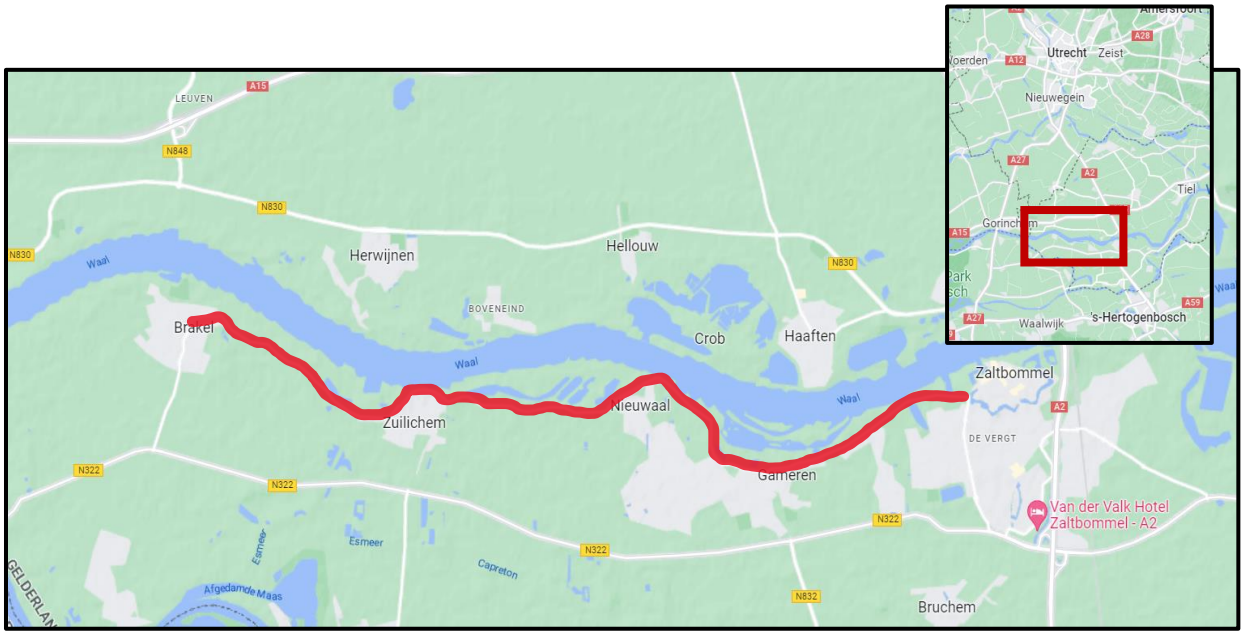
Succes criteria	LO Score:	Clarification
On budget (+)	0	
On budget (-)	0	
On schedule (+)	0	
On schedule (-)	-2	The part more than 100 m from the Lekdijk has not previously been subjected to a preliminary investigation (OOO) and little or no information is therefore available about this. The area around the railway bridge in particular has been designated as a suspicious area near the dike. The LO scores slightly negative (-) due to the involvement of the private plot east of the railway bridge. This private individual is more willing to cooperate, but cooperation is still required. This will always involve more risks than when cooperation is not necessary.
Quality (+)	0	
Quality (-)	0	
Hindrance and satisfaction (+)	2	Integrating the LO will reduce local hindrance in comparison to a later realization of this variant.
Hindrance and satisfaction (-)	-1	Houses along the dike can experience waterlogging of their garden or higher groundwater levels under the house, which can lead to nuisance.

D) Validation session with industry professionals

This appendix contains the background information that was given to the industry professionals in the validation session and the results of the assessment that followed from the evaluation of the fictional LOs provided in the test case.

Achtergrondinformatie Casus

De casus betreft een fictieve dijkversterking in de provincie Gelderland waar 11 km dijk versterkt moet worden, gelegen tussen Brakel en Zaltbommel, zie Figuur 8. Het project maakt onderdeel uit van de HWBP-subsidiering en bevind zich in de verkenningsfase.



