MSc Thesis

Developing a maintenance sourcing strategy for flood defences of the NCICD project

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DEVELOPING A MAINTENANCE SOURCING STRATEGY FOR FLOOD DEFENCES OF THE NCICD PROJECT

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Abstract. Floods are one of the biggest threats facing coastal urban areas. During the 2007 flood event in Jakarta it became evident that a maintenance backlog caused the flood damage to be worse than expected. Maintenance of flood defence structures in emerging countries in general is often problematic due to the prevalent maintenance culture and erratic financing. Construction of new flood defence infrastructure is given priority over maintaining exiting structures. Necessary maintenance knowledge and experience are often drained in the asset owning organization. One of the possible solutions is improving the sourcing strategy for maintenance of flood defences. Although infrastructure maintenance outsourcing is more prevalent in highway maintenance, there is evidence that flood defence maintenance can be outsourced. In countries like the Netherlands there are several cases in which maintenance is sourced with external contractors for flood defences is applied to a certain degree. Several sourcing strategies for maintenance can be found in other fields of industry. These strategies range from completely internalized maintenance to completely externalized maintenance. New infrastructure construction projects are more suited for new approaches to maintenance sourcing, since existing infrastructure maintenance will necessitate more adaption of the maintenance organization. This report aims to structure the sourcing strategy decision-making process. It describes a maintenance-sourcing framework for the National Capitol Integrated Development (NCICD) project in Jakarta, a new large flood defence system designed to provide flood protection to a large part of the city. To form the framework, the relevant sourcing and maintenance theory is explored as well as reference cases. The relevant technical requirements and strategic goals are taken into account, as well as national and organizational factors influencing the sourcing decision. The maintenance sourcing framework is applied to the NCICD case to find a suitable sourcing strategy for the aforementioned case and indicates potential issues. We recommend a adapting the framework for flood defence maintenance sourcing after practical trials.

Keywords. outsourcing, maintenance management, flood risk management, flood defence structures, Jakarta, Indonesia, National Capitol Integrated Development, asset management, decision support systems, maintenance contractors
EXECUTIVE SUMMARY

Introduction
Flood defence structures are raised to provide acceptable flood safety levels for the inhabitants of flood prone areas. These flood defences need to be maintained in order to sustain their design safety levels over their lifecycle. Traditionally all maintenance tasks for flood defences are provided by the asset owner. If maintenance is performed correctly, the flood defence structures perform as required during flood events, however in emerging countries, such as Indonesia, flood defence maintenance is often inadequate and delivers poor performance during flood events. This mainly due to two reasons: first, maintenance culture is not properly ingrained in the infrastructure management agency. Adequate maintenance knowledge and skills is not present and experienced staff is retiring. Second, maintenance funding is inadequate. Often fluctuating on yearly basis and underfunded because priority is given to new infrastructure instead. Over the years this has created a flood defence maintenance backlog. This maintenance backlog led to aggravated damages during the 2007 floods in Jakarta, when it was concluded that 40% reduction of flood risk could have been reached in case maintenance was carried out regularly.

Outsourcing of infrastructure maintenance for roads or flood defences by asset owners is increasingly being considered as an alternative for the internal provision of maintenance. This research is carried out to make recommendations as to how the asset owners can structure the maintenance sourcing decision for flood defence structures. This can help organizations focus their resources on their core activities while offloading non-essential tasks to an external service provider, thereby utilizing the potential of the market.

The aim of this research is to find a maintenance sourcing strategy for the NCICD flood defences through use of a sourcing decision making framework that incorporates all relevant aspects influencing flood defence maintenance sourcing. These include technical, strategic, national and organizational factors.

Research Methodology
This research is carried out in an exploratory case study research, it utilises qualitative data from the literature study and from interviews with experts to assess which theories guide the sourcing decision and which factors are found to be important in the practical application of maintenance outsourcing. Three Dutch reference cases are selected to provide information on relevant factors. These cases are the Maasvlakte 2, the pumping station of IJmuiden, and the Dutch water boards. The information is then used to form a maintenance sourcing decision framework that can be used to select an appropriate sourcing strategy. This framework will then be used to select a maintenance sourcing strategy for the flood defences of the National Capitol Integrated Coastal Development, or NCICD, in Jakarta, Indonesia.

Literature study
A literature study was carried out to get an understanding of domains related to flood risk management, sourcing theory and maintenance of infrastructure in emerging countries. There are few authors that deal with maintenance sourcing for flood defences.
Therefore existing frameworks for other types of infrastructure maintenance had to be adapted to suit the needs of flood defence maintenance sourcing.

**Findings**

From the sourcing theory and reference cases the elements influencing the sourcing strategy are found to be the asset specificity of the maintenance workload, the strategic goals of the responsible asset-managing agency, and the national and organizational parameters. These are incorporated into a sourcing decision framework (see Figure 1) that consists of 4 steps.

**Figure 1 Sourcing decision framework**

These 4 steps are (1) identification and assessment of maintenance for each separate type of flood defence structure, (2) sourcing selection matrix, (3) adaption of sourcing strategy to national and organizational context, and (4) implementation issues and risk mitigation. These 4 steps entail the following activities that are captured in paragraphs in this summary.

**Identification and assessment of maintenance for each separate type of flood defence structure**

Maintenance requirements follow from the design performance level of the flood defence structures and the possible failure modes of the asset. In order to identify these requirements, a flood defence structure register, the design safety level and the failure modes of flood defence structures are needed as input. The maintenance requirements are then extrapolated from these parameters. The output that is needed is a maintenance task register, the value of the maintenance activities and the asset specificity involved with
the maintenance tasks. The maintenance task register provides the scope of the workload considered for outsourcing. The value of the maintenance activities discern which maintenance tasks are considered as essential tasks the asset owning organization and which are non-essential. The asset specificity of the maintenance work relates to the asset specific investments needed for the maintenance work. These are investments that, once made, are not easily transferred to other works when contracts are ended, thus hampering the ability to outsource this maintenance work, due to contractor risk exposure.

**Sourcing selection matrix**

Using the value of the maintenance activities and the asset specificity as input, a sourcing selection matrix can be used to determine a preliminary sourcing strategy. This sourcing selection matrix is adapted from other maintenance sourcing selection matrices designed for other types of infrastructure such as roads, buildings and energy infrastructure. Four sourcing strategies that are available are derived from the six-stage model of Schoenmaker and sourcing theory. These strategies are In-house, Outtasking, Hybrid Outsourcing and Outsourcing. The strategies vary from completely sourcing maintenance internally (In-house) to completely sourcing maintenance by an external service provider (Outsourcing). Outtasking is a strategy where mostly operational maintenance task are outsourced to a contractor, whereas the contractor and owner share tactical and strategic maintenance responsibilities with Hybrid Outsourcing.

**Adaption of sourcing strategy to national and organizational context**

From the reference cases and theory it can be concluded that there are more influences on the sourcing decision then just the asset specificity and value of the maintenance activities. These factors are needed as input in the decision making process. These factors are (1) the maintenance culture of the organization, (2) suitable legal administrative power to control long-term contracts, (3) required management skills for complex contracts, and (4) a life-cycle approach to infrastructure maintenance. The case for which the sourcing strategy is considered is scored for each of these factors. The results provide feedback on the sourcing selection matrix and may alter the definitive sourcing strategy. Adaption to the national context improves the sourcing strategy to incorporate the limitations and needs locally.

**Implementation issues and risk mitigation**

The governance mode for sourcing strategy is different and the risk exposure for the client and contractor may vary accordingly. The final step of the framework describes which contracting type and which potential risks need to be treated to ensure a successful implementation of the sourcing strategy. Review of the framework is needed periodically and for each separate asset type the sourcing strategy may vary, due to asset specificity.

**Conclusion and recommendations**

Applying the framework to the NCICD case the sourcing strategies for the outer seawall and pumping station are found. The best sourcing strategy for the outer seawall is found to be Hybrid Outsourcing and for the pumping station Outtasking. Hybrid outsourcing for the outer seawall is seen as most beneficial since it utilizes the market potential and still allows the asset owning organization to exert sufficient control on the flood defence system. Since the pumping station maintenance is seen as more essential
and asset specific, more control is needed and only operational maintenance tasks are outsourced.

Although the sourcing framework is specifically designed for the NCICD case in mind, it could be adapted for use in other flood defence maintenance sourcing projects. The framework is recommended for asset owning organizations in emerging countries faced with maintenance challenges and, which cannot rely on previous experience with flood defence maintenance assets. Incorporating the national and organizational context into the maintenance sourcing decision provides a more complete sourcing decision and highlights the potential limitations and opportunities of selecting a novel sourcing strategy.

New infrastructure projects are more suited for new sourcing strategies, since existing infrastructure agency is biased towards the existing maintenance sourcing strategy. In other words, organizations are more likely to stick to the sourcing strategy that is already in use.

One limitation of the framework is that it provides only a qualitative analysis, but lacks quantitative evidence of the validity of the sourcing selection. Convincing asset owning organization to adapt new sourcing strategies requires cost-benefit analysis of the sourcing strategy.

Additional national and organizational factors may be required per case. This depends on which factors are active per country. By incorporating the national and organizational factors into the sourcing decision, the asset owning organizations are required to investigate all aspects that are relevant and to provide evidence substantiating their sourcing decision. Through focus of the organization’s resources through improved maintenance sourcing, the organization can learn and improve its maintenance knowledge. The aim of such a framework should be to introduce state of the art maintenance sourcing paradigms in to countries and organizations that are not experienced in excellent asset management. Often the maintenance challenges in these countries are greater then the local organizations can cope with.

The main goal is to ensure flood safety levels are provided throughout the entire lifecycle of the flood defence system through excellent maintenance sourcing. This requires not only knowledge on the flood defence structures concerned, but also the current conditions of the environment of the maintenance sourcing dilemma. Providing a structured and complete approach to the sourcing decision adds value to the flood risk management process and adds knowledge to the flood risk organization.
NEDERLANDSE SAMENVATTING

Introductie

Waterkeringen worden gemaakt om aanvaardbare waterveiligheid niveaus voor de inwoners van overstromingsgevoelige gebieden te verzorgen. Deze waterkeringen hebben onderhoud nodig om hun ontwerp veiligheid niveaus gedurende hun hele levenscyclus in stand te houden. Traditioneel worden alle onderhoudstaken voor waterkeringen geleverd door de eigenaar van de keringen. Als het onderhoud correct wordt uitgevoerd, presteren de waterkeringen zoals vereist tijdens overstromingen, maar in de opkomende economieën, zoals Indonesië, is onderhoud aan waterkeringen vaak onvoldoende en presteren de keringen slecht tijdens overstromingen. Dit is voornamelijk te wijten aan twee redenen: ten eerste, de onderhoudscultuur is niet goed ingebakken in het management van de beheerder van de waterinfrastructuur. Adequate kennis van onderhoud en onderhoudsvaardigheden zijn niet aanwezig en ervaren personeel gaat met pensioen. Ten tweede, is de financiering van onderhoud ontoereikend. Onderhoudsbudgetten fluctueren vaak op jaarbasis en zijn onder gefinancierd omdat voorrang wordt gegeven aan het bouwen van nieuwe infrastructuur. In de loop der jaren is er voor waterkeringen achterstallig onderhoud ontstaan. Deze achterstand in onderhoud leidde tot verergerde schade tijdens de overstromingen van 2007 in Jakarta, toen er geconcludeerd werd dat 40% vermindering van het overstromingsrisico zou bereikt zijn in het geval het onderhoud regelmatig werd uitgevoerd.

Uitbesteding van onderhoud van de infrastructuur voor wegen of waterkeringen wordt door eigenaren van infrastructuur assets steeds meer beschouwd als een alternatief voor de interne voorziening van onderhoud. Dit onderzoek wordt uitgevoerd om aanbevelingen te doen over hoe de eigenaren van infrastructuur asset de onderhoud sourcing beslissing voor waterkeringen kunnen structureren. Dit kan helpen om organisaties hun middelen te laten focussen op hun kernactiviteiten, terwijl zij overige taken aan een externe dienstverlener over laten, waardoor het potentieel van de markt gebruik kan maken.

Het doel van dit onderzoek is om een uitbestedings strategie voor onderhoud van de NCICD waterkeringen te vinden door het gebruik van een sourcing besluitvorming raamwerk dat alle relevante aspecten van invloed op waterkering onderhoud uitbesteding bevat. Deze omvatten technische, strategische, nationale en organisatorische factoren.

Onderzoeksmethode

Dit onderzoek wordt uitgevoerd als een verkennende case study onderzoek, het maakt gebruik van kwalitatieve gegevens uit de literatuurstudie en interviews met experts om te beoordelen welke theorieën leidraad zijn voor de sourcing beslissing en welke factoren belangrijk gevonden worden in de praktische toepassing van de onderhoudsuitbesteding. Drie Nederlandse referentie cases zijn geselecteerd om informatie over relevante factoren te verzorgen. Deze cases zijn de Maasvlakte 2, het spuigemaal IJmuiden, en de Nederlandse waterschappen. De informatie wordt vervolgens gebruikt om een onderhoud inkoop raamwerk te maken dat kan worden gebruikt om een geschikte sourcing strategie te selecteren. Dit raamwerk wordt vervolgens gebruikt om een onderhoud sourcing-strategie voor de waterkeringen van de Nationale Capitol Integrated Coastal Development oftewel NCICD, in Jakarta, Indonesië te selecteren.
Literatuuronderzoek

Een literatuurstudie werd uitgevoerd om een goed begrip van domeinen van overstromingsrisico management, inkoop theorie en onderhoud van infrastructuur in opkomende landen te krijgen. Er zijn maar weinig auteurs die zich bezighouden met onderhoud inkoop voor waterkeringen. Daarom zijn bestaande kaders voor andere vormen van onderhoud van de infrastructuur aangepast aan de behoeften van de waterkering onderhoud inkoop.

Bevindingen

Van de sourcing-theorie en referentie cases zijn de elementen die de sourcing-strategie beïnvloeden gevonden, dit zijn de specificiteit van het onderhoudswerk, de strategische doelstellingen van de verantwoordelijke assetbeheerder, en de nationale en organisatorische parameters. Deze zijn opgenomen in een sourcing raamwerk (zie Figuur 2), dat bestaat uit 4 stappen.

**Figure 2 Sourcing beslissing model**

Deze 4 stappen zijn: (1) de identificatie en beoordeling van het onderhoud voor elk afzonderlijk type waterkering, (2) inkoop selectie matrix, (3) aanpassing van de sourcing-strategie aan nationale en organisatorische context, en (4) implementatie problemen en risico mitigatie. Deze 4 stappen bevatten de volgende activiteiten die zijn vastgelegd in de paragrafen van deze samenvatting.
Identificatie en beoordeling van het onderhoud voor elk afzonderlijk type waterkering

De onderhoudsseisen volgen uit het ontwerp prestatieniveau van de waterkeringen en de mogelijke faal modi van de asset. Om deze eisen te identificeren is als input vereist: een waterkering register, de ontwerp-niveau veiligheid en de faal modi van waterkeringen. Het onderhoud wordt vervolgens geëxtrapoleerd uit deze parameters. De output die nodig is, is een onderhoudstaak register, de waarde van de onderhoudsactiviteiten en de specificiteit die betrokken is bij de onderhoudstaken. Het onderhoudstaak register biedt de omvang van de werklast wat in aanmerking komt voor outsourcing. De waarde van de onderhoudswerkzaamheden onderscheiden welke onderhoudstaken worden beschouwd als essentiële taken van de infrastructuur organisatie en welk als niet-essentiële taken worden beschouwd. De asset specificiteit van de onderhoudswerkzaamheden betreft de asset specifieke investeringen die nodig zijn voor het onderhoud. Dit zijn investeringen die, eenmaal gemaakt, niet gemakkelijk kunnen worden overgedragen aan andere projecten wanneer contracten worden beëindigd, waardoor de mogelijkheid om dit onderhoud uit te besteden wordt belemmerd, als gevolg van risicoblootstelling van de aannemer.

Sourcing selectie matrix

Met behulp van de waarde van de onderhoudswerkzaamheden en de asset specificiteit als input, kan een sourcing selectie matrix worden gebruikt om een voorlopige sourcing-strategie te bepalen. Deze sourcing selectie matrix is een bewerking van ander onderhoud sourcing selectie matrices ontworpen voor andere soorten infrastructuur zoals wegen, gebouwen en energie-infrastructuur. Vier sourcing strategieën zijn beschikbaar die zijn afgeleid van het six-stage model van Schoenmaker en sourcing theorie. Deze strategieën zijn In-house, Outtasking, Hybrid Outsourcing en Outsourcing. De strategieën variëren van volledig onderhoud intern (in-house) tot volledig verzorging van onderhoud bij een externe dienstverlener (Outsourcing). Outtasking is een strategie waar vooral operationele onderhoudstaken worden uitbesteed aan een aannemer, terwijl de aannemer en eigenaar elk een aandeel nemen in het tactische en strategische onderhoud bij Hybrid Outsourcing.

Aanpassing van sourcing-strategie voor nationale en organisatorische context

Van de referentie-cases en theorie kan worden geconcludeerd dat er meer invloeden op de inkoop beslissing zijn dan alleen de specificiteit en de waarde van de onderhoudswerkzaamheden. Deze factoren zijn nodig als input in het besluitvormingsproces. Deze factoren zijn: (1) de onderhoudscultuur van de organisatie, (2) geschikte juridisch bestuurlijke macht om langlopende contracten te regelen, (3) vereiste management vaardigheden voor complexe contracten, en (4) een life-cycle benadering voor het onderhoud van de infrastructuur. De case waarvoor de sourcing-strategie wordt gemaakt wordt gecoördineerd voor elk van deze factoren. De resultaten geven feedback op de sourcing selectie matrix en kan de definitieve sourcing-strategie wijzigen. Aanpassing aan de nationale context verbetert de sourcing-strategie om de beperkingen en behoeften ter plaatse op te nemen.

Implementatie kwesties en risicobeperking

De beheersing voor elke sourcing-strategie is anders en de blootstelling aan risico’s voor de opdrachtgever en opdrachtnemer kan ook variëren. De laatste stap van het raamwerk beschrijft welke aanbestedende type en die potentiële risico’s moeten
worden getrakteerd op een succesvolle implementatie van de sourcing-strategie te waarborgen. Herziening van het raamwerk wordt periodiek nodig is en voor elk apart soort troef van de sourcing-strategie kunnen variëren, als gevolg van specificiteit.

Conclusie en aanbevelingen
Het toepassen van het raamwerk op de NCICD case heeft de sourcing-strategieën voor de buitenste zeewering en pompstation gevonden. Als beste sourcing-strategie voor de buitenste zeewering is Hybrid Outsourcing gevonden en voor het pompstation is Outtasking gevonden. Hybrid outsourcing voor de buitenste zeewering wordt gezien als het meest gunstig, omdat het gebruik maakt van het markt potentieel en geeft de asset management organisatie voldoende mogelijkheden voor controle op de waterkeringen. Aangezien het spui gemaal wordt gezien als essentieel en asset specifieke, is meer controle nodig en worden alleen operationele onderhoud taken geouttasked.
Hoewel het sourcing-raamwerk speciaal is ontworpen met de NCICD in het achterhoofd, kan deze worden aangepast voor gebruik in andere onderhoudsvraagstukken voor waterkeringen. Het raamwerk wordt aanbevolen voor asset management organisaties in de opkomende landen die geconfronteerd worden met onderhoud uitdagingen, en die zich niet kan beroepen op eerdere ervaringen met waterkering onderhoud. De integratie van de nationale en organisatorische context in het onderhoud sourcing-besluit voorziet in een meer volledige sourcing beslissing en wijst op de mogelijke beperkingen en de mogelijkheden van het selecteren van een nieuwe sourcing-strategie.
Nieuwe infrastructuurprojecten zijn meer geschikt voor de nieuwe sourcing-strategieën, aangezien de bestaande infrastructuur organisatie vooral gericht is op de bestaande onderhoud sourcing-strategie. Met andere woorden, organisaties blijven liever bij de sourcing-strategie die al in gebruik is.

Een beperking van het raamwerk is dat het slechts een kwalitatieve analyse betreft, en ontbreekt aan kwantitatieve bewijs van de geldigheid van de sourcing-selectie. Om infrastructuur beheerder the overtuigen om nieuwe sourcing-strategieën aan te nemen is een kosten-batenanalyse vereist van de sourcing-strategie.
Aanvullende nationale en organisatorische factoren kunnen per geval worden vereist. Dit hangt af van welke factoren actief zijn per land. Door de integratie van de nationale en organisatorische factoren in het sourcing besluit, worden de asset organisaties verplicht om alle aspecten die relevant zijn te onderzoeken en met bewijzen hun sourcing-besluit te onderbouwen. Door de focus van de middelen van de organisatie door middel van betere onderhoud uitbesteding, kan de organisatie lenen en zijn onderhoud kennis te verbeteren. Het doel van een sourcing raamwerk moet zijn om ‘state of the art’ onderhoud sourcing-paradigma’s te introduceren in de landen en organisaties die vaak geen ervaring hebben met excellent infrastructuurbeheer. Vaak zijn onderhouds problemen in deze landen groter dan de capaciteit en capabiliteit van lokale beheers organisaties.
Het belangrijkste doel is ervoor te zorgen dat de waterkeringen gedurende de gehele levenscyclus voldoende veiligheid bieden tijdens overstromingen door gebruik te maken van de beste sourcing van onderhoud. Dit vereist niet alleen technische kennis van de waterkeringen, maar ook van de huidige omstandigheden van de omgeving waarin het onderhoud sourcing-dilemma zich afspeelt. Het geven van een gestructureerde en complete aanpak voor de inkoop beslissing voegt waarde toe aan het overstromingsrisico management proces en geeft kennis aan de overstromingsrisico organisatie.
PREFACE

The making of this Master’s thesis was one of the most challenging ventures I have undertaken thus far. The path leading to this report was always winding into every direction. The research started with a 3 month stay in Jakarta, which was eye opening in many ways. Being confronted with the real-life situation will always win from the textbooks. Since my return I have spent many months looking for solutions that may help the Indonesian people be safe from floods. In this thesis I present my findings and hope it may serve the greater cause of ensuring a durable and lasting flood defence of Jakarta.

This thesis would have never been accomplished without the help of some people. I am in their debt and would like to express my gratitude and thanks to them.

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1 INTRODUCTION

Flood defences such as seawalls, embankments and tidal barriers provide communities with flood protection. Once constructed these structures need to be maintained so they can keep their function of flood risk reduction. Flooding in urban areas is an increasingly important issue. Disaster statistics show flood events becoming more and more frequent (Jha et al., 2012). The impact of flooding is driven by a combination of natural and human-induced factors. As recent flood events in Pakistan, Brazil, Sri Lanka, New York, Australia and Indonesia show, floods can occur in widespread locations and can sometimes overwhelm even the best-prepared countries and cities. With new flood infrastructure projects underway, it is of importance that these assets are well maintained and not neglected after construction, as is often the case.

1.1 Flood risk in Jakarta

Jakarta is one of the cities in an emerging country that is at risk of flooding, either by discharge due to heavy rainfall or high sea water levels. To reduce the risk of flooding of urban development for the city of Jakarta a new Master Plan has been made called the National Capital Integrated Coastal Development or NCICD in short (W+B, 2014). The plan consists of a large-scale development for flood defences that includes the construction of new (and the upgrading of existing) seawalls, embankments and pumping installations. A new flood management organization will be formed, dedicated exclusively to the maintenance and operation of the flood defences that will be constructed for the NCICD project. Since Jakarta is in need of flood defence asset management knowledge, engineering firms from the Netherlands are offering their assistance in this endeavour.

The known and tested measures for urban flood risk management are typically classified as structural (or engineered) measures and non-structural (or management) techniques. The structural measures consist mainly of the flood risk infrastructure listed above. Maintenance management of flood risk infrastructure can be considered as a vital non-structural technique. A combination of measures to form an integrated approach is most likely to be successful in reducing flood risk. In the short term and for emerging countries in particular, the factors affecting exposure and vulnerability are increasing at the fastest rate as urbanization puts more people and more assets at risk. In the long term climate scenarios are likely to be one of the most important drivers of future changes in flood risk. Due to large uncertainties in climate change projections, adaption to the changing risk needs to be flexible to a wide range of future scenarios and to be able to cope with potentially large changes in sea level, rainfall intensity and snowmelt. In many countries dealing with flooding in urban areas, land subsidence due to groundwater extraction compounds the impact of sea level rise. This is also the case in Jakarta, where in some parts of the city relatively high rate of land subsidence occurs. Climate uncertainty and budgetary, institutional and practical constraints are likely to lead to a combining of structural and non-structural measures for urban flood risk management. The NCICD infrastructure is seen as the structural measure for flood risk reduction of Jakarta. A capacity building effort, where non-structural measures such as asset maintenance are devised to optimize the effect of the structural assets over their intended lifetime is undertaken simultaneously.
1.2 The Build-Neglect-Rebuild paradigm in emerging countries

Throughout the lifespan of infrastructure, maintenance activities are required to ensure that the required performance levels are upheld. Satisfactory lifetime performance of civil infrastructure assets is of critical importance to sustained economic growth and social development in a modern society. Public works infrastructure that is allowed to deteriorate leads to increased costs for businesses and ultimately consumers (Frangopol & Liu, 2007). Maintenance in general can be considered to entail all decisions related to upholding the high level of performance with respect to availability and reliability of assets (Ben-Daya, 2009). Maintenance tasks can consist of repair, replacement, modification or check-ups of assets (Parida & Kumar, 2009). The way maintenance is organised can vary from organisation to organisation, depending on the type of assets and the objectives of the organisation, however two aspects are to be taken into account, namely the level on which maintenance is carried out and a structure supporting maintenance that includes planning, day-to-day decisions and resources (Ben-Daya, 2009). According to Mobley (2008) maintenance is a science, an art and a philosophy. It is a science because carrying out maintenance depends on nearly all forms of science. It is an art because similar problems are solved in varying approaches and it is a philosophy because maintenance can be applied “intensively, modestly, or not at all”.

When critical infrastructure is neglected, consequences can have severe implications for the people who are dependent of the services of the infrastructure. Inadequate infrastructure maintenance has long been considered a challenge (World Bank, 1994, pp. 5-15). Failure to maintain physical infrastructure has led to its premature deterioration in what is sometimes referred to as the Build-Neglect-Rebuild (BNR) cycle (Mohanty, 2005). Breaking the BNR cycle is essential. For the introduction of improved maintenance methods in emerging countries, new infrastructure projects offer better opportunities for BNR paradigm shift than existing infrastructure, where certain maintenance habits are entrenched.

The problem of inadequate maintenance is essentially one of poor asset management (World Bank, 1994, p. 6). Limited attention is given to the management of infrastructure assets, resulting in insufficient resourcing and planning for on-going maintenance requirements. This has resulted in a large infrastructure debt – representing the gap between what has and what should have been spent on infrastructure. The premature deterioration of infrastructure affects lives. It translates into less people having access to hospitals; fewer children going to school; deaths from vehicles colliding when negotiating pot holed roads; and disease resulting from the contamination of water sources because of blocked drains, untreated sewerage, and the exposure of hazardous waste (McGovern et al., 2013). The lack of preventative maintenance is also costly in a financial sense. It is well known that preventative maintenance provides a better financial return than investment in new infrastructure. De Sitter’s Law of Fives estimates that in the case of concrete structures, “every dollar of routine maintenance that is deferred will end up costing $5 in repairs, or ultimately, $25 in rehabilitation or replacement as the asset declines overtime” (De Sitter, 1984).

Inadequate maintenance of flood risk management infrastructure can lead to diminished levels of flood safety that can lead to aggravated damages in critical events, such as flooding due to high intensity rainfall or high sea levels. In developed countries advanced concepts for maintenance and infrastructure asset management have been
produced which have lead to the establishment of international standards for the upkeep of infrastructure such as the ISO 55000 for Asset Management (IAM, 2008b), however much of these standards are not yet fully adopted in emerging countries. It is the author’s opinion that due to differences between developed countries and emerging countries, some of the novel and advanced concepts of these standards may be difficult to transpose on the prevalent maintenance culture in these emerging countries. The question then arises how emerging countries can bridge the infrastructure debt in a pragmatic way that is in line with the prevailing conditions and utilizes the state-of-the-art knowledge on (1) maintenance, (2) flood risk management and (3) outsourcing. Figure 3 presents this setting (emerging countries) in which the overlapping fields of knowledge should be seen.

![Figure 3 Thesis positioning](image-url)
1.3 Maintenance sourcing strategies

Traditionally maintenance of public infrastructure was provided internally by the government agency responsible for the infrastructure. Management thinking during the 1980s was emphasizing the benefits of vertical integration (Tsang, 2002). A company that is vertically integrated owns the supply chain of that company or more downstream elements for the service it provides. This is also known as the ‘make-or-buy’ decision companies are faced with for their supply chain. External suppliers are used when:

1. The in-house maintenance service provider does not have sufficient capacity, or
2. The expected volume of maintenance work is too small and the variety of maintenance related specialist skills too wide to justify a specialist, or
3. The organization did not have the expertise and facilities to perform the maintenance work.

In the past decades, a new trend has emerged that subscribes to the concept that unprecedented business performance can be achieved if the skills and resources are leveraged to focus on a set of core competencies – a bundle of skills and technologies that enables an organization to provide a particular benefit to customers. As a result maintenance activities for which the company has neither a strategic need nor a special capability can be subject to outsourcing. The maintenance services typically outsourced include the maintenance and repair of generic and common equipment, electronics, environmental equipment, buildings and grounds, projects and improvements, as well as asset overhauls. The selection of the way the maintenance service is delivered is not just a tactical matter. The decision of maintenance should be made in the context of the company’s overall business strategy. Existing maintenance sourcing strategies vary from in-house sourcing, where the organization itself does all maintenance activities, outtasking and hybrid outsourcing, where several maintenance activities are externalized and done by a contractor, and full outsourcing, where a contractor performs all maintenance activities for the client.
1.4 Problem analysis and formulation

Due to inadequate maintenance of flood defence infrastructure in emerging countries, urban deltas in those regions are at an increased risk of flooding. The effects of floods are compounded when design levels of flood defence infrastructure are not met due to lack of proper maintenance. This can lead to high costs for (re-) construction after disasters. This BNR paradigm must be broken to ensure flood safety levels are kept up. New infrastructure projects offer better opportunities to break the BNR paradigm then existing infrastructure. Studies have been done on the field of maintenance of infrastructure in emerging countries, but mainly have the road, building, and water supply sectors as its scope (Dailami & Klein, 1997; Hui & Tsang, 2004). Research on maintenance of flood defences in emerging countries has mostly been based on experiences in practice. Apparently flood risk management infrastructure differs in a way that makes it challenging for scholars to research. In the opinion of the author this is partly due the magnitude of infrastructure; the road sector is much bigger than the flood risk management sector and therefore demands much more attention in the academic literature. The way in which system performance is measured is also pivotal in the attention that it receives.

Outsourcing the delivery of maintenance activities for any civil infrastructure is seen as a way to improve business performance, however the practice of outsourcing of maintenance is rarely applied to the maintenance of flood defence assets. The practice of outsourcing is applied to infrastructure for which there is more emphasis on availability and where users can be clearly identified, such as road infrastructure or power utilities. Since the design life cycle of infrastructure is often 50-100 years, long-term maintenance provision is needed. There is a gap between the theoretical decision-making models concerning maintenance outsourcing for road and utilities infrastructure and decision-making models for maintenance of flood risk management infrastructure. The international standard for Asset Management doesn‘t give guidelines on how to structure the way maintenance is delivered through outsourcing strategies (IAM, 2008a). In some European countries pilot projects have been performed where flood defence maintenance is being delivered through outsourcing, however this is based on extensive experience in outsourcing maintenance in other infrastructure sectors.

Maintenance of flood defences is often neglected due to budgetary, institutional or practical constraints. Shortcomings of maintenance of flood defences are often not visible until a flood event and policy makers can postpone decisions with regard to maintenance in favour of more ‘pressing’ matters. Deferred maintenance is not performed until after flood events, when damages due to flooding have already been sustained. Transparency of flood management organization and spending is needed and adding transparency is seen as a benefit that can be achieved through outsourcing of maintenance. It can be concluded that decision-making process for maintenance of infrastructure is influenced by many external factors, often leading to sub-optimal maintenance decisions and action is often undertaken reactively after flood events have taken place.

To visualize the problem a model is presented which represents the variables of this research and aims to find the mechanism of dependencies between all the variables. This model is seen in Figure 4. The conceptual model entails 4 variables, namely, (1) Flood defence performance, (2) maintenance needs, (3) sourcing strategy decision, and (4) organizational design. These variables have a relationship and it is hypothesized that a
feedback loop is present between the variables organizational design and the sourcing strategy decision. The system is influenced by external factors, such as prevailing governmental regulations, access to asset specific knowledge, available budgets, cultural aspects, etc. The necessary flood defence performance determines the maintenance needs. These maintenance needs influences the sourcing strategy decision. Then a feedback loop occurs as the sourcing strategy decision determines the organizational design, while said design influences the sourcing strategy decision.

**Figure 4 Maintenance sourcing schematization**

It can be stated that despite previous research on flood risk management and new standards of asset management, there is a gap of knowledge of how an optimal sourcing strategy for flood asset maintenance is selected. Especially in countries with emerging markets there is a demand for knowledge on flood risk management, (flood defence) maintenance and outsourcing strategy selection. By focussing on the selection of an outsourcing strategy for the maintenance of flood defences in Jakarta a method can be devised which may be applicable for other emerging countries that face similar decisions.

### 1.5 Relevance of this research

Inadequate maintenance of flood risk infrastructure aggravates the damages caused by flooding. Outsourcing and privatization of non-core maintenance tasks have led to improved performance results for governments around the world, but the sourcing strategy decision is a complex undertaking that has many external influences that differ per case. There is a big challenge in ensuring that the design lifetime is reached through implementation of infrastructure maintenance in a way that optimizes all the costs and benefits. Flood defence infrastructure is different since it is public infrastructure for which the end users are often not taxed directly for its service. The context in which the maintenance outsourcing strategy decision is made influences the process. For instance, governmental, cultural and judicial characteristics of the subject country influence the applicability of a certain outsourcing strategy. This research aims to find a way to structure this process of strategy selection and help out managers faced with maintenance
delivery issues for non-productive infrastructure such as flood defences. The research will use the NCICD case to determine if a sourcing strategy can be determined in a structured way.

1.6 Research question and objectives

The purpose of this report is to address this gap in current knowledge and answer the following main research question:

What sourcing strategy for the maintenance activities of flood defence structures is best suited for the NCICD case in the Jakarta urban delta?

The research question is answered by dividing it into relevant sub-questions. The objectives of these sub-questions are to break the main research question into parts, to structure the research process. The research questions are exploratory, descriptive or explanatory in nature. Exploratory research can be defined as the initial research into a hypothetical or theoretical idea, descriptive research can be defined as attempts to explore and explain while providing additional information about a topic, and explanatory research can be defined as an attempt to connect ideas to understand cause and effect.

1. What are the relevant performance standards for flood defences?

To comprehend what performance standards there are for flood defences an analysis is needed to gain insights into how flood defence performance is defined and how this is measured. This part is seen as an exploratory research.

2. What are the maintenance requirements for flood defences?

To comprehend the scale of activity needed for flood defence maintenance an in depth research is needed to gain insights into the maintenance requirements for flood defences. This part is also seen as an exploratory research.

3. What are the conditions influencing the maintenance sourcing decision making process?

The conditions that influence the sourcing decision are seen as the variables that are needed for the decision process. By performing an analysis of the dependent and independent variables that influence the sourcing decision, the available control measures can be identified. This part is considered as an exploratory research.

4. Which outsourcing of maintenance strategy options can be considered for flood defence maintenance?

The strategies for outsourcing of maintenance need to be identified to provide possible solution space for the sourcing decision. The reference cases are used to gain practical insights. Each strategy has specific traits best suited to the strategy. These need
to be identified and evaluated on suitability for the NCICD project. This part is considered as descriptive research.

5. How can a theoretical decision-making framework for the selection of maintenance outsourcing strategy be constructed?

A decision support framework for maintenance sourcing is required to select the best suited sourcing strategy. If there is a suitable framework that helps the sourcing strategy decision-making process this can be used, otherwise a framework needs to be constructed for this research. This part is considered as explanatory research.

6. Which maintenance outsourcing strategy for the flood defences of the NCICD case is seen as most beneficial as the result of this research?

When all relevant variables are distilled from the literature it is possible to select the most beneficial maintenance outsourcing strategy for Jakarta through a decision-making framework. Thus the chosen strategy is based on the findings from the reference cases. This part is explanatory research.
1.7 Research strategy

This research uses mainly qualitative information. Quantitative analysis relates to financing schemes or cost efficiency calculation of a certain solution. To fulfil the objectives set out for this research first a literature review is performed. An understanding of the types of flood defences that are used is essential to determine the flood risk performance standards. The maintenance requirements that follow from these standards help us understand the work (packages) involved. With this knowledge a maintenance outsourcing decision can be made with help of a rough decision making framework. The reference cases are used to refine the choice of sourcing strategy. The reference cases have been selected in the Netherlands since the variety of flood defence assets that are planned in Jakarta are all currently in the Netherlands in similar fashion and various degrees of maintenance outsourcing is applied with these reference cases. Four variants of maintenance sourcing strategies will be formulated. The selection of maintenance sourcing strategy will be focussed on the NCICD project in Jakarta, but may be applicable to other Indonesian flood defences. In Figure 3 all elements can be seen in a model of the thesis research.

1.7.1 Reference cases

For this research three reference cases located in the Netherlands will serve as source of practical knowledge of maintenance sourcing of flood defences. The three cases have been selected for their high degree of asset specificity as well as their novel methods of maintenance sourcing and maintenance management in general. All cases are connected to a certain aspect of the test case of the NCICD project.

Maasvlakte 2 – Rotterdam

This project includes the construction of a new port and supporting infrastructure on reclaimed land adjoining the Maasvlakte in the Netherlands. An 11 km long seawall consists of partly soft flood defences (dunes and beach) and partly hard flood defences (dikes). Maintenance for the hard seawall is outsourced to Van Oord dredging. The NCICD project also entails large stretches of hard seawall.

Spuicomplex IJmuiden

The pumping station complex near the sluices of IJmuiden, Netherlands is the largest pumping station in Europe with a capacity of 260m³ per second. Part of the maintenance is included in the primary phase of the asset lifecycle. For the NCICD project a pump capacity of similar magnitude is considered.

Dutch Water boards

The Dutch water boards, or waterschappen offer valuable insight into maintenance practices for embankments and other flood defences. These water boards are responsible for maintenance and are frequently audited for their performance. The maintenance of the assets is in some cases outsourced to maintenance companies.

The structure of the final report is shown in Figure 5.
Figure 5 Thesis structure and content
2 LITERATURE STUDY

2.1 Introduction

In this chapter the gap of current knowledge needed for this research will be discussed in Section 2.2. From this starting point the literature study will examine the current knowledge on maintenance sourcing for flood defences. The literature study can be divided into 3 domains, namely knowledge on flood risk management (Section 2.4), knowledge on maintenance of infrastructure (Section 2.5), and knowledge on sourcing theory (Section 2.6). Knowledge of flood risk management forms the basis for sensible decision-making with respect to floods in urban areas. The importance of maintenance engineering in the upkeep of civil infrastructure forms the core of this thesis and will be discussed in detail. The goal is to ascertain the needed level and the right form of maintenance for flood defences. Sourcing theory in literature will be researched to find the guiding principles for the selection of a sourcing strategy for outsourcing. This will help form the framework for a maintenance sourcing strategy decision for the Jakarta NCICD flood assets.

These three domains of knowledge are either based on theoretical knowledge or organizational best practices. This research is focused on the area where these fields of knowledge overlap. This is conceptualized in Figure 3.

Maintenance of infrastructure has been researched by e.g., Frangopol and Liu (2007) and Coetzee (1999), whereas the sourcing of infrastructure maintenance delivery has been researched by e.g. Schoenmaker (2011) and Hui and Tsang (2004) and others (Baldwin, 1997; Kakabadse & Kakabadse, 2000; Murthy & Jack, 2008). With regard to flood risk management, maintenance of flood defences is sparsely included (Hall et al., 2003; Sayers et al., 2002). Maintenance management is mostly seen as a separate part of flood risk management, although some see benefits in integral flood risk management (Hall et al., 2003), where maintenance is included in the early stages of flood defence development. Strategic maintenance outsourcing has been researched by Hui and Tsang (2004) however other infrastructure, such as roads (Schoenmaker, 2011) are typically considered for outsourcing. Distinctions between asset functions might be the cause of this prioritisation in research with regard to outsourcing of asset maintenance. Research on asset maintenance in developing countries has been done, but mainly focuses on the lack thereof. With this literature study the first two sub-questions are answered and a context for the remainder of the research is given. These two sub-questions are “what are the relevant performance standards for flood defences?” and “what are the maintenance requirements for flood defences?”

2.2 Gap of knowledge

In this section the gap in necessary knowledge to make a well-founded maintenance sourcing strategy will be exposed. This thesis aims to provide new insights into maintenance sourcing strategies. It is however important to ensure this is not already broadly investigated by other authors. The lack of necessary knowledge will be presented in the following section.

Flood defences and drainage systems are subject to on-going operations interventions. For example pump operation and maintenance activities such as channel clearance. In England, the Environmental Agency tends to subject these activities to different decision-making procedures than large capital works. Hall et al. (2003) sees this
as incorrect as operations and maintenance interventions are no different in principle from more costly interventions; they are designed to alter the risk profile of the flooding system in some beneficial respect. Hall also argues that the principle of proportionality of analysis should be applied, and that it is inappropriate to set up elaborate maintenance models in systems where the cost of maintenance is fairly low. In the Netherlands, this is demonstrated by the development of statistical maintenance models for the maintenance of the scour protection on the huge Eastern Scheldt storm surge barrier (van Noortwijk et al., 1997), while for the majority of the country’s flood defences, maintenance is based on more simple rules of thumb, though these too reflect the need to direct attention to the most critical elements of the system (De Loof & Van Der Meer, 1998). Hall also addresses the linkage between operation and maintenance and monitoring activities. The monitoring activities are one of the most responsive types of intervention in the flooding system. Real-time control of drainage systems can significantly improve system performance by making efficient use of storage capacity and avoiding, where possible, system states that have undesirable outcomes.

Maintenance of infrastructure such as road, rail, and communication networks, public buildings, dams etc. owned by governments, local, provincial or national, was traditionally done by in-house maintenance departments. According to Murthy and Jack (2008) there is a growing trend towards outsourcing these maintenance activities to external agents so that the governments can focus on their core activities. For flood defences, maintenance outsourcing is mostly considered for specific maintenance tasks, although recent projects have shown more extensive forms of outsourcing applied in flood defence maintenance. The Maaslakte 2 and Spuicompex IJmuiden are such projects and will be discussed in Section 3.1 and 3.2. Outsourcing maintenance and maintenance management for large parts of flood infrastructure is relatively novel and therefore not often evaluated (Haughton et al., 2015). According to transaction cost economics, asset specificity, along with bounded rationality and opportunism influences the optimal governance structure for maintenance sourcing (Baldwin, 1997). Part of this research is to understand what specific traits of flood defences allow for outsourcing of maintenance activities.

While many developed countries are accustomed to outsourcing of maintenance, it is less so in many developing countries. This is partly due to low income levels that impose constraints on the maintenance activities that can be funded out of government revenue and through direct fees and charges (McGovern et al., 2013). This can also be said of Indonesia, where maintenance of infrastructure is executed primarily by the public works departments. This is a culturally embedded phenomenon known as swakelola, otherwise known force-account labour, and is extensively used for national road maintenance, which is increasingly out of line with international best practice (World Bank, 2012). As a result, the national road agency retains a large number of workers, which generally leads to less efficient maintenance work. International experience suggests that applying performance-based contracts can improve efficiency in (road) maintenance. Several countries in Latin America and Africa have phased out the force account approach and moved towards performance-based contracting. Some neighbouring countries, such as the Philippines, Cambodia, Thailand and Vietnam, already have ongoing performance-based contract pilot projects. However, Indonesia has

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1 Swakelola may be literally translated to self-management.
not yet commenced with a pilot of this nature although the debate about maintenance by forced account has been continuing for well over a decade.

2.3 Section Summary

When it comes to maintenance management in flood risk management literature, often the gap between the design and operational phase is addressed. From the perspective of hydraulic engineering more focus is given to the new construction of flood defences rather than on its operation and maintenance. Outsourcing of maintenance is often researched more intensively for productive infrastructure such as road networks or production plants used by the industrial sector. In European countries, such as the Netherlands, outsourcing of certain maintenance activities in flood risk management is becoming standard practice. In emerging countries a lack of infrastructure maintenance is often observed. Root causes can be found in force account labour, when the government agencies retain a large number of workers compared to the private sector. This leads to a costly execution of works without performance incentives.
2.4 Flood risk management

2.4.1 Introduction

In this section theory on flood risk management will be presented. Both the technical and non-technical measures to reduce flood risk will be investigated. Understanding what causes floods and damage by floods helps us better understand what impact correct application of maintenance of flood defences may have. Flood risk management skills are needed to analyse, assess and mitigate the risks of floods. After this chapter the following questions can be answered:

i. What are the basic principles of flood risk management and how are flood safety levels determined?

ii. What flood risk challenges do coastal cities in emerging countries face in the future?

iii. In what degree can maintenance contribute to attaining flood risk management goals?

iv. What are considered to be water governance opportunities in maintenance of the NCICD project in Indonesia?