Figuur 8 Project omgeving

Deze casus omvat een assessment van één meekoppelkans. Voor deze meekoppelkans zijn twee varianten ontwikkeld. Met het assessment moet een keuze gemaakt worden of de meekoppelkans in de plan uitwerkingsfase wordt geïntegreerd. Als er wordt gekozen voor integratie van de meekoppelkans moet er ook gekozen worden welke variant de voorkeur heeft.

Beschikbare informatie:

- De projectdoelstellingen van het fictieve dijkverstekingsproject zijn beknopt beschreven.
- Verkennende gespreken hebben de belangen van de stakeholders inzichtelijk gemaakt. Dat wil zeggen dat de waardering van de ecosysteem diensten, infrastructuur diensten en de succes criteria bekend zijn voor een vijftal stakeholders en zijn opgenomen in een Excel bestand.
- Een factsheet met beschrijving is beschikbaar voor beide varianten van de MKK.
- Beschrijving van het projectgebied

Projectdoelstellingen

Het (niet nader te noemen) waterschap dat de dijkversterking uitvoert heeft de volgende projectdoelstellingen:

- Een sobere en doelmatige realisatie van de dijkversterking
- Het projectgebied mooier achter te laten
- Het project zonder vertraging realisaren
- Overlast voor de omgeving tot een minimum beperken

Beschrijving projectgebied

In het projectgebied bevindt zich een drukke weg, gelegen op de dijk. Deze weg wordt intensief gebruikt voor verkeer van en naar Zaltbommel en ontsluit de plaatsen gelegen aan de dijk.

Staatsbosbeheer en de provincie zijn bezig met natuurontwikkeling rondom de dijk, met name buitendijks. Zeldzame en kwetsbare soorten komen in het gebied voor.

Het buitendijks gebied is slecht bereikbaar voor recreanten ook zijn er weinig parkeerplaatsen rondom de dijk.

Meekoppelkans

Staatsbosbeheer wil het buitendijks gebied bereikbaarder maken voor recreanten en heeft hiervoor twee varianten ontwikkeld:

Variant 1:

Op eigen grond wil Staatsbosbeheer een wandelroute realiseren. Dit brengt de recreant in contact met (kwetsbare) natuur. De wandelroute loop over een lengte van 5 kilometer langs de buitendijkse zijde van de dijk en voor een groot gedeelte langs de voet van de dijk. Deze variant maakt de wandelroute zelf niet beter bereikbaar, dat wil zeggen dat er geen extra parkeergelegenheid wordt gerealiseerd en dat de realisatie van de wandelroute als neveneffect kan hebben dat het nog drukker wordt op de weg. Staatsbosbeheer beschikt over de middelen voor de financiering en er worden geen problemen verwacht voor de vergunningverlening. Werk met werk maken is hier wellicht mogelijk.

Variant 2:

Op eigen grond wil Staatsbosbeheer een wandelroute realiseren. Dit brengt de recreant in contact met (kwetsbare) natuur. De wandelroute loop over een lengte van 5 kilometer langs de buitendijkse zijde van de dijk en voor een groot gedeelte langs de voet van de dijk. Om beter zicht te geven op de rivier wil Staatsbosbeheer in deze variant langs de wandelroute een plaatselijke ophoging realiseren met grond tot op een hoogte van 3 meter boven het huidige maaiveld (en 1 meter onder de kruin van de dijk). Deze ophoging wordt ingericht als uitkijkplaats en geeft zicht op een historisch object aan de overzijde van de rivier die zonder deze ophoging niet zichtbaar is. De water opstuwende effecten van deze ophoging zijn groter dan 1mm en moet daarom apart vergund (of gemitigeerd) worden. Verder wordt er in deze variant een binnendijkse parkeerplaats voorzien met een oversteekplaats over de dijk naar het begin van de wandelroute. Staatsbosbeheer heeft zicht op de financiering en werk met werk maken is hier, gezien de benodigde grondwerkzaamheden naar verwachting mogelijk.