The first part of this chapter will handle the basic principles of flood risk management, with a focus on emerging countries and maintenance of flood defences. The second part will concern water governance and the opportunities for Indonesia.

2.4.2 Floods and flood risk

Floods are considered to be one of the most threatening natural hazards for human societies (e.g. WBGU, 1999). An increase in damages due to a series of extreme floods in the last 50 years is testament to that fact (Munich Re Group, 2004). The 2004 tsunami in South East Asia caused 220,000 deaths, which makes it probably one of the most disastrous floods. During the International Decade of Natural Disaster Reduction (IDNDR) from 1990 to 1999 it was determined that the term “flood protection” was inappropriate (UNDRO, 1991; Plate, 1997). This paradigm gives the appearance that absolute protection from floods is achievable. Absolute protection is unachievable and unsustainable, because of high costs and inherent uncertainties. Instead, risk management has been recommended as being more suitable and this paradigm is now receiving growing attention within flood research (e.g. Hall et al., 2003; Hooijer et al., 2004; Plate, 1997; Schanze, 2002). Flood risk management deals with a wide array of issues and tasks ranging from the prediction of flood hazards through their societal consequences to measures and instruments for risk reduction. Structures involved with flood risk management are called “flood defence structures”, although there is some objection to this term for the reasons given above.

The Oxford English Dictionary defines a flood as “An overflowing or irruption of a great body of water over land in a built up area not usually submerged.” (OED, 1989). Phrased otherwise as “a temporary covering of land by water outside its normal confines” (FLOODsite-Consortium, 2005). Floods can occur in small and large river basins, in estuaries, at coasts and locally. Besides these settings, floods can be systematised according to the cause of events, such as monsoon rainfall floods, convective storm induced floods, snow-melt floods, sea surge and tidal floods, tsunamis, rising ground
water floods, urban sewer floods, dam break or reservoir control floods (Schanze, 2006). Each flood event can be characterised by features such as water depth, flow velocity, matter fluxes, and temporal and spatial dynamics.

Flooding in most cases is a natural phenomenon, which, for example, in natural floodplains cannot be classified as a threat. Still, floods in extensively used catchments are often influenced by man through land use, river training etc.

The probability of the occurrence of potentially damaging flood events is called flood hazard (ITC, 2004). Potentially damaging means that there are elements exposed to floods which could, but need not necessarily, be harmed (FLOODsite-Consortium, 2005). Floods become a cause of concern when they exceed the coping capacities of affected communities and damage lives and property (Jha et al., 2012).

The flood hazard encompasses events with various features. For instance, a building in a floodplain can be threatened by a 50-year flood, with a water level of 1 metre and by a 100-year flood, with a water level of 1.5 metres. Moreover, these events may be associated with different transport capabilities regarding debris, sediment and other (e.g. toxic) substances with varying impacts on man and the environment.

Damage by flood hazards depends on the vulnerability of exposed elements. The term vulnerability refers to inherent characteristics of these elements which determine their potential to be harmed (Sarewitz et al., 2003). It can be understood as a combination of susceptibility and societal value (FLOODsite-Consortium, 2005). In contrast to the societal value, which is independent from the hazard, susceptibility indicates the process of damage generation (Penning-Rowsell, 2005). It depends on both the type of flood event with its features and the nature of the elements at risk. Three basic areas of flood vulnerability can be distinguished according to the principle of sustainability: social and cultural, economic and ecological vulnerability. Social and cultural vulnerability refers to loss of life, health impacts (injuries), loss of vitality, stress, social impacts, loss of personal articles, and loss of cultural heritage. Economic vulnerability alludes to direct and indirect financial losses by damage to property assets, basic material and goods, reduced productivity, and relief efforts. Ecological vulnerability comprises anthropogenic pollution of waters, soils and ecological systems with their biota (Schanze, 2006).

**Flood risk**

Flood risk emerges from the convolution of flood hazard and flood vulnerability (WBGU, 1999). It can be defined as “the probability of negative consequences due to floods” and depends on the exposure of elements at risk to a flood hazard. In terms of floods it is seen as harm to elements at risk due to probable flood events. It should not be confused with risk in terms of reliability, which plays a major role for quantifying the safety of structural works for flood protection (Plate, 1997).
In order to describe flood risk the conceptual Source-Pathway-Receptor-Consequence Model (SPRC-Model) has been proposed (Fleming, 2002) see Figure 6. It shows a simple causal chain ranging from the meteorological and hydrological events either in inland or at coasts (sources) through the discharge and inundation (pathways) and the physical impacts on elements at risk (receptors) to the assessment of effects (consequences). The chain links ‘source’, ‘pathway’ and ‘receptor’ refer to the physical process, whereas the assessment of the ‘(negative) consequence’ is a matter of societal values.

In terms of flood risk, ‘source’ and ‘pathway’ represent the flood hazard. ‘Source’ is determined by the probability (p) of flood events with a certain magnitude and other features (m). Early warning (w) and the retention capacity of the source areas of inland floods (t) can be considered as two risk reduction factors. The ‘pathway’ can be described by the inland discharge or coastal overflow and inundation (i) with various attributes (a) and interventions for flood control (c). ‘Receptor’ and ‘(negative) consequence’ state the vulnerability, whereas ‘receptor’ specifies the susceptibility (s) with interventions to strengthen resistance and resilience (r). ‘Consequence’ stands for the harm to values (v; damage) with interventions to decrease or to compensate them (d). Accordingly, flood risk can be expressed by the following function:

\[
\text{Flood risk} = f ((p,m,w, t)_{\text{sources}}, (i, a, c)_{\text{pathway}}, (s, r)_{\text{receptor}}, (v, d)_{\text{consequence}})
\]

In reality the causal chain of the SPRC-Model occurs for each element at risk and each flood hazard. Moreover, complex interrelations exist between pathways, interventions for flood control and the exposure of vulnerable elements. In some cases the interrelations consist of multiple feedbacks. A system, which is assumed to include all related elements and processes, is called a “flood risk system”. For inland floods it refers to river catchments, for coastal floods to coastal cells as areas, which are hydraulically connected. The overall risk associated with a flood risk system can be described as the sum of risks of all individual elements.

Flood risk management

The term management is used in at least two different ways in the literature on floods, either excluding or including risk analysis. The first understanding is based on the hydrological reliability of existing flood risk infrastructure. Management is interpreted as decisions and actions undertaken to mitigate the remaining risk above flood protection design standards. Dealing with flood risks in this case means carrying out flood risk analysis and then flood risk management interventions (e.g. Hooijer et al., 2004;
Marsalek, 2000; Oumeraci, 2004). The second understanding defines management as decisions and actions undertaken to analyse, assess and (to try to) reduce flood risks. In this case flood risk management covers the risk analysis, risk assessment and risk reduction (Hall et al., 2003; Plate, 1997; Sayers et al., 2002). This thesis focuses on the maintenance of flood risk infrastructure so the second understanding of flood risk management is best suited. Against this background, it is recommended that flood risk management should be defined as ‘holistic and continuous societal analysis, assessment and reduction of flood risk’. ‘Holistic’ refers to the flood risk system which should be considered as comprehensive as possible. The term ‘continuous’ expresses the need for an on-going assessment of flood risks, their dynamic change and effects of reduction activities.

In more concrete terms the reduction of flood risk is performed in large part by technical measures. These flood defences are designed through analysis and assessment of flood risk and have the primary function of reducing flood risk. The performance of flood defences can be determined by:

1. Hydraulic loads; based on the return interval of a certain water level. So for instance a storm that occurs once per 100 years may result in a water level of 2 meters.
2. Probability of failure: the flood defence may fail due to load or other mechanisms.
3. Availability of service; some flood defences, such as pumps or flood gates need to be available during flood events and should work properly to fulfil their function.

These performance standards will guide the maintenance requirements that are needed to maintain the flood safety level. Studies into current and future flood safety levels have been performed to assess the need for adaption to future scenarios.

2.4.3 Flood exposure in coastal cities

Flood exposure is increasing in coastal cities (RJ. Nicholls et al., 2008) owing to growing populations and economic assets, the changing climate, and land subsidence. According to a recent study into future flood losses in major coastal cities. Average global flood losses in 2005 are estimated to be approximately US$ 6 billion yearly, increasing to US$ 52 billion by 2050 with projected socio-economic change alone (Hallegatte et al., 2013). When sea level rise, subsidence and adaption to maintain probability design level are taken into account the average annual losses (AAL) may differ significantly. This can be seen in Figure 7.
The study found the city characteristics that influence the vulnerability in 2050. The coastal cities that grow rapidly, have large populations, are poor, exposed to tropical storms, and prone to land subsidence are over represented in the top 20 for absolute average annual losses. When considering relative increase in annual average losses, and adaption to maintain present flood risk is included, these drivers are not as relevant. Land subsidence seems to be the only consistently good determinant of vulnerability for both absolute and relative measures of change, with twice the number of cities with subsidence in the top 20 based on the two indicators (absolute and relative losses). This is the case for Jakarta, that is experiencing severe land subsidence. According to the study Jakarta will have an increase of 54% of the AAL to GDP ratio when comparing the scenario with socio-economic change alone and scenario where land subsidence and sea level rise is taken into account. According to Hallegatte “the cities most vulnerable in relative terms may thus not be the ones suggested by the present situation and historic floods, nor are they the ones that necessarily attract the most research and analysis today with respect to managing risk.” Hallegatte concludes that “On the basis of anecdotal evidence (…) a few billion US dollars per city in initial investment—plus approximately 2% of the initial investment cost in annual operation and maintenance costs—is the possible order of magnitude for adaptation costs.” This corresponds with the findings of other studies mentioned earlier in this section. According to Brinkman and Hartman (2008) the flood damage in Jakarta sustained during the 2007 flood was aggravated due to a lack of maintenance.

### 2.4.4 Water Governance

Flood risk management takes place as a decision-making and development process of actors. According to potential interventions on the flood risk system these actors represent various fields (e.g. water board, spatial planning authority), adjacent areas (e.g. multiple municipalities) and different levels (e.g. local, regional, national, international). The decision-making and development process varies depending on the

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**Figure 7** The 20 cities with the highest loss in 2050 with scenario SLR 1 (Hallegatte 2013)

<table>
<thead>
<tr>
<th>Urban agglomeration</th>
<th>Scenarios with socio-economic change alone (SEC)</th>
<th>Scenarios with socio-economic change, subsidence, sea-level rise and adaptation to maintain flood probability (scenarios SLR 1, and adaption option PD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou (5)</td>
<td>11,928 (AAL (US$ million)) 1.52% AAL (percentage of city GDP)</td>
<td>Guangzhou (5) 11,928 (AAL (US$ million)) 13,200 (AAL (per cent of city GDP) 0.99% Increase in AAL compared with 2005 (%) 1.46%</td>
</tr>
<tr>
<td>Mumbai (5)</td>
<td>6,109 (AAL (US$ million)) 0.87% AAL (percentage of city GDP)</td>
<td>Mumbai (5) 6,109 (AAL (US$ million)) 6,414 (AAL (per cent of city GDP) 0.99% Increase in AAL compared with 2005 (%) 0.49%</td>
</tr>
<tr>
<td>Kolkata (5)</td>
<td>2,704 (AAL (US$ million)) 0.1% AAL (percentage of city GDP)</td>
<td>Kolkata (5) 2,704 (AAL (US$ million)) 3,350 (AAL (per cent of city GDP) 0.26% Increase in AAL compared with 2005 (%) 1.08%</td>
</tr>
<tr>
<td>Guayaquil (5)</td>
<td>2,633 (AAL (US$ million)) 0.96% AAL (percentage of city GDP)</td>
<td>Guayaquil (5) 2,633 (AAL (US$ million)) 3,136 (AAL (per cent of city GDP) 1.08% Increase in AAL compared with 2005 (%) 0.40%</td>
</tr>
<tr>
<td>Shenzhen (5)</td>
<td>2,629 (AAL (US$ million)) 0.38% AAL (percentage of city GDP)</td>
<td>Shenzhen (5) 2,629 (AAL (US$ million)) 2,549 (AAL (per cent of city GDP) 0.36% Increase in AAL compared with 2005 (%) 0.36%</td>
</tr>
<tr>
<td>Miami (5)</td>
<td>2,099 (AAL (US$ million)) 0.03% AAL (percentage of city GDP)</td>
<td>Miami (5) 2,099 (AAL (US$ million)) 2,276 (AAL (per cent of city GDP) 0.30% Increase in AAL compared with 2005 (%) 0.30%</td>
</tr>
<tr>
<td>Tianjin (5)</td>
<td>1,910 (AAL (US$ million)) 0.24% AAL (percentage of city GDP)</td>
<td>Tianjin (5) 1,910 (AAL (US$ million)) 2,056 (AAL (per cent of city GDP) 0.08% Increase in AAL compared with 2005 (%) 0.08%</td>
</tr>
<tr>
<td>New York—Newark (5)</td>
<td>1,643 (AAL (US$ million)) 0.6% AAL (percentage of city GDP)</td>
<td>New York—Newark (5) 1,643 (AAL (US$ million)) 1,933 (AAL (per cent of city GDP) 0.83% Increase in AAL compared with 2005 (%) 1.42%</td>
</tr>
<tr>
<td>Ho Chi Minh City (5)</td>
<td>1,483 (AAL (US$ million)) 0.74% AAL (percentage of city GDP)</td>
<td>Ho Chi Minh City (5) 1,483 (AAL (US$ million)) 1,864 (AAL (per cent of city GDP) 1.8% Increase in AAL compared with 2005 (%) 1.42%</td>
</tr>
<tr>
<td>New Orleans (5)</td>
<td>1,483 (AAL (US$ million)) 1.7% AAL (percentage of city GDP)</td>
<td>New Orleans (5) 1,483 (AAL (US$ million)) 1,483 (AAL (per cent of city GDP) 1.7% Increase in AAL compared with 2005 (%) 1.7%</td>
</tr>
<tr>
<td>Jakarta (5)</td>
<td>1,339 (AAL (US$ million)) 0.41% AAL (percentage of city GDP)</td>
<td>Jakarta (5) 1,339 (AAL (US$ million)) 1,750 (AAL (per cent of city GDP) 0.22% Increase in AAL compared with 2005 (%) 0.22%</td>
</tr>
<tr>
<td>Abidjan (5)</td>
<td>1,226 (AAL (US$ million)) 0.72% AAL (percentage of city GDP)</td>
<td>Abidjan (5) 1,226 (AAL (US$ million)) 1,023 (AAL (per cent of city GDP) 0.89% Increase in AAL compared with 2005 (%) 0.89%</td>
</tr>
<tr>
<td>Chennai (Madras)</td>
<td>825 (AAL (US$ million)) 0.12% AAL (percentage of city GDP)</td>
<td>Chennai (Madras) 825 (AAL (US$ million)) 939 (AAL (per cent of city GDP) 0.14% Increase in AAL compared with 2005 (%) 0.14%</td>
</tr>
<tr>
<td>Surat (5)</td>
<td>905 (AAL (US$ million)) 0.25% AAL (percentage of city GDP)</td>
<td>Surat (5) 905 (AAL (US$ million)) 928 (AAL (per cent of city GDP) 0.26% Increase in AAL compared with 2005 (%) 0.26%</td>
</tr>
<tr>
<td>Zhanjiang (5)</td>
<td>806 (AAL (US$ million)) 0.5% AAL (percentage of city GDP)</td>
<td>Zhanjiang (5) 806 (AAL (US$ million)) 891 (AAL (per cent of city GDP) 0.55% Increase in AAL compared with 2005 (%) 0.55%</td>
</tr>
<tr>
<td>Tampa—St. Petersburg</td>
<td>763 (AAL (US$ million)) 0.26% AAL (percentage of city GDP)</td>
<td>Tampa—St. Petersburg 763 (AAL (US$ million)) 859 (AAL (per cent of city GDP) 0.29% Increase in AAL compared with 2005 (%) 0.29%</td>
</tr>
<tr>
<td>Boston (5)</td>
<td>741 (AAL (US$ million)) 0.3% AAL (percentage of city GDP)</td>
<td>Boston (5) 741 (AAL (US$ million)) 793 (AAL (per cent of city GDP) 0.14% Increase in AAL compared with 2005 (%) 0.14%</td>
</tr>
<tr>
<td>Bangkok (5)</td>
<td>596 (AAL (US$ million)) 0.07% AAL (percentage of city GDP)</td>
<td>Bangkok (5) 596 (AAL (US$ million)) 734 (AAL (per cent of city GDP) 0.09% Increase in AAL compared with 2005 (%) 0.09%</td>
</tr>
<tr>
<td>Xiamen (5)</td>
<td>572 (AAL (US$ million)) 0.22% AAL (percentage of city GDP)</td>
<td>Xiamen (5) 572 (AAL (US$ million)) 729 (AAL (per cent of city GDP) 0.29% Increase in AAL compared with 2005 (%) 0.29%</td>
</tr>
<tr>
<td>Nagoya (5)</td>
<td>564 (AAL (US$ million)) 0.26% AAL (percentage of city GDP)</td>
<td>Nagoya (5) 564 (AAL (US$ million)) 644 (AAL (per cent of city GDP) 0.30% Increase in AAL compared with 2005 (%) 0.30%</td>
</tr>
</tbody>
</table>

* (5) indicates that the city is prone to significant subsidence. Most of these cities are located in deltoid regions, where subsidence influences local sea level in 2050.
political, administrative, planning and cultural systems. How these systems vary is part of the water governance policy of a nation and that is the topic of this section.

The term ‘water governance’ is an increasingly popular term in water management context. In the 1990s, scholars seized on the term ‘governance’ to make better sense of the situation that had arisen in many countries after the 1980s, when ‘big’ government had retreated under the pressure of neo-liberal reformers like Margaret Thatcher and Ronald Reagan (IVM, 2012). In essence power and authority from the nation state has been transferred to markets, to civil society, to independent bodies and the courts, and to both higher and lower jurisdictional levels (based on Huitema 2005).

![Governance model](#)

**Figure 8 Governance model**

The shift from government to governance is illustrated by this diagram, which shows the transfer of power and authority from the nation state towards:

- Lower and higher jurisdictional levels (de-concentration, decentralization, devolution, Europeanization, globalization);
- Markets (privatizations, quasi markets, contracting out, public–private partnerships);
- Civil society (networks, self-governance, participation);
- Independent bodies (agentification) and courts (juridicialization).

Water governance can be described as a range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society (Rogers & Hall, 2003). With these three different levels of governing/governance are meant:

1. The level or layer of the problems to be solved or the opportunities to create,
2. The level or layer of the institutions,
3. The level or layer of the normative foundation.

The Dutch Water Governance Centre (WGC) sees water governance as “the way the management of flood risk and water resources, fresh water supply and waste water treatment are organized, and the interaction between the organizations responsible for
the related political, administrative, social, legal and financial elements.” Many organizations are involved in water issues, all on their own competences and disciplines. Together they make sure that clean and fresh water supply is guaranteed, while flood risk is reduced to a minimum (Havekes, Hofstra, et al., 2013). More information on water governance is available in Appendix A.

Although the organization of water management varies globally, the WGC has identified five basic principles for a sound administrative organization for water management:

- A clear allocation of water-related tasks;
- Sufficient administrative organizational scale;
- A number of suitable (legal) administrative powers;
- An adequate system of funding;
- Transparency, participation and accountability.

Of these principles the WGC notes that adequate maintenance of flood defences is “unfortunately all too often forgotten” (Havekes, Hofstra, et al., 2013). These principles must be present in a country as the core prerequisites good water governance, a part of which is sound flood defence maintenance. Outsourcing of maintenance might be considered as a way to give substance to some of these principles. The benefits of outsourcing can lead to more cost-efficient maintenance delivery, improved accountability of maintenance and a focus on core competencies.

### 2.4.5 Indonesian water governance opportunities

In a quickscan performed by the Netherland Water Partnership (NWP) the opportunities for Dutch-Indonesian cooperation on water governance have been identified (Havekes, vd Kerk, et al., 2013). The research team assessed the Jakarta Coastal Development Strategy and identified the opportunities for water governance. A recurring theme in the quickscan findings is the lack of maintenance organization in the current situation. This is indicated as the need for institutional development and capacity planning and the need for a life cycle approach to project including maintenance and operation. The quickscan also recognizes Public-Private partnerships as an opportunity to improve water resources management in Jakarta area. The report further gives guidelines on how Dutch assistance in Indonesian water governance opportunities can be structured. It mostly deals with the non-technical aspects of water governance and gives the conditions for water governance in Indonesia that need specific attention.

### 2.4.6 Section Summary and conclusion

Communities that are at risk from floods need flood risk management interventions to analyse, assess and reduce the risk of floods. Floods can never fully be prevented, however the risk of flood must be treated through technical and non-technical measures. The performance of flood defences is based on design water level, probability of failure and availability of service and adequate maintenance of flood defences is needed to ensure flood safety levels are kept during the asset life cycle. Maintenance of flood defences should be considered as an integral part of the development of flood defences. Port cities need to adapt to future socio-economic changes as well as sea level rise and land subsidence. Cities that experience subsidence, such as Jakarta, relatively are among
the most exposed to flood damage. Neglected maintenance often results in aggravated costs of flooding.

Governments are moving from government to governance, transferring water management tasks, such as maintenance, to the markets. Water governance concerns the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society. The five principles of sound organization for water management prescribes the conditions needed for good water governance. The maintenance organization in water governance of Indonesia has been shown to have opportunities for improvement according to the WGC.

This chapter began with some questions, which now can be answered.

- **What are the basic principles of flood risk management and how are flood safety levels determined?**

  Flood risk management is the holistic and continuous societal analysis, assessment and reduction of flood risk. Flood safety provided by flood defences is determined by the design water level, probability of failure and availability of the asset. Maintenance requirements flow from these flood safety levels.

- **What flood risk challenges do coastal cities in emerging countries face in the future?**

  Coastal cities are increasingly exposed to floods due to growth of population and wealth, sea level rise and land subsidence. Even if investments to adapt current flood defences remain the same flood probability, subsidence and sea-level rise will increase the global losses due to floods. If cities want to maintain present flood risk, they will need adaption to reduce flood probabilities below current values. In this case, the magnitude of losses when floods do occur would still increase, often by more than 50%, making it critical to also prepare for larger disasters than are experienced today. Jakarta is one of the cities that experiences land subsidence and of which it is expected that flood losses would increase significantly even when maintaining present flood risk.

- **In what degree can maintenance contribute to attaining flood risk management goals?**

  Maintenance of flood defences is needed to maintain the design flood safety levels. Neglect of maintenance leads to added losses during floods. In Jakarta neglected maintenance resulted in aggravated flood losses after the 2007 floods. It is estimated that 40% reduction of flood risk could been reached if regular maintenance had been carried out. Based on experience approximately 2% of the initial investment cost should be spent annually on operation and maintenance. Maintenance should be considered as an integral part of flood defence development.

- **What are considered to be the water governance opportunities for maintenance in the NCICD project Indonesia?**
According to the WGC the water governance opportunities for maintenance for the NCICD are:

- **Adopting a lifecycle approach to ensure maintenance and operation cost are provided for the entire life cycle of the project.** A life cycle approach might lead to higher initial investments, if that means lower lifecycle costs on the long term.

- **Institutional development and capacity building.** The programme management of the NCICD will have new responsibilities. The institutional design, embedment, budget and legal framework for the organization need to be established. Maintenance should have an important role in this new organization.

- **Public private partnerships, innovative contract management and alternative financing mechanisms.** Private sector involvement is essential and there should be incentives that engage the private sector. Maintenance for the NCICD should also offer private sector incentives such as innovative contracts, with more emphasis on quality and long-term objectives than only procurement based on price.

In the following chapter infrastructure maintenance will be researched.
2.5 Infrastructure Maintenance

2.5.1 Introduction

In this section the infrastructure maintenance theory will be presented. Maintenance is often seen as a part of asset management, a perspective that views the whole asset life cycle. The principles of asset management give a broader, more complete picture of what is needed to properly deal with assets during their lifecycle. In the following section the following questions will be answered:

1. What is asset management and how does it help organizations?
2. What is maintenance and what maintenance strategies are suited for flood risk management?
3. How is maintenance of infrastructure performed by emerging countries?

In the first part asset management and maintenance are researched and the relevant definitions and views on maintenance will be examined as well as the advantages of maintenance. The following part will concern the outsourcing of infrastructure maintenance in other industries besides flood risk management. This chapter will conclude with maintenance in emerging countries.

2.5.2 Asset Management

Asset maintenance is a vital process for maintaining infrastructure in good working condition, but it is only one component of asset management. The concept of asset management is not a new but an evolving idea that has been attracting attention of many organisations operating and/or owning some kind of infrastructure assets. The term asset management has been used widely with fundamental differences in interpretation and usage (Too, 2010; Woodhouse, 1997, 2006). Regardless of the context of the usage of the term, asset management implies the process of optimising return by scrutinising performance and making key strategic decisions throughout all phases of an assets lifecycle (Sarfi & Tao, 2004). The primary contributors to the literature in asset management are largely government organisations and industry practitioners. These contributions take the form of guidelines and reports on the best practice of asset management. More recently, some of these best practices have been made to become a standard such as the PAS 55 (Institute of Asset Management, 2008a, 2008b) in the UK. As such, current literature in this field tends to lack well-grounded theories.

For infrastructure asset management, Too (2010) observed two barriers that prevent the advancement and development of asset management in this context. First barrier against the progression of the concept of asset management is the general lack of interest from an organisation due to its operational perspective and therefore it is not able to contribute value to their stakeholders. The second barrier is the contentious state of what constitutes asset management. Over the years many definitions of asset management have been provided (Too, 2010). For the first barrier to be overcome, asset management needs to belong to and involve the entire organization and not just the maintenance department (Davis, 2007). The second barrier is not a clear-cut case. How infrastructure asset management is defined in this report will now be elaborated on.

The working definition of this thesis of asset management is “a process of guiding the acquisition, use and disposal of assets, to make the most of their service delivery
potential and manage the related risks and costs over the full life of the assets” (Leong, 2004). This definition involves all the activities that ensure assets help fulfill the objectives of an organisation, and is therefore concerned with asset “performance, risks and expenditures” (Hooper et al., 2009). Asset management is a relatively new discipline, which over the last 20 years has integrated into a coherent framework a range of disparate activities, including economic and financial analysis and governance, internal control, technical knowledge, performance management, risk management, and systems engineering (Brint et al., 2009). This framework has been formalized into the Asset Management Landscape (GFMAM, 2014), a list of 39 subjects which is comprised of all whole fields of interest for asset management. Maintenance has influence or major impact in at least 26 of the 39 subjects stipulated by the GFMAM (2010), however asset management is more than just maintenance; it also concerns design, procurement, installation, commissioning, operation, decommissioning etc.

More information on the asset management principles and systems can be found in Appendix B.

The Asset Lifecycle

Good asset management requires organisations to consider the ‘whole-life-cycle’ of infrastructure in asset management planning and activities. This means that decisions relating to investment, maintenance, upgrading and operation of assets should be made with consideration for their benefits and costs over the whole-life of an infrastructure asset. Good asset management over the whole-life-cycle of infrastructure assets involves various elements, including:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Initial planning</td>
<td>The planning phase must take into account the current stock of infrastructure and the level and standard of service it provides, environmental factors, customer/community needs and expectations, and how these can be met using available resources. There are many factors that should be considered at this stage, including future demand for infrastructure, possible revenue sources, delivery modalities, and expected impacts of climate change.</td>
</tr>
<tr>
<td>2. Capital Budgeting</td>
<td>A capital management plan consolidates the initiatives, objectives and strategies underlying the current and future management of an entity’s asset base. It sets out a projected long-term outlook and details the asset budget funding strategies for asset acquisitions as well as projected financial impacts on the entity’s financial reports. The long-term budget estimates the operation and maintenance requirements over the life cycle of the asset to identify the future recurrent budget allocation.</td>
</tr>
<tr>
<td>3. Detailed design specification</td>
<td>The detailed design specification of new and upgraded infrastructure assets, with consideration given to the life-cycle costs and benefits/adaptability of different designs. Designs take into consideration the interaction between infrastructure assets and how they result in the delivery of services that are valued by the community.</td>
</tr>
</tbody>
</table>
4. Construction
The construction of new infrastructure, often involving management of external contractors. This can take various models, including contracting out of construction; build, operate and transfer models; or the auctioning of concessions. It also involves collaborating with related sectors to optimise the benefit to the community from the infrastructure.

5. Accounting
A comprehensive asset management policies and procedures guide is important in identifying requirements for compliance with relevant legislation and accounting standards. An effective risk-based internal control structure will ensure that assets are safeguarded against loss, damage or misappropriation.

6. Organisational management
Asset management is integrated into the organisational planning and strategic outlook. Asset performance indicators are applied to the non-financial asset base to establish the condition of an asset and the necessary level and frequency of maintenance. Required standards reflect the quality levels required for optimum asset efficiency and management.

7. Operation & Maintenance (O&M)
O&M of infrastructure is an important stage of the asset life cycle that ensures the infrastructure fulfills the function for which it was designed. O&M, combined with good design, and ongoing adaptability/development, ensures the sustainability of infrastructure. O&M is comprised of many elements, and can involve different modalities.

8. Disposal and decommissioning
The disposal and decommissioning stage can be costly, depending on the infrastructure, and although important is commonly neglected in the planning process.

Source: (McGovern et al., 2013)

It is important to take into account the life cycle and the affiliated costs per activity. This can be demonstrated with reference to typical costs at each stage of the life cycle. Life-cycle costs can be much higher than initial construction and supply costs when operation, maintenance and disposal of infrastructure are considered. Life cycle costing can be defined as “a method of economic analysis for all costs related to building, operating and maintaining a project over a defined period of time” (Harvard, 2010). Maintenance costs alone are often equal to or higher than the discounted initial cost of infrastructure. This is illustrated in Table 2 and Figure 9. If the useful life of an infrastructure asset is assumed to be 20 years, this implies that annually maintenance spending should be approximately five to six per cent of the non-depreciated value of the asset.

The World Bank has developed rough estimates of maintenance needs for different infrastructure sectors: 2% of the replacement costs of the capital stock for electricity generation, rail and road; 3% for water and sanitation; and 8% for mobile and mainline telecommunications. For buildings, 5% is used. According to Jonkman et al. (2013) estimated costs of management and maintenance of flood defences in the Netherlands and Vietnam are about 1%–2% of the typical unit costs of raising the defences. For complex storm surge barriers the maintenance costs are relatively high. These costs have been estimated at 5%–10% of the construction costs.
These numbers represent the minimum annual average expenditure on maintenance required to maintain the network’s functionality. They do not include maintenance required to rehabilitate infrastructure where routine maintenance has led to its deterioration (Fay & Yepes, 2003). The results of Hallegatte presented earlier of approximately 2% of the initial investment cost in annual operation and maintenance costs.
Table 2 Cost breakdown of infrastructure (McGovern et al., 2013)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Rate %</th>
<th>Construct/ Supply only ($)</th>
<th>+ Other Up-front ($)</th>
<th>20 year Maintenance ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept &amp; Planning</td>
<td>2-5</td>
<td>2-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detailed design specification</td>
<td>5-10</td>
<td>5-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction/ supply</td>
<td></td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Contingency/ escalation</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contract supervision</td>
<td>2-5</td>
<td>2-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating 1</td>
<td>Variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance – Routine 2</td>
<td>0-5</td>
<td>0-100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance – Periodic 3</td>
<td>5-10</td>
<td>10-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disposal &amp; decommissioning 4</td>
<td>Variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>100</td>
<td>120-130</td>
<td>10-120</td>
</tr>
</tbody>
</table>

Notes:
1. Varies from zero (e.g. for buried pipes) to 20 per cent p.a. for mobile plant and equipment.
2. Varies from close to zero (e.g. for buried pipes) to five per cent p.a. for routine maintenance of assets such as gravel roads.
3. Based on 20-year asset life with periodic maintenance every seven years.
4. Varies from close to zero to 100 per cent (e.g. clean-up of toxic chemical sites).
5. Varies based on the infrastructure in question and across sectors.

Source: National infrastructure Investment Plans, various.

Figure 9 Cash flow over asset lifecycle

The adoption of a life-cycle approach is also important due to links between the various life-cycle stages. Poor construction can increase maintenance requirements of an infrastructure asset. UN-HABITAT even goes so far as to describe adequate infrastructure maintenance “as a corrective measure to faulty design and construction practices” (UNHABITAT, 1993).
2.5.3 Maintenance

An important element of asset management is maintenance, which involves activities designed to prolong the useful life of an asset and/or add functionality. In a broad sense, maintenance is seen as the sum of the decisions related to maintaining a high level of availability and reliability of assets. Maintenance can be defined as “the combination of all technical and administrative actions, including supervision, intended to retain an item in, or restore it to a state in which it can perform a required function” (Parida, 2006). Maintenance tasks can consist of repair, replacement, modification or check-ups (Parida & Kumar, 2009). Aiming at optimal maintenance can be reached through setting the right maintenance objectives; does a company strive towards lowest cost, maximal availability of equipment or maximal flood safety for civilians. Van Horenbeek and Pintelon have identified the definition of maintenance objectives as “…to support the production process with adequate levels of availability, reliability, operability, and safety at an acceptable cost (Van Horenbeek & Pintelon, 2014).

Types of maintenance

There are many terms that can be used to denote maintenance. A very practical insight into the different types of maintenance is provided by Seeley (1987).

![Figure 10 Maintenance types (Seeley, 1987)](image)

Other forms of maintenance types are suggested by Schoenmaker (2011) and Gordon and Shore (1998) who have suggested three maintenance planning horizons that illustrate the conflicting nature of long-term decision-making for asset managers: operational, tactical, and strategic. The operational planning horizon is identified as that within the two-year time frame; the tactical planning is the two to five year time horizon, whereas the strategic planning is planning beyond the five-year term.

On the strategic planning level maintenance relates to the realization of the long-term organizational objectives. On the tactical planning level maintenance planning concerns the achievement of medium to long-term goals. On the operational planning level maintenance relates to the execution of maintenance works and inspection of the assets (Parida, 2006; Schoenmaker, 2011). The way that maintenance is viewed changes from subjective on the strategic level to objective on the operational level.
Operational Maintenance

The execution of maintenance task can be divided into (1) daily maintenance needed to keep the asset functioning, (2) minor maintenance such as small damage repair, (3) structural maintenance and (4) large scale maintenance.

Tactical Maintenance

Maintenance at the tactical level can be divided into fixed and variable maintenance. Fixed and variable maintenance indicate the amounts of financing needed annually for the execution of maintenance. Fixed maintenance concerns the annually returning maintenance activities; in the budget this type of maintenance should lead to a yearly fixed amount. Variable maintenance coincides with planned, large-scale conservation, renovation, and/or renewal that do not return annually (within a limited area). Maintenance that falls under the terms daily and minor maintenance largely correspond with the activities under the term fixed maintenance, whereas activities that fall within the terms structural and major maintenance largely correspond with the activities under the term variable maintenance. It is important for organizations that maintain infrastructure to find the right mix of fixed and variable maintenance. Also important is to realize these two types of maintenance interact. When the interval for variable maintenance is too short, this leads to avoidable costs. The extended continuation of fixed maintenance on the other hand is only justified to a certain interval where the total costs of fixed and variable maintenance are minimal. After that the costs for fixed maintenance increase more strongly than the replacement costs of the asset or part of the asset.
Strategic Maintenance

The third classification illustrates the strategic choices that are possible in planning the right moment for maintenance intervention. The strategic decision is made by balancing the importance of the function of the asset with the risk at failure. Most commonly a distinction is made between run-to-failure, also known as corrective maintenance (CM), and preventive maintenance (PM) (Schoenmaker, 2011). Also recognized, as methods for maintenance are condition based maintenance and design improvements. Based on an assessment of function and risk a choice can be made as illustrated in Figure 12.

Figure 12 Maintenance strategy flowchart (adapted from Schoenmaker, 2011)

The maintenance strategies that can be seen in Figure 12 are:

- **Run-to-failure (RTF).** Only routine servicing is performed on the asset until it fails. This can be justified when the impact of failure is inconsequential or the investment in preventive measures exceeds the expected benefits of improved reliability or higher availability.

- **Preventive maintenance (PM).** The asset is replaced or returned to good condition before failure occurs. The most common forms of this policy are scheduled PM and condition-based maintenance (CBM), respectively. In the former approach, PM action is performed on the item at the scheduled time regardless of its actual condition. The schedule can be usage based or time driven. Since the schedule is often drawn up on the supplier's recommendation made with limited, if any, local knowledge of actual use conditions, or from past experience, it is seldom optimal.

- **Condition-based-maintenance (CBM).** Under the regime of scheduled PM some assets may be over maintained, that is, replaced prematurely. However, if the condition of the item can be monitored continuously or intermittently it will be possible to carry out PM actions only when failure is considered to be imminent. This is the
concept of CBM. Condition-monitoring techniques that support CBM are designed to detect a specific category of faults. For example, vibration monitoring can be deployed to detect wear, imbalance, misalignment, loosened assemblies or turbulence in a plant with rotational or reciprocating parts. A survey of recent work on CBM models can be found in Tsang (Tsang, 1995).

- **Design improvement.** The design is modified to achieve one or more of these objectives: improve reliability, enhance maintainability, minimize maintenance resource requirements and eliminate the need for routine servicing.

The maintenance strategies affect the rate at which deterioration of the asset takes place. The difference between the maintenance strategies can best be illustrated with asset performance models as seen in Figure 13 (Hong et al., 2007).

![Figure 13 Influence of maintenance on deterioration curve (Hong et al., 2007)](image)

According to Schoenmaker (2011) it is important to find the right mix between corrective and preventive maintenance. Too early delivery of maintenance leads to avoidable costs, whereas too late delivery leads to avoidable damage, due to failure of the infrastructure. This leads to a comparable consideration with the mix between fixed and variable maintenance. A right mix between the two strategies leads to minimisation of maintenance costs.

A common methodology to determine the right maintenance strategy is Reliability Centred Maintenance (RCM). RCM is suited to an item and provides a structure for determining the maintenance requirement of any physical asset in its operating context, with the primary objective of preserving system function cost
effectively (IEC, 2009; Moubray, 1997; Smith, 1993). More information on RCM can be found in Appendix B.

When considering flood defence maintenance often only preventative maintenance is considered, since other strategies might lead to failure of flood defences, which leads to unacceptable losses. In most cases significant consequences will follow from failure of flood protection. Thus a run-to-failure or corrective strategy is not considered since this does not help the function of flood defences, namely to prevent damage above the flood protection level. So it should be logical that preventative or condition base maintenance is considered for flood defences and other maintenance strategies should not have to be considered for flood defences.

**Six stage model for maintenance**

Numerous publications (Coetzee, 1999; Crespo Marquez & Gupta, 2006; Sherwin, 2000) address the cyclical nature of maintenance. These publications distinguish three cyclic processes:
- The planning and execution of routine maintenance.
- The identification, planning and execution of maintenance aimed at improving within the existing performance requirements.
- The identification, planning and execution of maintenance due to revised requirements.

Schoenmaker (2011) has developed a six-stage model for maintenance, based on earlier models from Dunn (1999), and Murthy and Kobbacy (2008). All the stages and cycles of the maintenance process can be seen in the six-stage model. Each process step is described in Appendix C. The input needed for the six-stage model consists of the performance requirements of the client, followed by a cyclic process of measurement, analysis, work identification, planning, work preparation and execution. These are the six-stages of maintenance. Data management is seen as a process that supports the maintenance process steps. The output of the model is the performance of the system (of maintained assets).

![Six-Stage model of maintenance](image-url)
The area within the dotted line is the maintenance process that has the goal of maintaining the desired function (of the asset). The output of the maintenance process is the performance that has to comply with the performance requirements that are the input to this model. The model encompasses two of the three cyclic processes mentioned before. The third cyclic process is considered to be a feedback loop from the effects of the delivered performance back to the goals and objectives leading to adjustments when necessary. Should the requirements change, this will show as a change in the input to the maintenance process. A detailed, more formal description of every step in the process is given in Appendix C.

The activities and steps move from abstract to more concrete from left to right. The steps in the right part of the model represent the short-term loop of routine or cyclic maintenance. The work is executed according to predefined plans and the data is updated. The loop with the steps analysis and work identification also includes renewal and improvement of the assets. Based on measurement and inspection, a maintenance database is kept up to date with condition data and performance data of the assets. These data are analysed, and based on the results certain works are identified. The works are planned and budgeted while taking usage, urgency and other interventions into account. Periodically the required budget is confronted with the available budget and possibly leads to different prioritisation of works or to an adjustment of performance requirements. This prioritisation leads to a more detailed planning and preliminary design. Only then will the work be scheduled and finally executed (Schoenmaker & Verlaan, 2013).

The six-stage model is partly to be used to communicate between stakeholders when sourcing maintenance. It can help illustrate the allocation of tasks and responsibilities with different degrees of maintenance sourcing. This can be helpful in strategic discussion on the applicability of maintenance outsourcing for the NCICD assets in Jakarta.

2.5.4 Maintenance in emerging countries

The quality of infrastructure service provision by State Owned Enterprises or SOEs is closely linked to infrastructure asset management and maintenance. Suboptimal asset management happens for more than one reason. A number of interrelated factors are responsible, as highlighted by the United Nations Human Settlements Programme (UN-HABITAT):

“The problem results largely from a lack of awareness of the importance of maintenance and the insensitivity to this issue at the decision-making level; from unclear institutional responsibilities and the resulting lack of accountability; from a lack of trained staff, particularly at the middle-management levels; from a lack of incentives to foster good maintenance; from a lack of planning and rational budgeting; and perhaps most critically, from a lack of financial resources” (UNHABITAT, 1993).

Factors responsible for poor asset management and lack of maintenance that are identified in the literature can be grouped under three headings:

- Resource constraints.
- Organisational constraints, including lack of reliable information and requisite skills.
- Incentives

These factors are illustrated in Figure 15.

![Figure 15 Factors causing maintenance deficit (McGovern et al, 2013)](image)

Most of these factors seem to be present in Indonesia as found by the NWP quickscan and other reports (Havekes, vd Kerk, et al., 2013; The World Bank, 2011; World Bank, 2012).

These barriers lead to a lack of preventative infrastructure maintenance and this lack seems to be the cause of compounded damage by floods. There seems to be a Build-Neglect-Rebuild paradigm that leans on costly corrective maintenance performed after premature deterioration of infrastructure has occurred. Performing timely preventative maintenance actions can improve the costs of maintenance in these emerging countries.

The benefits of preventative maintenance are well documented. Actual benefits differ enormously based on the infrastructure in question, the assumptions that are used, and the infrastructure sector that is being considered. It is clear nevertheless that preventative maintenance reduces service delivery costs in the long run. Consider these cases:

1. De Sitter’s Law of Fives establishes the general rule that for physical concrete structures, every dollar of routine maintenance that is deferred results in a cost of $5 in repairs, or $25 in rehabilitation or replacement (De Sitter, 1984).
2. A study of Longfellow Bridge in Boston found that the total cost of maintaining the bridge in a useable condition would have been $80.8 million lower had an annual maintenance program equivalent to one per cent of the capital cost of the bridge been put in place (Westerling & Poftak, 2007).

3. The South African National Road Agency Ltd. (SANRAL) estimates that the cost of repairing roads increases to six times the cost of preventative maintenance after three years of neglect, and to 18 times after five years of neglect (Burningham & Stankevich, 2005).

Preventative maintenance is equally important in emerging countries such as Indonesia. Although economic analysis of the benefits of preventative maintenance in Indonesia is limited, several cases demonstrate the impacts of poor maintenance:

- The Flood Hazard Mapping of the 2007 flood in Jakarta assessed what would have happened in case regular maintenance was carried out (i.e. in case cross sections are in accordance with the design). In 2007, the floods affected the lives of 2.6 million people in Jakarta. In case all canals were in accordance with the original design, 1.6 million people would have been affected. The conclusion is that about 40% reduction in flood risk could be reached in case maintenance was carried out regularly (Brinkman & Hartman, 2008).

- Deterioration of the electricity network due to lack of adequate maintenance lead to frequent electricity brownouts. In autumn 2009 brown-outs severely affected the city of Jakarta, prompting the state-owned company Perusahaan Listrik Negara (PLN) to start urgent maintenance works (OECD, 2010).

- A study by the World Bank has shown that the costs of maintaining roads in Indonesia have increased and are high when compared to international norms. While many countries have now contracted out most of their routine maintenance works, Indonesia still uses a self-managed approach (known as ‘force account’, or swakelola. Hence, the unit cost of routine maintenance in Indonesia is relatively high (World Bank, 2012).