Casus Results

Service	Definition	Examples	Variant 1	Variant 2
Food provisioning	The conversion of energy into edible plants by means of photosynthesis	Produced food	0	0
Water regulation	The timing and magnitude of runoff, flooding, and aquifer recharge	Soil and vegetation store water during heavy precipitation events	0	0
Temperature regulation	Photosynthesis, shadow, and evaporation.	Vegetation provides shade, creates humidity and blocks wind	0	0
Noise reduction	Absorption of sound waves	Absorption of sound waves by vegetation and objects	0	0
Purification of air	Filtering of harmful gases and particles	Removal of pollutants by vegetation	0	-1
Water purification	Removal or degradation of contaminated substances	The natural degradation of phosphorus, magnesium and calcium carbonate	0	0
Climate regulation	CO2 storage by photosynthesis	CO2 storage in biomass	0	0
Pollination	The distribution, abundance, and effectiveness of pollinators	Ecosystems provide habitat for birds, insects and pollinators	-1	-1
Recreation	The pleasure experienced as a result of services provided	Includes (eco)tourism, playgrounds, etc.	2	3
Erosion-prevention	The holding of soil and the prevention of landslides	Vegetation holding ground	0	0

Cultural heritage	Cultural assets	Culturally important landscapes and objects	0	0
Disease/pest regulation	The reduction of unwanted species and/or diseases	The deterrence of pests and diseases	0	0
Educational services	The education provided or strengthened by the environment	Knowledge of nature, history, and surroundings	0	0
Mobility	he available transport infrastructure	Roads, waterways, cables, and pipes.	1	1
Traffic safety	Includes the safety of the available infrastructure	The separation of traffic types and the visibility in traffic	-2	-2
Shelter	The availability of accommodation	Accommodation	0	0
Energy provisioning	Providing energy	Energy out of biomass, wind and solar.	0	0

Success criteria	Definition	Examples	Varriant 1	Varriant 2
On Budget	LO Integration has a positive influence on the required budget	> Less costs	0	1
	LO integration has a negative influence on the required budget	> More costs	-1	0
On schedule	LO integration has a positive influence on the planning/schedule	Less time needed for: > Contracts > Procedures > Design phase > Realization phase	0	0

	LO integration has a negative influence on the planning/schedule	More time needed for: > Contracts > Procedures > Design phase > Realization phase	-1	-1
Quality	LO integration has a positive effect on the project quality	> Exceeds specifications > Improved maintainability > Extended lifetime	0	0
	LO integration has a negative effect on the project quality	> Decreased maintainability > Shortened lifetime	0	0
Hindrance and satisfaction	LO integration reduces hindrance and improves satisfaction	Less: > Road closures > Noise pollution > Scattered contact points > Business limitations And more support	2	2
	LO integration increases hindrance and reduces satisfaction	More: > Road closures > Noise pollution > Scattered contact points > Business limitations And less support	0	0

Conducting interviews in the validation session was expected to take too much time and was therefore explained but not simulated Using the same evaluations of the services and success criteria as the interviews have provided in the research the following LO assessment scores were obtained in the validation session. In the session the influence and cost parameters were used and changed to present this feature of the assessment to the industry professionals.

LO assessment

Stakeholder:	Influence
Local water authority	1
Department of Waterways and Public Works	1
Province of Gelderland	1
State Forestry	1
Interest group	1

Linking opportunity	Costs in 100.000:
Variant 1	1,0
Variant 2	2,0

	Variant 1	Variant 2
Effect on SC	15,8	34,8
Local water authority	-0,7	2,0
Department of Waterways and Public Works	-3,1	-0,6
Province of Gelderland	0,3	6,1
State Forestry	18,6	26,3
Interest group	23,9	41,3
Total	39	75
Total with influence correction	39	75

Cost-effectiveness		
Total	39	38