It is important to distinguish between the financial and economic costs/benefits of routine maintenance. Financial cost-benefit analysis considers the monetary impact of maintenance on the asset management organisation. Economic cost-benefit analysis is more complex, and considers the impact of asset maintenance on society as a whole. The true value of maintenance from a societal perspective – the point of view of both governments and development partners – should be measured using broad-based economic cost-benefit analysis, with consideration of non-monetary externalities such as impacts on health, education, and the environment. The multi-faceted impact of infrastructure makes undertaking these assessments difficult. Financial cost-benefit analysis or least-cost analysis is more common as a result (McGovern et al., 2013).
2.5.5 Section Summary and conclusion

Infrastructure asset management is a more complete approach to asset governance than just asset maintenance. It involves all the activities that ensure assets help fulfill the objectives of an organisation, and is therefore concerned with asset performance, risks and expenditures. The principles of asset management give guidance on how to structure infrastructure asset management.

Implementing asset management requires a lifecycle approach that involves the entire organization and not just the maintenance department. Life-cycle costs can be much higher than initial construction and supply costs when operation, maintenance and disposal of infrastructure are considered. Rough estimates imply that annually maintenance spending should be approximately five to six per cent of the non-depreciated value of the asset.

Maintenance is the combination of all technical and administrative actions, including supervision and monitoring, intended to retain an item in, or restore it to a state in which it can perform a required function. The different types of maintenance are preventative maintenance, corrective maintenance, condition based maintenance and design improvement. Maintenance planning horizons that illustrate the conflicting nature of long-term decision-making for asset managers are the operational, tactical, and strategic horizons. Maintenance managers need to execute the right maintenance tasks (operational), find the right mix between fixed and variable maintenance (tactical) and choose the right maintenance strategy (strategic).

Maintenance can be seen as a cyclical process. The six-stage model encapsulates the three cyclical processes and offers a visual tool that can help allocate the responsibilities of contractor and client in a maintenance outsourcing situation.

In emerging countries often barriers are in place that block the delivery of good asset management. These barriers can be categorized in resource constraints, organisational constraints and incentives. The result is an infrastructure maintenance gap that must be closed. Since preventative maintenance is what is most lacking in these countries each opportunity to break the Build-Neglect-Rebuild paradigm must be seized and applied if proposed change offers improvement in infrastructure maintenance delivery.

The questions at the beginning of this chapter can now be answered:

1. What is asset management and how does it help organizations?

Asset management is the process of guiding the acquisition, use and disposal of assets, to make the most of their service delivery potential and manage the related risks and costs over the full life of the assets. Adopting an asset management approach helps organizations better manage their asset over the entire life cycle of the asset. Asset management concerns the entire organization and not just the maintenance department. Asset management can help organizations reduce costs over the entire life cycle by providing a coherent framework between the different disciplines in an organization.

2. What is maintenance and what maintenance strategies are suited for flood risk management?


Maintenance concerns all technical and non-technical actions, including supervision and monitoring, intended to retain an item in, or restore it to a state in which it can perform a required function. Determining a suitable maintenance strategy often concerns a cost benefit analysis. Since failure of flood protection might lead to unacceptable costs, a preventative maintenance strategy is best suited for flood risk management. This is in line with the greater philosophy behind flood risk management, namely to prevent damage from floods.

3. **How is maintenance of infrastructure performed by emerging countries?**

Preventative infrastructure maintenance in emerging countries is often neglected. There seems to be a Build-Neglect-Rebuild paradigm that prevents the delivery of adequate infrastructure maintenance. The factors responsible for poor asset management and lack of maintenance are:

Organisational constraints;

- Lack of required information
- Lack of required skills
- Roles and responsibilities not clear
- Lack of accountability
- Limited private sector capacity

Resource constraints;

- Inadequate government budgeting for maintenance due to lack of revenue or other priorities
- State Owned Enterprises (SOEs) may not have resources for maintenance, given pricing regimes

Incentives:

- Moral hazard arising from development assistance
- Political incentives lead to prioritisation of new infrastructure
- No culture of maintenance
- Service not valued by customer

Some of these factors need to be taken into account when determining a sourcing strategy. Which factors that should be might follow from the sourcing theory literature study.
2.6 Sourcing of maintenance

2.6.1 Introduction

In this section sourcing theory and its theoretical underpinnings will be investigated as well as its application for maintenance within flood risk management. The following questions will be answered in this chapter:
1. What are the principles of sourcing theory and how can it help organizations?
2. Which are important factors to consider with outsourcing according to transaction cost economics?
3. When is maintenance outsourcing beneficial for a governing organization?
4. How can an asset management authority select a sourcing strategy for maintenance in a structured manner?
5. Is outsourcing of infrastructure maintenance a viable alternative for emerging countries?

In the first part of this chapter the principles of sourcing theory will be presented as well as the benefits for organizations and the potential risks. The second part will concern transaction cost economics, also seen as the theoretical foundation of sourcing theory. In the final part of this chapter the selection of a sourcing strategy will be discussed as well as sourcing in emerging countries.

2.6.2 Sourcing theory

Sourcing theory is guided by the theoretical underpinnings of Transaction Cost economics. Coase (1937) was the first to show that, in situations of uncertainty, it is more efficient for an organization to perform the transaction in-house than to incur the obstructive costs of turning to the market. The framework proposed by Coase, created the basis for the development of the transaction costs theory, which has come to dominate the literature dealing with outsourcing decisions. Using the market or having own staff perform the service both has their own transaction costs and optimal governance structures. Understanding how a transaction can best be sourced helps us form a decision-making framework that can be applied for maintenance of flood defences. Different groups of assets can demand different transactions to be used. Normally generic items can be easily bought on the market. More specific assets can demand more specific contracting or even vertical integration. The type of transaction also determines the governance structure that is best used. The way maintenance sourcing is governed is crucial for the correct delivery of maintenance. Opportunism by contractors is always a point of concern when an organization engages in long-term contracts. Good contracting and correct implementation of the chosen sourcing strategy can mitigate the risks involved with outsourcing. Well-informed decision-making helps to form robust maintenance and asset management of infrastructure.

In the field of maintenance, outsourcing of activities is being increasingly used in the last few years (Akkermans et al., 2012; Gómez et al., 2009), as companies continue to focus more and more on their core competencies and keep look for opportunities for greater flexibility with regard to their non-core operations. This trend has been driven by changes in the business environment and the pursuit of lean operations. Corporations stay lean to reap the benefits of cost reduction, better strategic focus, and agility in responding to fast market changes. The traditional approach to staying lean is through
outsourcing, whereby a whole package of support function is off-loaded to an external service provider (Hui & Tsang, 2004). This contrasts with insourcing, which is defined as the management process of performing a service by in-house staff.

Many definitions of outsourcing are given in the literature. Outsourcing can very strictly be defined as the “managed process of transferring activities to be performed by others” (Bevilacqua & Braglia, 2000). Schoenmaker (2011) defines outsourcing as “engaging an external service provider for the delivery of products or services that contribute to the achievement of the objectives of the outsourcing party, without taking the ownership of specific costs and risks”. This definition is suitable for the remainder of this thesis. The main advantage of outsourcing is conceptually based on two strategic pillars (Campbell, 1995):

1. The use of domestic resources mainly for the core competencies of the company; and
2. The outsourcing of all other (support) activities that are not considered strategic necessities and/or whenever the company does not possesses the adequate competencies and skills.

In terms of maintenance outsourcing, a set of potential and attractive benefits can be reached such as:

- Increase of labour productivity;
- Reduction of maintenance costs;
- Focus of in-house personnel on “core” activities;
- Reduction of the number of staff;
- Obtaining specialist skills not available in house;
- Improvement of work quality, etc.

However, there are some drawbacks to outsourcing that must be taken into account by the customer. Outsourcing exposes the company to the following risks (Campbell, 1995; Schoenmaker, 2011; Tsang, 2002):

- Loss of critical skills. The company can quickly lose its critical maintenance skills after the related services have been outsourced. It will be devastating if it is subsequently found that the contractor does not have the capability or commitment to perform up to expectations and a promising replacement cannot be identified promptly.
- Loss of cross-functional communication. When complete or partial maintenance activities are outsourced, contacts between maintenance and other functions that interact with it tend to reduce, especially when the contractor is operating away from the company's site. This is especially so for the informal communication, not explicitly present in the organization. The contractor’s staff is seldom as prepared as in-house colleagues to go beyond their immediate remit and take the time to work out innovative solutions to problems encountered.
- Loss of control over a supplier. A contractor, after building up its expertise with the outsourcing company’s support, may decide to offer the acquired knowledge to competitors.
Apart from these risk there are other factors that may render the expected benefits of outsourcing unattainable.

1. **Shifts in the balance of power during the contract period** – Managers often overlook the possibility that the balance of power may change during the period of a contract. Companies that have lost their maintenance skills will be at the mercy of their service suppliers when the contractual relationships are adversarial.

2. **Switching costs** - Outsourcing requires internal organizational changes. These switching costs also play in the transition from one contractor to another contractor under the transaction. High switching costs can lead to a hold-up of the client by the contractor. The contractor may exhibit opportunistic behaviour due to the high costs incurred by the client to change the contractor.

3. **Employee morale** - Most employees perceive outsourcing as a negative development.

4. **Hidden costs** - Companies often underestimate the set-up costs of outsourcing.

5. **Hidden services** - There is often internal, hierarchical undocumented services that is absent in the formalization of service in outsourcing (Schoenmaker, 2011).

An important paradigm used to explain outsourcing decisions is based on efficiency considerations of transaction–cost analysis (TCA). The basis of this analysis can be found in transaction cost economics.

### 2.6.3 Transaction cost Economics

The basis for transaction cost economics was the article ‘The nature of the firm’ by Ronald Coase (1937). He posed the question why firms exist if every transaction can be efficiently performed via the price mechanism. Transactions occur “when a good or service is transferred from a provider to a user across a technologically separable interface” (Williamson, 1985). Coase highlighted the difference between market transactions and the structure of organizations, which does not rely on the price mechanism. He stated that the market transactions are not free of costs. Even though firms present a more efficient way of exchange, costs are incurred to structure the organization. So transaction costs depend on how the transaction is organized, i.e., the governance structure. Within an organization, transaction costs include managing and monitoring personnel and procuring inputs and capital equipment. The transaction costs when buying from an external service provider can include source selection, contract management, and performance measurement and dispute resolution (Baldwin, 1997). Thus, the organization of transactions, or “governance structure” affects transaction costs. Following this reasoning on can say that the extent of internalized transactions depends on transaction costs associated with a market transaction and the costs of organizing the transaction internally. Overall, Coase (1937) implicitly derived the concept of transaction costs economics. More on the details of the findings of Coase and transaction cost economics can be found in Appendix D.
2.6.4 Sourcing strategy selection

There are many different authors that have studied the sourcing decision (Kakabadse & Kakabadse, 2000; Kremic et al., 2006; Kremic & Tukel, 2006; Tsang, 2002). When considering the selection of the optimal sourcing strategy the choice between in-sourcing and outsourcing is just the beginning (Hui & Tsang, 2004).

In a seminal paper Kraljic (1983) introduced a comprehensive purchasing portfolio approach, including a matrix that classifies a firm’s purchased items into four categories on the basis of their profit impact and supply risk. Kraljic highlighted purchasing as an important managerial area with an enormous impact on profit. Companies must act in its own advantage and this changes the perspective from purchasing (an operating function) to supply management (a strategic one). Kraljic continues that supply management becomes relevant when critical items are procured throughout complex situations. Supply management becomes even more important if the uncertainty in the buyer-supplier relationship increases. Kraljic means that two factors are important for a supply strategy. The first factor concerns the strategic importance of the purchasing in terms of the value added by the product line, the percentage of raw materials of the total costs and the impact on profitability and so forth (profit impact). The second factor concerns the complexity of the supply market measured by supply scarcity, pace of technology and/or materials substitution, entry barriers, logistics cost and/or complexity, and monopoly and/or oligopoly conditions (supply risk).

![Figure 16: Kraljic matrix (Kraljic, 1983)](image)

Although the Kraljic matrix has a focus on the manufacturing industry, it gave a framework that in the years has been modified by others to suit specific needs. It is focused on the procurement of strategic supplies whereas this research focuses on the off-loading of maintenance tasks. The difference is in that activities currently being performed by the company are assessed on the possibility of outsourcing them instead of the best way to deal with supply management.

Kremic and Tukel (2006) have developed a decision support model for public organizations that consider outsourcing. Their model consists of several steps: first step is “to develop a list of factors and their priorities (...) these are then incorporated in the decision model to guide the organization in making more structured decisions about outsourcing”. After this the functions to be outsourced and the number of contracts have to be determined.
This model provides a structured approach that decision makers can use for the outsourcing decision.

The selection of which functions if any to outsource has been researched by Hui and Tsang (2004), which have developed a sourcing strategy decision matrix for the maintenance of facilities. They identified four service delivery strategies namely:

- a. in-sourcing,
- b. out-tasking
- c. outsourcing for cost saving, and
- d. outsourcing for capability

Core activities are derived directly from the corporate strategy. Once an activity has been identified as non-core, the conventional wisdom is to outsource it to external parties. However, it would be too simplistic a decision to outsource every activity that is classified as non-core, because these non-core activities may contribute to the successful implementation of the corporate strategy to different extents.

Outsourcing often fails to fully meet client expectations. A study of the failure cases has revealed that some of the outsourcing should have been administered from a strategic perspective (Hui & Tsang, 2004). In some situations more input from the client organization was required. In other situations, selective outsourcing or out-tasking may be a better alternative to outsourcing. Outsourcing an entire function might cost more to the company and might be harmful from a strategic perspective (Dubbs, 1992). If, for some reason, slower response cannot be tolerated, quality of outcome is essential or the skill set is important for development of future capabilities, outsourcing the services of an entire function en bloc may not be in the best interest of the company.
From a strategic perspective, a sourcing decision can be made by taking into account both the scope and the purpose of sourcing (Kakabadse & Kakabadse, 2000). If a service is regarded as essential and the purpose of sourcing is for maintaining a capability, the activity will be classified as core and according to the decision matrix, it should be in-sourced. When well-defined tasks have an uneven workload out-tasking is preferred when it can lower the total costs. When a whole package of support functions is off-loaded to an external service provider, this is typically called outsourcing. Outsourcing can either have as primary objective to ensure cost saving or to ensure capability. Outsourcing for capability occurs when the technical requirements are emphasized because qualified service agents are in short supply. This can be formed in a decision matrix that provides guidance for making a sourcing decision as seen in Figure 18.

![Sourcing decision matrix](image.png)

**Figure 18 Sourcing decision matrix (Hui & Tsang, 2004)**

After the sourcing decision is made, the effectiveness depends on the right governance structure and the implementation process of the sourcing method. Choosing the appropriate governance structure has been described in the previous section. The implementation process will be described below.

### 2.6.5 Implementation process

The chosen sourcing strategy will have effect on the organization. According to Tsang the process of implementing a sourcing strategy consists of five stages, namely planning, setting of performance standards, work transactions, performance review, and review of strategy. More can be found in Appendix G.

### 2.6.6 Section Summary and conclusion

Outsourcing is the process where the client offloads a certain task or set of tasks to an external service provider. The advantages of outsourcing are amongst others a better focus on core activities and a reduction of workforce. Some disadvantages are the possibility of losing a critical skill and losing control over the supplier. Outsourcing is guided by the theoretical underpinnings of Transaction cost economics. This theory states that market transactions are not free of costs. Even though firms present a more
efficient way of exchange, costs are incurred to structure the organization. The organization of transactions between providers and users should be designed to maximize net value of the sum of production and transaction costs, based on the characteristics of the transactions. Transactions differ in asset specificity. Governance structures differ in their incentives to maximize net value of costs and in their ability to protect investments in transaction-specific assets. Transactions using relatively generic assets can be outsourced more easily. The governance spectrum varies from the two poles spot markets and vertical integration with in between them contracts of increasing duration and complexity. When asset specificity, bounded rationality, and opportunism make contracting problem severe, vertical integration may be needed to ensure that the value of transaction-specific assets is internalized. These predictions are supported by empirical evidence. Selecting an outsourcing strategy should be done with care, as there are numerous examples of outsourcing gone wrong. Numerous scholars have adapted Kraljic’s decision matrix for supply management. A sourcing strategy decision matrix for maintenance of facilities was developed by Tsang and could be adapted for this thesis. There are 4 sourcing strategies have been identified namely in-sourcing, outsourcing for cost efficiency, outsourcing for capability and out-tasking. Selection between these strategies is done by taking into account the scope and purpose of sourcing. Implementing a sourcing strategy often lead to issues that must be addressed or failure of the new sourcing strategy may follow.

The questions from the beginning of this chapter can now be answered.

1. **What are the principles of sourcing theory and how can it help organizations?**

   The pillars where sourcing theory is based on are (1) the use of domestic resources mainly for the core competencies of the company; and (2) the outsourcing of all other (support) activities that are not considered strategic necessities and/or whenever the company does not possesses the adequate competencies and skills. Applying the right sourcing for services allows organizations to focus on their core tasks. It can help organizations reduce costs, and staff, while becoming more flexible and importing specialist skills that were not present in the organization. There are risks involved with unloading tasks to the market. If outsourcing is to be considered these need to be treated by applying the right governance structure.

2. **Which are important factors to consider with outsourcing according to transaction cost economics?**

   The factors that influence outsourcing can be found in transaction cost theory. These are:
   - **Asset specificity**: the more generic an asset is considered the more it can be outsourced to the market. Increasing specificity adds more transaction specific costs for a potential contractor and these might be better integrated in the client organization.
   - **Duration and complexity**: long term contracts and/or more complex contracts require more attention to the type of contract that is used.
• **Bounded rationality**: because of limited managerial time and span of control, organizations cannot effectively manage an unlimited and even an limited number of transactions internally. This however also works the other way around since bounded rationality limits the capability of markets and simple contracts to handle asset specificity, because the parties cannot foresee and contract for all possible contingencies.

• **Potential opportunism**: if the risk of potential opportunism is severe, vertical integration of the service may be preferred instead of outsourcing.

Findings from the field seem to confirm the predictions of transaction cost economics.

3. **When is maintenance outsourcing beneficial for a governing organization?**

   Maintenance sourcing can help organizations that manage public infrastructure reduce cost and staff, focus on their core activity and allow for more transparency. Specialist skills that are needed can be accessed through outsourcing.

4. **How can an asset management authority select a sourcing strategy for maintenance in a structured manner?**

   There are outsourcing strategy decision support model available. These are often designed for private organizations that are in search of maximizing their net profit. Public or non-profit organizations can also use these models, although they need to be adapted to suit the specific needs. In general sourcing strategy selection requires technical analysis of the functions or services that are considered for outsourcing and an analysis of the organization and its capabilities and objectives. Sourcing strategies can be developed beforehand and selection can take place based on the results of the first two steps. Implementation of the chosen strategy is important, since different strategies may have different issues that may arise.

5. **Is outsourcing of infrastructure maintenance a viable alternative for emerging countries?**

   Outsourcing of infrastructure maintenance is becoming standard practice in western countries, but is still in development in emerging countries. It is suggested that force account labour, which is a barrier to good infrastructure maintenance, might be resolved through outsourcing strategies. If new approaches to maintenance and asset management are to be introduced, new project offer better opportunities then existing infrastructure. Considering outsourcing of maintenance for the NCICD project seems to be a viable and worthy undertaking.
3 SOURCING STRATEGIES OF REFERENCE CASES

3.1 Introduction

In this chapter three reference cases will be presented. These reference cases give insight into maintenance outsourcing for flood defences. Also the results of these reference cases can help form and calibrate the outsourcing strategy decision framework. Three maintenance sourcing examples in Dutch water management have been selected. These are:

- The seawall of the Maasvlakte 2, a land reclamation project of the Port of Rotterdam,
- The pumping station in IJmuiden, one of Europe’s largest pumping stations, and
- The dike maintenance of the waterschappen, the water boards in the Netherlands.

Of each case the flood project will be briefly described, after which the chosen maintenance sourcing and the maintenance tasks themselves will be presented. Also contractor performance monitoring and the used payment and contracting scheme will be addressed. The information is obtained through expert interviews and desk research. The main objective is to observe how maintenance outsourcing is applied in the Dutch setting and how this can help form a maintenance sourcing framework.

3.2 Maasvlakte 2

Project description

<table>
<thead>
<tr>
<th>Project facts:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flood defence:</strong> In total 11.5 km of seawall, 3.5 km ‘hard’ and 8 km ‘soft seawall**</td>
</tr>
<tr>
<td><strong>Asset owner:</strong> Port authority of Rotterdam, transfer to Rijkswaterstaat in 2023</td>
</tr>
<tr>
<td><strong>Maintenance contractor:</strong> PUMA consortium (van Oord, Royal Boskalis Westminster)</td>
</tr>
<tr>
<td><strong>Construction started:</strong> 2008</td>
</tr>
<tr>
<td><strong>Project finished:</strong> 2013</td>
</tr>
<tr>
<td><strong>Maintenance period:</strong> 2013 until 2023, divided in two 5-year contracts.</td>
</tr>
<tr>
<td><strong>Maintenance tasks:</strong> Bi-yearly suppletion of sand and cobblestone; reshaping block dam; repairing damage after storms. Costs of repair after extreme calamities or ‘acts of God’ are not included in contract.</td>
</tr>
</tbody>
</table>

The Maasvlakte 2 (MV2) project is a port expansion of the port of Rotterdam in the Netherlands. The Port of Rotterdam Authority commissioned the expansion and the consortium PUMA, led by Royal Boskalis Westminster and van Oord, was awarded the tender. The cost of construction was estimated to be 2.9 billion euro, but the work ended up 150 million euro under the expected cost. To realise this expansion approximately 2000 hectares of land was reclaimed of which ca. 230 hectares on the outer contour of
the reclamation is intended as seawall. The length of the total seawall is 11.5 km of which 3.5 km is so called ‘hard’ seawall and 8 km is ‘soft’ seawall. The ‘soft’ seawall consists of a sand beach and dune with a crest height of 14 m +NAP\(^2\). The hard seawall can be described as a “cobble stone dune with a concrete block dam” and has a crest height of 14 m +NAP. It consists of:

- A stony dune up to a height of NAP + 14,0 m with a thick covering layer of light rubble (20 – 135 mm), a so called cobble stone beach;
- A block dam up to a height of NAP + 2,0 m applied to the slope of the stony dune, that is fully stable for once per 10,000 year flood conditions.

The design of the seawall is based on a sustainable cost philosophy, applying hard seawall where necessary and soft seawall where possible. Although more expensive in construction then a sand dune, the stony dune will suffer less wear and tear due to the block dam breaking the waves, resulting in a reduced wave attack on the stony dune. This means that the stony dune will need maintenance only after severe weather conditions. The ‘soft’ seawall will require regular sand nourishments, when too much of the dune section is washed away.

**Maintenance sourcing**

The seawall of the Maasvlakte 2 project was commissioned in 2008 and was finished by the contractor in April 2013. The seawall will be handed over to the port authority of Rotterdam in 2018, after a 5-year setup period that has been defined in the contract. Subsequently there is a separate contract for the maintenance of the seawall for the five following years, de facto this means that maintenance is provided by the contractor until 2023. After 2023 the Port authority of Rotterdam will hand over the seawall to the Dutch national public works authority, Rijkswaterstaat, who will become the eventual owner of the seawall. Rijkswaterstaat is responsible for the maintenance of 10% of the primary flood defences, including the entire coastline of the Netherlands. Through this construction, Rijkswaterstaat will be owner in 2023, after the contractor has maintained the seawall for 10 years. This way a track record of 10 years worth of maintenance activities is formed, increasing the predictability and knowledge of maintenance of the asset and thus reducing the risk from the transfer of the asset for Rijkswaterstaat. With this contract, provision of maintenance and operation is the responsibility of the contractor for 10 years, during which he must maintain a level of protection of 1/10000 years. This type of maintenance sourcing, where design and construction is combined with a 10 year maintenance period, will not lead to reduction in maintenance costs, however it does improve the quality and certainty of the asset. Because of this arrangement, the contractor is forced to think about the quality of the construction since this influences the maintenance costs of the asset.

**Maintenance**

During the interview with project engineers it is said that in the contract the responsibility of the contractor is defined as “The management and maintenance needed to ensure that the entire outer contour continues to meet requirements meaning:

\(^2\) NAP or Normaal Amsterdams Peil is vertical datum in use in large parts of Western Europe
minimizing wear and tear due to normal operation, repair of damage to the outer contour’. Maintenance tasks that are needed are sand and cobble stone nourishments, redistribution of sand or cobblestones on the slopes or reshaping the block dam. There is one condition for the maintenance activities of the sand beach, namely that they take place outside of the recreational season.

Not all maintenance tasks are wholly the responsibility of the contractor. Repairs needed to fix “damages due to calamities, including but not limited to ship strandings and extreme storm surges” are not the contractor’s responsibility. These calamities, or ‘acts of God’ exempt the contractor of maintenance or repair costs, however the contractor will perform the repairs. The severe weather conditions are defined as being storm surges with a wave height of 6.75 meters and a minimum duration of 3 hours and gale force winds of 8 Beaufort and higher. After such calamities an inspection must be held to determine the damage caused by the event e.g. how much sand is blown away. The costs of the seawall repair after these events are compensated to the contractor. If the contract would state that the costs of these calamities are the responsibility of the contractor then this would lead to extreme high yearly commissions and the continuity of the contractor’s company would be at risk. The risks of these calamities are in general best borne by the government.

**Monitoring performance**

The contractor must present yearly inspection reports that will be verified by the Port of Rotterdam. This is part of the Management and Maintenance Plan that has been included in the contract. In this plan is defined that in the month of April of each year, after the storm season, a complete survey of the seawall condition has to be presented, where the contractor indicates how much sand or cobblestones have been washed away or displaced and if the safety level is being upheld by the seawall. There should be a buffer of sand enough to last for least 2 storm-seasons. If the contractor is able to provide yearly inspection reports that pass scrutiny, it is relatively free to perform maintenance in every way it sees fit. The contractor can propose a new method or alternative time interval of sand nourishments if he is able to provide proof that the safety level of the seawall doesn’t decline. If it is found that additional design alterations could lead to a reduction of yearly maintenance costs, these can be implemented after consultation with the Port of Rotterdam. Rijkswaterstaat doesn’t interfere with these matters, but watches from the sideline, so it has experience of the maintenance history of the seawall.

**Payment scheme**

The contractor receives a yearly lump sum for maintenance and operation paid out per quarter. Each 3 months the contractor bills the asset owner for following the guidelines set in the Management and Maintenance plan. Maintenance tasks do not have to be specified on the bill; the contractor only needs to indicate that it has followed the commitments established in the management and maintenance plan. If the estimations of maintenance costs have been pessimistic, then the contractor may keep the surplus funds. If maintenance costs prove to be higher than estimated then the contractor suffers the loss. The contractor has the freedom to apply his knowledge of the operation and maintenance of these flood assets to reduce maintenance costs. The money saved is for the contractor, however when there is competition the contractor may have to reduce the price of their services to obtain contracts. If the contractor fails to meet the requirements defined in the contract, the client can impose penalty points on the contractor. For
instance, if the client finds a deviation from the survey of the contractor he can impose 2 penalty points. When the contractor has 5 penalty points or more, the client can deduct money from the quarterly payment.

**Conclusions**

The novel combination of outsourcing of maintenance for the seawall of the Maasvlakte2 with the construction does not lead to a reduction of total cost for the asset owner, however it does improve incentive for innovation in maintenance management. The contractor can apply their knowledge of maintenance and operation of such assets and they can apply their maintenance experience with the seawall to reduce maintenance costs during the contract period. This improves the quality of construction and efficiency during the maintenance phase. For further tenders this may lead to cost reduction if there is sufficient competition between contractors. The asset owner, in this case the port authority can focus on their core business, while sourcing the maintenance to the contractor. The monitoring of performance of the contractor is a responsibility of the client, to check if contractor performs maintenance in compliance with the contract. For the government asset management agency Rijkswaterstaat, the risk of uncertainty associated with the transfer is reduced due to the maintenance track record. It is uncertain if this type of maintenance outsourcing would be applied when the seawall is only protecting residential zones instead of industrial zones. The revenues generated by the Rotterdam Port authority harbour fees fund the seawall at the Maasvlakte 2, which make maintenance more suitable for outsourcing due to private funding of the project.

**Pumping Station IJmuiden**

**Project description**

<table>
<thead>
<tr>
<th>Project facts:</th>
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<tbody>
<tr>
<td><strong>Flood defence</strong>: Pumping station consisting of 4 original pumps with 40 m³/s and 2 newer pumps of 50 m³/s capacity</td>
<td></td>
</tr>
<tr>
<td><strong>Asset owner</strong>: Rijkswaterstaat</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance contractor</strong>: Spie (since 06-2015)</td>
<td></td>
</tr>
<tr>
<td><strong>Construction started</strong>: original 4 pumps constructed 1975, with expansion in 2005.</td>
<td></td>
</tr>
<tr>
<td><strong>Project finished</strong>: 2005</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance period</strong>: tendered for 5 years.</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance tasks</strong>: monitoring pumps performance; replacing worn out parts; major maintenance each 5 years, repairing damage to pumps.</td>
<td></td>
</tr>
</tbody>
</table>

The pumping and drainage complex in IJmuiden is essential for the water management in the western part of the Netherlands (VONK). The owner of the complex is Rijkswaterstaat. The pumping station along with the adjacent locks and sluices and connecting dykes is part of the primary flood defence ‘Sluices IJmuiden’ and performs the primary task of flood protection from sea. The complex also performs a second primary function namely the discharge of water to sea through means of pumping (pumping station) and draining (sluices). The pumping station and sluice together provide by far the most important contribution (+/- 95%) to the regulation of the level of the water system consisting of the North Sea canal, the IJ river and the city canals of
Amsterdam, and the Amsterdam-Rhine canal, including the Lek canal. This water system acts as a drainage canal for large parts of nearby located water boards. The sluices can only drain water into sea when the sea water level is low, so it is only possible to sluice for a few hours a day. The drainage capacity of the sluices is in total 500 m$^3$/s. In extreme conditions, when difference in water level is high, the drainage capacity can reach 700 m$^3$/s. If it is not possible to drain due to high sea water levels and the water levels of the water system are reaching unacceptable heights, the pumping station will be used to maintain water levels in the water system. The goal is to drain about two-thirds of the water through the sluices and one third of the water via the pumping station. In reality this amounts to a 50%-50% ratio.

The pumping station consists of six horizontal screw pumps of which four date from 1975 and have a capacity of 40 m$^3$/s per pump. The other two date from 2005 and have a capacity of 50 m$^3$/s. This expansion meant an increase in pumping capacity from 160 m$^3$/s to 260 m$^3$/s, the current total capacity of the pumping station. This extra pumping capacity was needed to accommodate the drainage need for the coming 50 years. With this capacity it is Europe’s largest pumping complex.

Each pump can be hoisted out by crane and placed into an adjacent maintenance building, where maintenance can be performed in dry conditions. This way every pump can be serviced out of storm season. The newly installed pumps have been manufactured by Pentair Fairbanks Nijhuis.
**Maintenance sourcing**

Maintenance of the pumping station of IJmuiden is outsourced as part of a larger area containing other drainage pumps belonging to the catchment area (Tendernet, 2014). Maintenance is awarded to a contractor for the period of five years, with the option of two times a one-year extension. After five years the contract is either extended or tendered out to another contractor.

**Maintenance and operation**

Hydraulic pumps in general consist of an engine, a gearbox and an impeller. The moving parts of pumps are most prone to wear and tear. These parts are the bearings, pump wear rings, and gearbox of the pump. Inspection of the asset state is an important part of pump. Pump parts can be inspected automatically by installing vibration and temperature sensors and leak detection systems on critical parts of the pump. When installed inspection can be performed off-site in many cases, without the need for hands-on inspection. The contractor can access inspection data from their office instead of visiting the pump.

With regular use major maintenance is required every five years. The contractor is exempt from unforeseen damage to the pump caused by accidents. Unforeseen damage can be caused by debris entering the pump inlet and blocking the impeller or chipping the coating leading to corroding parts, etc. After such damage is discovered, the contractor consults with the client for the appropriate course of action. The costs of repair of these unforeseen damages are mainly for the pump owner, not the maintenance contractor. The contractor will repair the pump after which the client reimburses the costs involved.

Most commonly a preventive maintenance strategy is applied to pumps that fulfil an important flood defence function. The pumping capacity to drain excess water from the water system can be required in a flood emergency that can occur at any given time. A non-functioning pump can be the cause of aggravated flood water levels in the catchment area. When corrective, or run-to-failure, maintenance strategies are used with pumps, repair costs can run up significantly compared to the costs of preventive maintenance. These strategies are applied in other industries when the pump is part of a productive process and the cost downtime and repair are insignificant compared with the revenues of the production process. The pumping complex in IJmuiden has one back-up pump that is used when a regular pump is in service, so the required pumping capacity is available even when a pump is being maintained.

**Monitoring performance**

For the pumping complex in IJmuiden, the contractor presents a yearly maintenance plan to the client. This contains the frequency of planned maintenance and inspection activities and the course of action when a deficiency is found. Since Rijkswaterstaat has extensive experience in the operation and maintenance required for the pumping station of IJmuiden, this performance monitoring of the contractor is often considered tacit knowledge.

**Payment scheme**

A yearly fee is paid to the maintenance contractor for the performed maintenance activities. This consists of monitoring, and the minor and some major maintenance activities included in the contract. As said before, the pump owner carries additional costs.
due to unforeseen events. There is little incentive in the contract to reduce pump maintenance costs. The maintenance contractor is not free to change the maintenance plan at its own will. Any changes to the maintenance frequency and activities have to be approved by the pump owner, in this case Rijkswaterstaat.

Conclusions
A large capacity pumping station as the one in IJmuiden is considered as a relatively generic asset to maintain by the pump maintenance contractor. Extensive experience with pump maintenance by the contractor and client leads to familiarity with costs and maintenance performance monitoring. Outsourcing pump maintenance for the IJmuiden pumping station and sluice complex is not considered novel and when the market is mature and capable pump maintenance can be outsourced to contractors with a duration of several years. By outsourcing not only the pumping station of IJmuiden, but also the other hydraulic structures in the area, the client has only one contractor with whom it has to coordinate activities.
Water management is undertaken at all levels of government in the Netherlands: central government, provinces, water boards and municipalities. Formally the 2009 Water Act allocates the task of water management exclusively to central government and the water boards. In real terms the tasks are shared as follows (Havekes, Hofstra, et al., 2013).

The national government is both responsible for national water policy and, via the agency of Rijkswaterstaat (RWS - the Directorate General for Public Works and Water Management), it is responsible for managing the hydrological main system consisting of the North Sea, the IJsselmeer lake, the Wadden Sea, the Eems-Dollard estuary, the Zeeland delta waters, the major rivers and a number of canals. The national government also bears responsibility for the coastline and is manager of three major flood defences (the Afsluitdijk and the Eastern Scheldt and Maeslant barriers). Central government also manages the main navigation channel.

The 12 provinces are responsible for water policy and the issuing of permits for three significant categories of groundwater extraction (for drinking water, industrial extraction in excess of 150,000m3 per year and for so-called geothermal energy systems). In general they are also responsible for regional navigation channel management.

The 23 water boards, or waterschappen, are responsible for water safety and manage the water quantity and water quality of all other waters, including groundwater and wastewater purification. The water boards are the oldest form of local government in the Netherlands, some of them being founded in the 13th century. They manage approx. 3,600 km of primary flood defences. These primary defences are dykes, dunes and storage basin embankments. They also manage 13,500 km of secondary flood defences, 3,700 pumping stations, 235,000 km of drainage ditches and approximately 360 sewage purification plants. The water boards are also responsible for the control of muskrats and coypu. In certain cases, water boards are also in charge of navigation channel management. The boundaries of the water boards are not just random lines on the map. The area for which a water board is responsible is not determined by municipal or provincial borders, but by the catchment area or drainage basin in a region.

The 408 municipalities are responsible for managing sewerage systems. They also have legal duties of care for rainwater run-off and urban groundwater.
The 10 water supply companies, finally, are responsible for the public drinking water supply. With the exception of the Amsterdam Waternet, which is in the form of a foundation, these are private companies. However, the Drinking Water Act specifies that the shares of these companies must be in public hands, which effectively qualifies them as semi-public organizations (Havekes, Hofstra, et al., 2013).

![Figure 19 Water government organizations in the Netherlands (Havekes, Hofstra, et al., 2013)](image)

This perspective demonstrates that on the one hand the water organization in the Netherlands is entirely public while on the other hand it is extremely decentralized. However, the private sector does play an important role in water management, for example in the construction and strengthening of dikes, the building of pumping stations and waste water purification installations, the maintenance of the embankment and weirs and the replacement of sewerage systems. These are tasks not undertaken by government.

**Maintenance**

Because of the wide array of activities the water boards have, we will focus on the maintenance of dykes, one of the primary flood defences under management of the water boards. Flood protection is regulated in chapter 2 of the Water Act. The water boards have the obligation to ensure good water management in their area. All waterways (ditches, streams, rivers and canals) need to be properly maintained, to ensure that excess water can be drained during the wet season and water can be supplied in dry period.

In order to provide for the long-term safety, these dykes have to be maintained on the basis of 5-yearly inspections as laid down in the Dutch Flood Protection Act. Unfortunately, due to a combination of settlement, subsoil consolidation, and relative sea-level rise, the dykes slowly sink “away into the sea” and should therefore be heightened and strengthened regularly. Regular maintenance of dykes consists of mowing of the embankments and clearing debris from the channel. Every year the water board will inspect every section of dyke it is responsible for and will report its findings to the province. Every 6 years a national review of the state of the primary flood defences is performed. Major maintenance is undertaken when a primary flood defence fails to meet statutory safety standards. Major maintenance is often performed in the context of national plans. These plans prescribe a prioritization scheme for major maintenance...
activities for primary and secondary flood defences. The nHWBP (new Flood Protection reinforcement Programme) is such a programme and will take effect from the year 2014.

Maintenance sourcing
The water boards often source the maintenance for the dykes internally. The water boards have traditionally kept an independent position with the preparation and execution of planned water projects (Economisch Instituu voor de bouw, 2013). They have significant technical knowledge and capacity to perform these tasks. These skills have also been used for the maintenance of their water management assets. Some maintenance execution tasks are outsourced, such as mowing and small maintenance tasks. Also in the performance reviews several tasks such as measuring and reporting are outsourced.

Since several years the water boards have embarked on a process towards other means of tendering and contracting. The main goal is an intensified involvement of the market in projects by using more innovative contracts. In line with the new approach there is more attention to the investment and maintenance challenge in the coming years and for the different types of projects the best-suited ways to engage the market are being sought. In 2013 a uniform purchasing and procurement policy was determined by the water board union, which is aimed at improving the quality of the procurements and the possibilities for innovative procurement.

The extent of maintenance outsourcing is considerably less compared with the preparation and execution of water projects. When outsourcing of maintenance is applied, it concerns limited maintenance work. Some water boards still perform a significant amount of asset management activities themselves, such as maintenance and failure repair. There is however potential for outsourcing of maintenance and there is an increasing degree of maintenance outsourcing on going.

Monitoring performance
All primary flood defences are periodically tested nation wide by Rijkswaterstaat against statutory safety standards (Jongejan & Maaskant, 2013). Dikes that fail to meet these standards have to be strengthened by the water board. The multi-billion euro nHWBP (new Flood Protection Programme) aims to strengthen all primary flood defences that failed the most recent statutory safety assessment. Due to the scale of the nHWBP, priorities have to be set. Yet present-day safety assessments only say which flood defences have to be strengthened (outcomes are binary: flood defences ‘pass’ or ‘fail’), they do not indicate where risks are highest, making it hard to distinguish between the hundreds of kilometres of flood defences that failed the assessment.

To be able to make better-informed decisions about flood risk management, the Dutch Ministry of Infrastructure and the Environment, the Association of Water boards and the Association of Provincial Authorities commissioned a study to gain insight into the probabilities and consequences of large-scale floods. The resulting VNK2-project (VNK is the Dutch acronym for Flood Risk in the Netherlands) is a multi-million dollar, fully probabilistic quantitative risk analysis (QRA) for all fifty-three major levee systems in the Netherlands, as well as a number of embankments along the river Meuse.

The outcomes of these analyses are used to compare the effectiveness of alternative strategies for reducing risks (e.g. strengthening levees, reducing vulnerabilities, or improving crisis management capabilities) and to set priorities within national levee reinforcement programmes. In other words by modelling the effects of different
approaches such as a cost benefit approach to flood risk management, critical elements in the water system in need of maintenance or redesign can be identified better, thus providing a better return on investment.

**Payment scheme /contracting**
The total government expenditure on water-related tasks, including those of the water companies, was 6.9 billion euro in 2013. Of this amount, 2.8 billion euro was allocated to the water boards. In that year, a household that owned its own home paid an average of €696 in rates and taxes for water. This amount is made up of water board taxes (€305) and payments for sewerage charges (€183) and drinking water (€208). In addition, households contribute to the costs taken on by the State by means of their State taxes.

The water boards have the right to tax the constituents of their drainage basin. This tax is divided in a charge for the water treatment and a charge for flood defences and drainage canals construction and maintenance. The yearly costs of works ordered by the water board are currently around 1.04 billion euro (EIB, 2013). This is estimated to increase for the coming years to 1.16 billion euro.

The water boards in recent years seem less inclined than other clients in the water-engineering branch to bring maintenance tasks to the market. Contractors who work for the water boards report that there is hardly any activity unlike other companies. In comparison, Rijkswaterstaat brings relatively more maintenance tasks to the market. It is anticipated that in the coming years the maintenance will become an important market for maintenance contractors in the water sector. This move toward more market participation is also expected to lead to an increase of integrated contracting as opposed to traditional contracting that are still dominating the contracts of the water boards.

For works that fall within the national flood protection programmes such as the nHWBP, a 50/50 financing scheme by the national government and the water boards is used (I&M, 2011).

**Conclusions**
The water boards have extensive knowledge and skills that have allowed them to perform flood defence maintenance tasks primarily themselves. Intensified cooperation with the market is desired to encourage innovative procurement and water management solutions. This move towards the market can also be seen in light of the shift from government to governance. New approaches to prioritization of maintenance activities and participation of the market is also expected to lead to reduction of cost, however it is not clear if this is seen as a driver of maintenance outsourcing.
3.4 **Comparison, summary and conclusions**

In the Table 3 the results of the reference cases is presented. The different approaches to maintenance outsourcing.

<table>
<thead>
<tr>
<th>Flood defence description</th>
<th>Asset owner</th>
<th>Maintenance contractor</th>
<th>Degree of maintenance outsourcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maasvlakte 2</td>
<td>Port of Rotterdam, transfer of assets in 2023 to Rijkswaterstaat</td>
<td>PUMA consortium</td>
<td>Maintenance fully outsourced. Client only monitors performance.</td>
</tr>
<tr>
<td>Pumping station IJmuiden</td>
<td>Rijkswaterstaat</td>
<td>Pentair Fairbank Nijhuis</td>
<td>Maintenance execution and planning outsourced. Client has say in prioritization.</td>
</tr>
<tr>
<td>Water boards</td>
<td>Water boards</td>
<td>Various</td>
<td>Maintenance almost fully performed in-house. Small tasks outsourced to contractors.</td>
</tr>
</tbody>
</table>

**Conclusions**

The cases display a variety of maintenance outsourcing approaches. From the results the following conclusions concerning maintenance sourcing may be drawn:

1. Maintenance sourcing depends on whether maintenance knowledge is internalized or present with private contractors
2. Historical and cultural factors influence the organizational behaviour. The sourcing strategy is enshrined in the organizations collective mind.
3. The intrinsic maintenance performance goals and internal policies of the asset owning organization influence the sourcing decision
4. Public and semi-public flood defence asset owning organizations have different views on sourcing selection
5. New and large projects or project portfolios are more likely to encourage organizations to consider novel sourcing strategies

*Maintenance sourcing depends on whether maintenance knowledge is internalized or present with private contractors*

When maintenance knowledge is internalized in the asset owning organization, the incentive to outsource is less than when the private sector has greater knowledge. Asset management organizations where the client has sufficient knowledge and skills to
perform the maintenance task themselves. Organizations that possess sufficient and have a strong maintenance culture will not resort to external suppliers to provide them with maintenance capacity. The water boards have internalized knowledge on flood risk management. The decentralisation of national water management provides good local water management, with extensive knowledge and expertise by the individual water boards of their own flood defences. The water boards therefore prefer to perform their duties for dyke maintenance in the more traditional manner by sourcing the maintenance activities mainly in-house.

When maintenance is externalized, this will result in a reduction of in-house staff, which may cause objection by the personnel. Since contractors specialise in certain types of flood defences, they may possess extensive knowledge and offer better maintenance performance than the client could. Performance improvement may relate to cost-efficiency, innovative maintenance delivery, or improved construction design.

*Historical and cultural factors influence the organizational behaviour. The sourcing strategy is enscribed in the organizations collective mind.*

The Dutch water boards were formed in the 13th to 17th century. The execution of their tasks predates any sourcing theory. The organizational behaviour is heavily influenced by this historical and cultural factor. The water boards themselves historically execute the maintenance of the flood defences. The water boards do not easily adapt outsourcing partly due to ingrained thoughts on maintenance management. Rijkswaterstaat does move towards more market based sourcing of maintenance. This is due to external political influence and internally meets resistance due to the historical organizational behaviour.

*The intrinsic maintenance performance goals and internal policies of the asset owning organization influence the sourcing decision*

The organizational objectives concerning maintenance determine in part the organization’s maintenance sourcing preference. When the asset owning organization has the objective to ensure that all flood defences are properly maintained by the organization itself, this will mean that all or most maintenance will be sourced in-house. When an asset owning organization has the objective to utilise the potential of the market if possible, this should mean that the market will perform all or most maintenance activities and only the activities that can’t be outsourced will be performed in-house.

Rijkswaterstaat is owner of several large flood defences and is looking for innovative and sustainable ways to maintain these flood defences. Outsourcing offers more innovation and reduces the workforce of Rijkswaterstaat. The principle applied by Rijkswaterstaat is “Market, unless…” indicating the desire to utilize the potential of the market.

Other organizational objectives that may have an influence on the sourcing strategy can relate to innovation, or the workforce size. Innovation in maintenance is primarily market driven, so when an organisation has such goals for innovation its sourcing strategy should be focused on external contractors.

*Public and semi-public asset owning organizations have different views on sourcing selection*

When the semi-public sector initiates flood risk projects they combine commercial interests as well as public interests. Often commercial interests are more compatible with the maintenance outsourcing then sourcing maintenance in-house. Since semi-public have more commercial interests, they are interested in gaining advantages through
outsourcing of tasks. The port authority of Rotterdam has chosen to outsource the maintenance for the Maasvlakte 2 project in contracts with 5-year periods. This strategy offers potential for innovative maintenance, because the contractor can profit from improvements in maintenance delivery. A public asset owning organization provides a public service without having to satisfy commercial interests of shareholders. This does not provide the same incentive to pursue strategic advantages through outsourcing of maintenance.

New and large projects or project portfolios are more likely to encourage organizations to consider novel sourcing strategies

The application of maintenance outsourcing is especially present at larger flood risk management projects, with significant budgets and room for innovation by contractors, such as the Maasvlakte 2 and the pumping station IJmuiden. The period of the maintenance contract used in these cases is 5 years, allowing enough time for the contractor to adapt to the project and enough time for the client to review the contractor’s performance adequately, yet short enough to avoid exposing themselves to risks involved with longer term contracts.

The water boards together have a significant flood defence portfolio, however the organization is decentralized. This means that the separate maintenance work packages are limited. Transaction costs are relatively high when small maintenance packages are outsourced. The water boards themselves are adjusted to provide most of the maintenance work in-house and can levy their own water system tax, thus reducing the incentive to outsource maintenance.

The reference cases show that the experience with outsourcing of maintenance flood defences can be used to develop a framework that incorporates all aspects that are relevant to the flood defence owning organizations. The cases indicate that resistance towards this shift from in-house to market sourcing of maintenance can be expected, when historical and cultural factors influence the organization and the expertise and knowledge on flood risk maintenance is mainly present at the asset owning organization. There is some evidence that adoption of outsourcing is underway. Overall the cases display an increasing move towards outsourcing of maintenance of flood defences. Outsourcing of maintenance is intended to allow innovation of maintenance and reducing the size of the asset owning organization, focussing an organization on their core strategic activities. Reduction of cost is not a primary objective of flood risk maintenance outsourcing in the Netherlands, however outsourcing does improve the transparency of the costs of maintenance towards the general public and other stakeholders. The performance of outsourced maintenance must be reviewed over an extended period of time. Currently there are no indications that outsourcing of flood risk maintenance has a negative effect on the quality of the infrastructure.

These conclusions may not be considered as universal truths concerning flood risk infrastructure maintenance sourcing. The conclusions included here are based on a very limited set of three reference cases. These offers insight into Dutch approaches to flood risk maintenance sourcing, however the results and conclusions based on these cases may not apply to all flood risk infrastructure maintenance sourcing cases and extra care should be applied when non-Dutch cases are interpreted based on these conclusions.
4 BUILDING THE FRAMEWORK

4.1 Introduction

In this chapter the framework for the selection of an outsourcing strategy for the NCICD flood defence will be constructed. The framework will consist of 4 steps:

1. Identification and assessment of maintenance for each separate asset type;
2. Sourcing selection matrix;
3. Adaption of sourcing strategy to national and organizational context;
4. Implementation issues and risk mitigation

This framework will be elaborated in the following sections. The framework and the activities for each step will be described. In the following chapter an initial run of the framework to determine the optimal sourcing strategy for the NCICD assets will be made.

4.2 Framework description

The framework is constructed by applying the theory from the literature study on maintenance sourcing and the conclusions of the reference cases. The cases refine the framework to include experiences from the field in the theoretical framework. Especially steps 3 and 4 are based on the results from the reference cases. The framework setup is seen in Figure 20. With this framework an effort is made to envisage a technical approach to the maintenance outsourcing decision-making. In this following section the steps will be described.

![Figure 20 Sourcing decision framework](image-url)
**Step 1: Identification and assessment of maintenance for each separate asset type**

The first step of the framework consists of identifying and assessing the maintenance workload per asset type. With this step the scope of maintenance work and feasibility of potential outsourcing is given. This step answers the questions ‘*What is the maintenance workload per asset type?*’ and ‘*what is the bare minimum of maintenance that needs to be done by the owner?*’ In other words ‘*which maintenance activities for this asset type can be outsourced?*’

The first question is a straightforward analysis of the maintenance workload. To do this the following is needed:

- A complete flood defence register; this contains all the flood defences that form the flood protection system.
- The design safety levels; abstract design safety levels can be used to derive the performance requirements.
- Failure modes of flood defences; the failure modes determine the maintenance activities that are needed for the asset.

The flood defence register consists of information on the different flood defence types that make up the entire flood defence system. It should contain the designs and characteristics of the flood defence types. The design safety levels of the flood risk system can be broken down into asset specific safety requirements. Combined with the failure modes, the maintenance workload can be identified.

The six-stage model of Schoenmaker can now be used to visualize all maintenance process steps that need to be assessed (Schoenmaker & Verlaan, 2013). All the process steps in the six-stage model form the total maintenance scope. These steps can be seen in Figure 21. The maintenance steps can be seen from left to right moving from more strategic process steps towards tactical and operational.

![Six-stage model maintenance process steps](image-url)
The answer of the second question is more complex namely *what is the bare minimum of maintenance that needs to be done by the owner?* According to sourcing theory the answer is dominated by two things:

- The degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization.
- The asset specificity assessment involved per maintenance process step.

The justification for these two elements follows from the literature from chapter 2 and reference cases from chapter 3. Asset specificity refers to the level of reutilization of the considered goods/process for many different uses. Asset specificity can depend on physical location or unique skills in terms of resources and techniques. Outsourcing processes that need asset specific investments can cause hidden costs and thus determines the ability to bring the work to the market (Baldwin, 1997; Franceschini *et al.*, 2003; Kippenberger, 1997).

The degree in which the maintenance process step is considered essential to ensure the core strategic goals of the asset owning organization are met is determined by the core strategic goals of the asset owning organization. The principle is that in-house resources should only be used for the core competencies of the company and that all other activities that are not considered strategic necessities should be outsourced. Later on in the third step also the organizational skills e.g., whether the company possesses the adequate competencies and skills (provided there is an external agent who can carry out these activities in a more efficient manner) will be incorporated in the sourcing strategy (Murthy & Jack, 2008; Tsang, 2002).

These two elements are needed for the next step in which a preliminary sourcing strategy is chosen based on the results of these two questions.

- The degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization.

The strategic goals of the asset owning organization determine which parts of the maintenance are essential to the asset owning organization and cannot be externalized. The strategic goals can be derived from the organizational mission statement and objectives concerning the asset (Campbell, 1995; Dunn, 1999).

The main strategic goal of a flood risk management organization can shortly be described as *“providing an acceptable level of flood risk for the inhabitants of the hinterland”*. With this strategic goal in mind we can determine if that there are critical maintenance process steps that pose undesirable risks when they are outsourced. Each maintenance process step must be assessed if it is essential or non-essential to the asset owning organization. The definition of an essential maintenance process step is important for this analysis and is defined for this framework as *“an activity that is needed to ensure the design safety level against flooding for a 5 year period”*. The period of 5 years is chosen to ensure that the asset owning organization does not externalize risks that may lead to reduced flood safety levels.

- The asset specificity assessment involved with the maintenance process steps
The expected specificity of the maintenance work is the other important element that determines the degree in which maintenance can be outsourced. The asset specificity of the maintenance transaction determines in significant degree the suitability for outsourcing. If the asset specificity is considerable, the risks for the contractor may be a barrier for maintenance contractors to apply for the tender procedure. For the framework asset specificity is defined as “The degree of transaction-specific investments involved that cannot easily be put to other uses then for the maintenance of the flood defences if the Client/Contractor relationship breaks down” (Baldwin, 1997). For each separate maintenance process step the level asset specificity must be assessed.

**Sequence of maintenance process step analysis**

The maintenance process steps are analysed from operational to strategic. So first the operational maintenance process steps will be analysed. These are *Work Execution* and *Work Scheduling*. Then follow the operational maintenance process steps *Planning/design*, *Data Management*, and *Measurement Inspection*. Finally the strategic maintenance process steps *Prioritisation*, *Work identification*, and *Analysis* are analysed. This sequence is visualised in Figure 22.

![Sequence of assessment](image)

It is important to first assess the operational maintenance process steps that might be essential or asset specific and are therefore not easily outsourced. When this is the case it is follows that the maintenance process steps on the tactical and strategic level are not suitable for outsourcing, since the asset owning organization performs the operational level maintenance process steps itself anyway. This is not explicitly mentioned in literature, however it would be illogical if the client performs the operational maintenance process steps and the contractor would perform all the strategic and tactical level maintenance process steps. How the operational maintenance analysis is performed can be seen in Appendix F.

Once all maintenance process steps have been analysed on the value of the maintenance activities and asset specificity, an assessment of the value of the maintenance
activities and specificity of the total maintenance workload for the asset type can be made.

For this framework the total maintenance workload will be essential when 1 or more of the 8 maintenance process steps are considered essential. If none of the process steps is considered essential, the entire maintenance workload is non-essential.

The total maintenance workload will be considered asset specific when 2 or more of the 8 maintenance process steps have a high degree of specificity. If 1 of the process steps has a high degree of asset specificity, the process step in question determines whether the entire maintenance workload is specific or generic. If none of the process steps is considered specific, the entire maintenance workload is considered generic.

The choice for the value of the maintenance activities and specificity is based on sourcing theory and the reference cases (Dunn, 1999; Hui & Tsang, 2004; Kakabadse & Kakabadse, 2000). It is in part adapted from sourcing theory meant for commercial businesses, where either profit impact and supply risk are the elements (Kraljic, 1983), or the scope of sourcing and the purpose of sourcing (Hui & Tsang, 2004). The scope of sourcing is a very common factor influencing the sourcing decision. Kakabadse and Kakabadse (2000) more aptly adopt the term “Value of activities” to indicate which activities are essential or not.

The asset specificity is more prevalent in technical work requiring specific technical knowledge (Baldwin, 1997). The reference cases have shown that although the sentiment is that flood risk maintenance is difficult to outsource, the practice of maintenance outsourcing is possible in the field of flood risk management.

The more dominant factor is the scope of sourcing. This is due to the fact that it concerns the core competencies the asset owning organization should possess to maintain control over their flood risk system. Asset specificity issues might be resolved by resolved by technological advances or linkages with other projects by the contractor.
Step 2: Selection of a sourcing strategy through the selection matrix
With the next step the sourcing strategy will be determined. The sourcing strategy can be selected on the level of asset specificity and scope of sourcing of the entire maintenance workload for an asset type. The outcome of the first step provides two of the three important elements needed for the sourcing selection. The final elements needed are the sourcing strategies themselves. The strategies are seen in Table 4. Each of the boxes within the dotted line represents a maintenance process step. The maintenance process steps are white when performed by the owner and the black when performed by the contractor. Hatched boxes can be either performed by the owner or contractor or jointly.

Table 4 Sourcing strategies illustrated with six-stage model

**In-house**
The maintenance staff of the owner performs all maintenance tasks. Contractors are not involved in the maintenance process.

**Out-tasking**
An external maintenance contractor is responsible for the work scheduling and work execution of maintenance. The owner is responsible for all other maintenance steps such as prioritization, planning and work identification. The owner also manages the contracts with the contractor.

**Hybrid outsourcing**
Responsibility for maintenance is shared between the external contractor and owner. The planning, work scheduling and work execution is done by an external contractor. The owner either performs the prioritization, work identification and analysis themselves or in collaboration with the contractor.
Outsourcing:
The entire maintenance package is the responsibility of the external contractor. The owner reimburses the contractor based on performance review.

Figure 23 Levels of outsourcing (Schoenmaker & Verlaan, 2013)

These strategies are derived from the literature such as (Dunn, 1999) and implicitly correspond in with the levels of outsourcing found by Schoenmaker and Verlaan (2013). These levels can be seen in Figure 23. The strategy out-tasking corresponds with the outsourcing of the level C activities. The strategy hybrid outsourcing corresponds with the outsourcing of the level B and C activities and joint performance of level A activities. The strategy outsourcing corresponds with the outsourcing of the level A, B and C activities. The strategy in-house can be described as the internal sourcing of all the maintenance process steps, sometimes this is also referred to as insourcing however this thesis uses the term in-house.

The sourcing strategies are more explicitly mentioned in (Hui & Tsang, 2004; Kakabadse & Kakabadse, 2000). The strategies are elaborated on in table 5.
### Table 5 Sourcing strategies

<table>
<thead>
<tr>
<th>Strategy aspects</th>
<th>In-house</th>
<th>Out-tasking</th>
<th>Hybrid Outsourcing</th>
<th>Outsourcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Internal organization</td>
<td>Contractor management</td>
<td>Joint maintenance organization</td>
<td>Contract administration</td>
</tr>
<tr>
<td>Governance mode</td>
<td>Vertical integration</td>
<td>Short term Contract management</td>
<td>Medium to long term relational contract</td>
<td>Medium to long term relational contract</td>
</tr>
<tr>
<td>Size of contractor</td>
<td>N/A</td>
<td>Small</td>
<td>Medium to Large</td>
<td>Large</td>
</tr>
<tr>
<td>Experience with outsourcing</td>
<td>Not required</td>
<td>Preferred</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>Workload of Contractor</td>
<td>None</td>
<td>(Part of) maintenance execution</td>
<td>Maintenance execution and part of maintenance management</td>
<td>Entire function of maintenance</td>
</tr>
</tbody>
</table>

This sourcing strategy is chosen with help of a sourcing strategy selection matrix. This matrix is a two by two matrix with on the vertical axis the asset specificity and on the horizontal axis the scope of sourcing. This matrix can help choose between the four different sourcing strategies. These strategies are clearly formulated to indicate the difference in maintenance sourcing. The matrix is adapted from the matrix of Kraljic (1983).

![Sourcing selection matrix](image)

**Figure 24 Sourcing selection matrix (adapted from Hui & Tsang, 2004)**

The sourcing matrix was adapted for facilities maintenance by Hui and Tsang (2004). This matrix formed the basis for the matrix that is used in this framework, which can be
seen in Figure 24. As was stated in the previous section, the total maintenance workload is considered specific when 1 or more maintenance process steps are asset specific and the workload is considered essential when 1 or more process steps are considered essential. If none of the process steps are essential or specific the maintenance workload is considered non-essential or generic.

Reference cases
Using the sourcing matrix the a sourcing strategy for the reference cases can be devised based only on their asset specificity and value of maintenance activities.

Maasvlakte 2:
The asset specificity of the maintenance tasks are generic and the value of the maintenance activities is non-essential. The Port authority of Rotterdam is a semi-public organization that is primarily tasked with running the harbour. Using the sourcing matrix the sourcing strategy would be Outsourcing. In reality this is also the chosen maintenance sourcing strategy.

Pumping station IJmuiden:
The asset specificity of the maintenance is relatively generic and the value of the maintenance activities is essential. Using the sourcing matrix the sourcing strategy would be Outtasking. In reality the maintenance sourcing strategy is Outsourcing.

Water boards:
The asset specificity of the maintenance is generic and the value of the maintenance activities is essential. Using the sourcing matrix the sourcing strategy would be Outtasking. In reality the maintenance sourcing strategy is In-house.

In the textbox can be seen that the sourcing strategies that follow from the sourcing selection matrix differ from those chosen in reference cases. Maintenance for the pumping station in IJmuiden is fully outsourced instead of out-tasked. Apparently, there are other factors influencing the sourcing decision. The water boards also use a different
sourcing strategy then the sourcing selection matrix indicates. The sourcing selection matrix does not comprehend all factors that influence the sourcing decision. These national and organizational factors must be taken into account and therefore an additional step is needed to find the right sourcing strategy.
Step 3: Adapting sourcing strategy to national and organizational context

The third step is adapting the selected sourcing strategy to the country and organizational context. The conditions in a country might hamper the chosen strategy or might act as a catalyst for outsourcing. By combining the barriers to infrastructure maintenance in emerging countries found in McGovern et al. (2013) with the WGC principles of water governance (Havekes, Hofstra, et al., 2013) the list of organizational and national factors can partly be made. The list is further added by the results of the reference cases.

The factors that have to be taken into consideration for the Indonesian situation are:

1. Maintenance culture of the organization;
2. Suitable legal administrative power to control long-term contracts;
3. Required management skills for complex contracts;
4. Life-cycle approach to infrastructure maintenance;

What these factors entail and how they influence the sourcing of maintenance will briefly be explained.

Maintenance culture

The track record of the infrastructure maintenance performance indicates the present maintenance culture of an organization. Adequate maintenance culture means that the ability of infrastructure to deliver its service is enough to meet the needs of society. Inadequate maintenance culture means that a nation’s maintenance delivery cannot cope with the existing infrastructure maintenance needs to deliver its service. Maintenance of infrastructure is put under further pressure when a country puts more emphasis on the construction of new infrastructure instead of adequately maintaining its existing infrastructure. The presence of maintenance culture within an asset owning organization can be indicated by the maintenance related availability of infrastructure. The occurrence of unrepaired potholes in roads, electricity blackouts and similar disruptions in infrastructure indicate a maintenance culture that is inadequate (McGovern et al., 2013). For flood risk maintenance this shows most clearly during flood events when the flood risk system cannot meet the design safety levels.

When a maintenance culture in an organization is insufficient this will affect the maintenance sourcing strategy decision. When the maintenance culture is not sufficient to meet the maintenance needs, maintenance sourcing should be focussed on obtaining the right maintenance knowledge and skills externally to perform maintenance task. Thus ‘in-house’ sourcing of maintenance is not recommended when maintenance culture is inadequate. ‘Out-tasking’, ‘hybrid outsourcing’ or ‘outsourcing’ are strategies more likely to produce significant advantages when the organization’s maintenance culture is not sufficient. The chosen maintenance strategy can be used to reinforce the maintenance culture within the organization, allowing the organization to mature and providing more options for maintenance sourcing in the future. If an effective maintenance culture is clearly present, then ‘in-house sourcing’ of maintenance can fulfil all the strategic maintenance needs of the organization.

Suitable legal administrative power to control long-term contracts

The ability to manage long-term contracts is dependent of the legal administrative powers of a country’s judicial system. When the judicial system is strong enough, contractors are more likely to engage in long-term contracts with the government. If this
is not the case the risks involved with long-term contracts can present a barrier for contractors to participate in the tender.

This will affect the selection of a maintenance sourcing strategy, since outsourcing requires more long-term relational contracts. If a country cannot enforce long-term maintenance contracts properly then the preferred maintenance outsourcing strategies are ‘in-house’, ‘out-tasking’ or ‘hybrid outsourcing’. ‘Outsourcing’ can still be an option if the contract period can be short enough for contractors to participate in the tender and long enough for asset owning organization to cover the contracting costs.

**Required skills; management skills for complex contracts**

If an asset owning organization shifts its role from maintenance provider to maintenance contract manager it must have the skills and experience required to manage the contractual relation between one or more maintenance contractors. If the organization lacks the ability to manage these types of contract it will affect the choice of sourcing strategies. Then ‘outsourcing’ maintenance is then not preferred because of potential contract management difficulties. ‘Hybrid outsourcing’, ‘out-tasking’ and ‘in-house’ can offer better means of managing the contractual relationship. ‘Outsourcing’ can still be applied if the organization recruits a managing agent that manages the maintenance contractors.

**Life-cycle approach to infrastructure maintenance**

It is important to assess if an organization sufficiently takes into account the entire life cycle of a flood risk infrastructure. The design lifetime for flood risk infrastructure often comprises many decades. Maintenance should enable the infrastructure to perform its function for the duration of its design life cycle. A lack of a life-cycle approach to infrastructure maintenance leads to mismatch between maintenance intervals and maintenance contract periods and the design safety levels over the lifetime of the asset. Short-term goals of the asset owner and the maintenance contractor should be in line with the long-term goals of the flood risk system. This does not affect the selection between the sourcing strategies, however it does guide the contract period and financing scheme for infrastructure maintenance. If life-cycle approach is lacking in the organization, then contract periods should be extended to ensure long-term goals are met and funding schemes should be made to ensure sufficient maintenance funding for the entire life cycle of the flood defence.

The national and organizational context is obtained by analysis of situation in Indonesia. The information is gathered and based on relevant cases that display the performance of Indonesia with respect to these factors. The information on which it is based can be found in:

1. **Maintenance culture of the organization**;
   - Based on organizational analysis and maintenance track record
2. **Suitable legal administrative power to control long-term contracts**
   - Based on evidence of strong judicial power
3. **Required management skills for complex contracts**
   - Based on past experience with outsourcing or similar complex contracts
4. **Life-cycle approach to infrastructure maintenance**;
   - Based on infrastructure asset performance, with a focus on flood defences
Besides these factors there are two national conditions are considered a prerequisite for sourcing of maintenance, namely sufficient funding to satisfy the yearly maintenance need and sufficient capacity of the private sector. Sufficient funding means that the organization takes into account that yearly maintenance cost for flood defences satisfy the international average of 1-2% for the dykes and 5-10% of construction cost for more complex structures (Jonkman et al., 2013). Capacity of the private sector is based on the market share of companies that are able to perform flood defence maintenance. If these two requisites are not present, it will be difficult to find external contractors willing to participate in the tender.

If it turns out that the factors are of such influence that the strategy must be adapted, this can be done based on evidence of proper strategy adaption from the literature (Power et al., 2004).
Step 4: Describe the best governance mode and identify implementation issues.

The final step describes the best governance mode for the chosen strategy as well as a list of issues that may arise with the chosen strategy.

The governance mode for the chosen sourcing strategy provides guidelines on which contract type is best used for the relationship between asset owner and maintenance contractor. The governance structures that may be chosen can vary from long-term to short-term contracts. Furthermore the issues that may arise with the chosen strategy will be inventoried and guidelines on how to deal with these issues will be presented. This provides a strategic implementation overview that can be used to give insight into where the organization must adapt to accommodate the chosen sourcing strategy.

4.3 Summary and conclusion

This framework differs with other sourcing selection frameworks for infrastructure maintenance as those tend to start with an organizational and contextual analysis followed by an analysis of the scope of work resulting in a sourcing decision. However, that mostly concerns businesses that are profit driven and that method does not reflect the importance of the flood defence and the maintenance activities involved. This framework focuses on the technical need for maintenance delivery and incorporates organizational and national context.

The framework will provide the asset owning organization with structured approach to the selection of a maintenance sourcing strategy. It takes into account the important guidelines offered by transaction cost economics and maintenance theory. Also it takes into account the significant national context issues as well as implementation issues.

Several iterations may be needed after several years to check if the sourcing strategy still is the optimal sourcing strategy for the assets. Establishing a baseline for maintenance cost in the current condition can assess the cost performance of the chosen strategy. Once a sourcing strategy has been selected it is best to review the results after each year and to monitor the performance of the sourcing strategy.
5 MAINTENANCE SOURCING STRATEGIES FOR THE NCICD

5.1 Introduction

In this chapter the framework will be applied to the National Capitol Integrated Development (NCICD) case to determine the best sourcing strategy for the flood defences of the NCICD project in Jakarta. In Section 5.2 a description of the National Capitol Integrated Coastal Development, or NCICD, will be given. This will contain an overview of the history of flooding in Jakarta, the flood defence system and the flood defences that are planned. In Section 5.3 the maintenance requirements are decomposed in practical maintenance tasks and responsibilities. In Section 5.4 the framework steps are applied for the sourcing of maintenance for seawall type flood defences of the NCICD project. In Section 5.5 the pumping station maintenance sourcing strategy is produced with the framework. In Section 5.6 the results and reflection on the sourcing strategy for the NCICD assets will be presented.

5.2 Project description

5.2.1 Background of the NCICD project

The National Capitol Integrated Coastal Development (NCICD) project is an integrated plan for the coastal development of the city of Jakarta. When a public call for tenders was issued in 2012, Dutch engineering firm Witteveen+Bos sought collaboration with other parties. This resulted in a consortium that also includes Grontmij, KuiperCompagnons, Deltares, Ecorys and Triple-A. Their proposal was based on a two-phase approach: flood protection in the short term, and sustainable urban development in the long term. The Dutch government (Partners for Water) decided to award the contract to the aforementioned consortium. The project beneficiary is the Indonesian government. (W+B, 2014).

Every year, Jakarta suffers from floods. Jakarta experiences three types of floods (CMEA, 2014):

- Flooding as a result of insufficient water storage whereby heavy rains overwhelm inadequate drains. As excessive rainfall in the city flows towards the low-lying coastal zone, this area is especially vulnerable for this type of floods.
- Flooding from rivers or canals as a result of high discharges upstream. At many places the capacity of the water system cannot cope with peak demands. River dikes in many places are not high or strong enough and rivers, streams and pumps become clogged with sediment and garbage. As a result rivers overflow.
- Flooding from the sea when sea dikes, and river dikes in the coastal area, are not high or strong enough. When the sea is at its highest these dikes overflow and sea water floods the city as happened in 2007.

In the current situation these floods are imminent as the flood defences of Jakarta are inadequate: preliminary surveys from 2013 indicate that currently over 40% of the coastal flood defences is not able to withstand the highest high water spring level. When water flows into the city it often cannot be drained off quickly enough. Soil subsidence due to groundwater extraction is a major cause of the flooding problems. In some places,
the soil subsides by up to 17 cm per year. But subsidence is not the only cause for Jakarta’s water problems. No fewer than thirteen rivers flow from the volcanic hinterland into Jakarta Bay, and growing urbanisation upstream is exacerbating the problem. In 2030, some 80 % of North Jakarta will be located below sea level. The masterplan calls for offshore flood protection measures in Jakarta Bay, the only area that still offers enough room for such measures in this densely populated metropolis. The coast will be reinforced as a temporary measure, and a new enclosure dam will be built in the bay. The dam can be financed through simultaneous large-scale land reclamation. Plans calls for a new waterfront shaped like the mythical Garuda bird, the national symbol of Indonesia. An artist impression of this can be seen in Figure 25. Realisation of the NCICD project would require massive investment in one of the world’s largest hydraulic engineering projects (W+B, 2014).

![Figure 25 Artist impression of completed NCICD project (source: Kuiper compagnons)](image)

The plan has been assessed for its financial, technical, socio-economic and ecological feasibility. The costs of implementing the various measures are currently estimated at USD 10 to 40 billion (W+B, 2014). The accelerated construction of urban sewer systems and water treatment plants is a key aspect of the plan. This will prevent the development of a dreaded ‘black lagoon’ of sewage lapping at the city’s waterfront behind the new seawall.

### 5.2.2 Flood defences of the NCICD project

The master plan provides both short and long term flood defence solutions. Rapid construction of a complete enclosure dam between the eastern and western end of Jakarta Bay is logistically unfeasible. For instance, supplying enough soil would require more dredging vessels than are currently available in the entire world. The volume of soil needed to construct the western section is comparable to the volume required for the Maasvlakte 2 land reclamation project near Rotterdam. Many factors will determine if and how this masterplan is to be implemented. Factors like the growth of the Indonesian economy, currently at an annual rate of + 5 to 6 %, or presidential elections. To tackle the problems in phases, a sound plan has been prepared.
5.2.3 Phase A: Reinforcement of existing dikes; short term flood defence solutions

Phase A facts & figures:

Flood defences:
- Strengthening 35 km of existing seawall
- Upgrading existing river pumping stations
- Reinforcing river embankments

Function:
- Providing short term flood safety up to 2022. Adaptable to ensure flood safety to 2027-2032.

Construction period:
- 2014 till 2017

Figure 26 Phase A: Strengthening existing seawall (source: NCICD masterplan, Witteveen + Bos)

Phase A consists mostly of upgrading the current coastal flood defences of Jakarta. This is a set of high priority, no-regret measures that include
1. slowing down land subsidence (by providing alternatives for ground water extractions),
2. strengthening and heightening existing sea walls,
3. upgrading the urban drainage system and
4. preventing upstream river water entering the low-lying Jakarta area.

Some seawall sections in coastal areas such as Pluit and Ancol are under immediate threat and therefore implementation has already started in 2014. The design levels for these sections take current subsidence rates into account, and have been designed to provide safety until 2022. If the implementation of long term measures is delayed, the dike profile offers sufficient basis to further increase the dike height providing additional safety for another 5-10 years. Several dike typologies have been
developed to meet local requirement: basic dikes, reduced dikes, green dikes, inland dikes and beach dikes. In addition dikes with land reclamations have been developed, thus providing a wide range of options.
5.2.4  Phase B: The Giant Garuda; long term flood defence solutions

Phase B facts & figures:

Flood defences:
- Construction of 35 km long outer seawall
- Two pumping stations with a total capacity of 730 m$^3$/s
- A retention basin of 75 m$^2$ that could retain up to 200 million m$^3$ of water

Function:
- Providing long term flood safety. Providing finance for flood defence through large scale land reclamation.

Construction period:
- 2018 till 2025

Figure 27 Phase B: Giant Garuda and seawall (source NCICD master plan, Witteveen + Bos)

It is unlikely that the rate of subsidence will be reduced in the foreseeable future seeing that it will take time to develop and implement alternatives for ground water extractions. Sea water levels will rise, causing the gradual stop of canals and rivers flowing under gravity into the sea. Large drainage pumps are needed, especially in central Jakarta where subsidence rates are high. Pumping stations require pumping lakes to temporarily store peak river discharges. The need for a large waduk, or retention basin, is one of the main reasons for creating the offshore retention basin, rather than seeking room for such storage lakes in the city of Jakarta. The location of the outer sea wall (phase B) is mainly determined by the required storage capacity of the giant waduk between current coastline and sea wall. It provides sufficient room for future expansion of the land reclamation and storage capacity for bulk water supply.
5.2.5  Phase C: Expansion of Tanjung Priok harbour; long term development

Phase C facts & figures:

Flood defences:
- NA

Function:
- Offer economic opportunities to redeem the cost of the flood protection project

Construction period:
- 20xx till 2040

Figure 28 Phase C: Expansion of Tanjung Priok harbour (source NCICD master plan, Witteveen + Bos)

Phase C consist of a port expansion of Tanjung Priok harbour, located on the east side of Jakarta Bay. It will offer economic opportunities to redeem the costs of the giant seawall. Since the eastern part of Jakarta Bay has little adverse effect of subsidence and lower risk of flooding, the flood defences involved with this phase are not critical for the flood defence of Jakarta.

5.2.6  Project planning

Due to a lack of data it is difficult to statistically determine the moment when rivers will stop flowing into sea due to land subsidence and when flood risks become unacceptable. In the master plan a closing date of 2022 was chosen, because it estimated that around 2022 sea water levels will be around 3-4 meters above street level, which is a critical level as many houses in poor areas are below this height and ‘vertical’ evacuation will not provide safety against floods anymore. The current sea wall and the many rivers open to
the sea would provide a safety risk, requiring a more robust and shorter Outer Sea Wall. By 2022 also many rivers and canals will not be flowing freely to the sea, thus requiring pumps and pumping lakes either onshore or offshore.

Table 6 Timeline NCICD phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>Start</th>
<th>Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2014</td>
<td>2017</td>
</tr>
<tr>
<td>B</td>
<td>2018</td>
<td>2025</td>
</tr>
<tr>
<td>C</td>
<td>20xx</td>
<td>Until 2040</td>
</tr>
</tbody>
</table>

5.2.7 Safety level

The NCICD project aims to significantly increase the flood safety of northern Jakarta. As required in decree 121-2012 of the Governor of Jakarta, the design of the outer sea wall will be based on an extreme event that statistically occurs only once in 1,000 years. For design of the embankments along rivers and the large retention basin, a safety standard of once in 100 to 200 years is used.

The urban drainage water and water from upstream rivers will flow into the giant retention basin. To keep the water level in this reservoir low and meet the safety standards in the rivers, the largest pumping station in the world is required with a pumping capacity of 730 m$^3$/s. This is taking into account a fluctuation of 2.5 meters above the minimum water level in the retention basin and a size for the retention basin of at least 75 km$^2$ (CMEA, 2014).

Figure 29 Cross-section of outer seawall and retention basin (source: NCICD master plan, Witteveen+Bos)
Facts on outer seawall:

1. The outer sea wall is an impressive structure that will be 25 kilometres in length and, at the deepest point, it will be 24 metres high of which 7.7 metres will be above sea level (+7.7 LWS-2012). Low water spring tide.
2. At its widest, the base of the dike will be 380 metres wide.
3. The outer slopes of the dike will be designed at a slope of approximately 1:7 because of geotechnical stability and wave run up.
4. To protect the inner and outer slopes of the sea wall an armour layer of rock will be applied. Sheet piling will be applied at inner slopes in combination with urban development.
5. The outer sea wall will be closed around 2022.
6. The construction time of the sea wall, the pumping station and the toll road is estimated at 4-6 years.

**Flood defences**

The specific flood defences for the NCICD project are given in Table 7.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Asset</th>
<th>Flood defence</th>
<th>Length/number/size</th>
<th>Capacity</th>
<th>Description</th>
</tr>
</thead>
</table>
| A1    | Strengthened existing seawall | 35 km | N/A | - Crest height of +2.8 LWS  
- Safety level of 1/100-200 years  
- Slope 1:4  
- Different types of dikes used such as: basic dikes, reduced dikes, green dikes, beach dikes and inland dikes  
- If Phase B is delayed, seawalls can be upgraded to 5-10 years additional protection |
| A2    | Reinforced river embankments | 54.4 km | N/A | - Kali Kamal, Kali Angke, Kali Muara Karang, Ciliwung and Kali Sentiong river.  
- Reinforce river embankments to 1/100-200 years safety level. |
| A3    | Upgraded river pumping stations | 6 pumping stations | Capacity unknown | - Closes rivers off from Jakarta Bay, so no seawater intrusion can take place  
- Needed to pump water into bay due to subsidence |
| B1    | Outer slope seawall | 25 km | N/A | - Crest height of +7.7 LWS.  
- Height at deepest point 24 metres  
- Safety level of 1/1000 years  
- Slope 1:7  
- Armour layer of rock applied for slope stability |
| B2    | Inner slope seawall retention basin | 20-30 km? | N/A | - Crest height of +2,77 LWS.  
- Safety level of 1/100-200 years  
- Slope 1:7  
- Armour layer of rock applied for slope stability  
- Sheet piling |
| B3    | Pumping stations | 2 pumping stations | 730 m³/s | - 2 pumping stations; 1 at west wingtip garuda and 1 at east wingtip. Maximum total pumping capacity of 730 m³/s |
| B4    | Retention Basin | 75 km² | 200 million m³ water | - When retention basin is closed off, water level will be -0,90 m LWS-2012 during the rainy season  
- During peak discharges from the rivers, the water level can increase 2,5 m, offering a storage capacity of almost 200 million m³ of water. |
| C     | No critical flood defences planned | - | - |  |

Table 7 Flood defence register
5.3 Decomposition of maintenance requirements for the outer seawall

From these flood defences and their abstract performance requirements we can now derive the functional maintenance requirements per asset type. The needed maintenance activities flow forth from the more practical safety requirements that are derived from the design safety level of 1/1000 years.

Once this decomposition has been performed the maintenance activities can be assessed on their importance to the strategic goals of the asset owning company and the asset specificity of the tasks. The decomposition will be undertaken per separate asset or asset type of the NCICD. First the outer sea wall will be described.

5.3.1 Description of outer seawall

The entire outer seawall can be seen in Figure 30

![Figure 30 Contour of outer seawall (source NCICD master plan, Witteveen + Bos)](source NCICD master plan, Witteveen + Bos)

The outer seawall has length of approximately 25 kilometres. There are 4 structures located on the outer seawall, namely 2 locks and 2 pumping stations. The seawall connects with the original coastline of Jakarta on two locations, one in the western part of the coastline and one near Tanjung Priok harbour.
The cross-section of the outer seawall can be seen in Figure 31. The slope of the seawall is 1:7; the height of the sea wall at the deepest point will be 24 metres. The seawall is made of sand with a rock armour layer for slope stability and erosion protection. The crest height of the seawall is +7.7 LWS. The design sea water level is 1.56 m LWS.

5.4 Application of the framework for outer seawall

The framework can now be tested to identify the best-suited sourcing strategy for the outer seawall. The 4 steps of the framework will be followed to guide the decision making process.

5.4.1 Step 1: Identification and assessment of maintenance for each separate asset type

First off the workload must be identified. The input needed for this is:

- A complete flood defence register; this contains all the flood defences that form the flood protection system.
- The design safety levels; abstract design safety levels can be used to derive the performance requirements
- Failure modes of flood defences; the failure modes determine the maintenance activities that are needed for the asset

1. Flood defence register

In the flood defence register seen in Table 7 all flood defences can be seen. The framework must be run for each separate asset type. First off a sourcing strategy will be found for the outer seawall. The outer seawall can be seen in Table 7 as asset B1. Since the strengthened seawall (asset A1) and inner slope of the seawall (asset B2) are similar to the outer seawall, it is reasonable to say that the sourcing strategy for these assets will be similar as well.
2. Define the safety levels
The outer seawall has a design safety level that corresponds with a sea water level that occurs 1/1000 years. Besides water overtopping the outer seawall should also be able to withstand failure due to erosion or a breach in the seawall. How these more practical safety levels can be derived from this will be the subject of this section.

The abstract level of safety for the outer seawall can be formulated as follows:
- The outer seawall should offer protection for events with a return period of 1/1000 years.

3. Failure modes of the flood defence
The failure modes that flood defences can endure have been researched by Allsop et al. (2007). The failure modes that are listed below are those for the flood defence types of ‘sand beach and dune’, ‘shingle/gravel/rock beach or ridge’ with ‘revetment protection to embankments’

1. Water level difference across a structure;
   a. Erosion of surface by overflow
   b. Shallow slip/slide
   c. Piping and/or internal corrosion
   d. Crest level too low – overflow (functional failure)
2. Wave loading;
   a. Erosion of seaward face/slope
   b. Local surface failure or element displacement
   c. Erosion of landward face/slope
   d. Crest level too low - overtopping
3. Lateral flow velocities.
   a. Erosion (scour) of bed or bank
4. Structure impact
   a. Ship or similar impact
   b. Debris

More information on these failure modes can be found in (Allsop et al., 2007).

Maintenance workload for outer seawall
Maintenance of the outer seawall can be defined as:
- All the activities needed to ensure that the entire outer contour of the seawall meets the design safety level of 1/1000 years during the asset lifecycle.

The maintenance work can be derived from the known failure modes of similar flood defences and wear and tear from normal operation.

The maintenance work is divided into three sections:
1. Monitoring;
2. Maintenance;
3. Repair.

Table 8 shows the known failure modes induced by hydraulic loading and the issues concerning wear and tear and the maintenance work related to these failure modes and wear and tear issues. To determine the maintenance work we examined which type of maintenance influences a certain element of the flood defence structure. Subsequently we examined if that element plays a part in a certain failure mode.
The green coloured boxes indicate when a certain maintenance task is needed to monitor, repair or maintain the corresponding failure mode.

It is also important to address asset deterioration modes that influence long term flood safety. These could consist of land subsidence, sea level rise, encroachment of seawall, and vandalism of seawall by inhabitants. These effects should be taken into account in the maintenance process. The manner in which these effects are taken into account now is an indication of the life cycle approach and is handled in step 3.
Table 8 Failure modes and maintenance workload for outer seawall

<table>
<thead>
<tr>
<th>Maintenance and inspection tasks</th>
<th>Water level difference across structures</th>
<th>Erosion of rock armour</th>
<th>Wear &amp; Tear issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inspections</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual inspection of asset</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsea asset inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement of crest level height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement of sand quantity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement of rock armour layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suppletions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suppletion of sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suppletion of rock armour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shaping</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaping sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaping rock armour layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mowing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removing trees and shrubs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removing burrowing animals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heightening</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heightening crest level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Repair/Upgrade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair after calamity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Assessment of value and asset specificity of maintenance process steps

The maintenance work can now be assessed on their value and asset specificity. The maintenance process steps will now separately be assessed on:

- The degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization.
- The asset specificity assessment involved per maintenance process step.

To determine the degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization the maintenance process step should be assessed along the established criteria of an activity that is needed to ensure the design safety level against flooding for a 5-year period. This period is chosen so that a possible negative performance by a contractor will not lead to the deterioration of the entire flood defence. The maintenance process steps will all be measured against this criterion. The results can be seen in Table 9.

Table 9 Value assessment of seawall maintenance process steps

<table>
<thead>
<tr>
<th>Value assessment of maintenance process</th>
<th>Operational</th>
<th>Tactical</th>
<th>Strategic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work scheduling</td>
<td>Influences flood safety on a yearly basis. Long-term flood safety is only hampered after prolonged absence of work scheduling.</td>
<td>Influences flood safety on a yearly basis. Long-term flood safety is only hampered after prolonged absence of work execution.</td>
<td></td>
</tr>
<tr>
<td>Work execution</td>
<td>Asset owner inspection does not need to perform measurement inspection itself, however it does need to verify the contractor’s inspection.</td>
<td>Asset owner inspection does not need to perform measurement inspection itself, however it does need to verify the contractor’s inspection.</td>
<td></td>
</tr>
<tr>
<td>Planning/design</td>
<td>Although important step in maintenance it can not be considered a core activity for the asset owning organization.</td>
<td>Planning/design of maintenance work is not considered a core activity of the asset owner.</td>
<td></td>
</tr>
<tr>
<td>Data management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Priority identification</td>
<td>Work identification is not an essential task the asset owner should perform itself.</td>
<td>Work identification is not an essential task the asset owner should perform itself.</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>Analysis of maintenance work is not needed to be performed by the asset owner to ensure flood safety levels over long term.</td>
<td>Analysis of maintenance work is not needed to be performed by the asset owner to ensure flood safety levels over long term.</td>
<td></td>
</tr>
</tbody>
</table>

Of all maintenance process steps involved in the maintenance of the outer seawall only **Prioritisation** of maintenance activities is seen as an essential activity that is needed to ensure the design safety level against flooding for a 5-year period. Not being able to prioritize maintenance work, will lead to a reduced level of control of the flood safety level. In the framework description it is stated that if 1 or more maintenance process steps is essential, the entire workload is considered essential.

Asset specificity of maintenance process steps

The maintenance process steps will be assessed on their asset specificity. This is defined as ‘the degree of transaction-specific investments involved that cannot easily be put to other..."
uses then for the maintenance of the flood defences if the Client/Contractor relationship breaks down”. The results can be seen in Table 10.

Table 10 Assessment of asset specificity of seawall

<table>
<thead>
<tr>
<th>Maintenance process step</th>
<th>Asset specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work execution</td>
<td>Low; all equipment can be utilized for maintenance of other flood defences or other infrastructure assets.</td>
</tr>
<tr>
<td>Work scheduling</td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td>Measurement inspection</td>
<td>Low-Medium; measurement equipment is not for flood defences specifically. Sub-sea measurement might require some specialist equipment.</td>
</tr>
<tr>
<td>Data management</td>
<td>Low; IT infrastructure required which could be utilized for other maintenance projects.</td>
</tr>
<tr>
<td>Planning/design</td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td>Analysis</td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td>Work identification</td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td>Prioritisation</td>
<td>Low; no specific equipment needed.</td>
</tr>
</tbody>
</table>

According to the assessment of asset specificity of the total maintenance workload, the asset specificity is considered to be low for almost all maintenance process steps.

Conclusion
The output of the first step of the framework is:
- A maintenance task register
- The value of maintenance activities
- The asset specificity involved with maintenance

The maintenance task register is presented in Table 8. The value of the maintenance workload can be considered essential. In order to adequately perform the task of ensuring flood safety it is considered essential to at least perform the maintenance process step prioritisation internally. The activities are essential because the fact that the process step prioritisation cannot be externalized from the asset owning organization. The flood safety level cannot be ensured for the period of 5 years if this is outsourced to an external contractor.

The investment in equipment that is required for the maintenance work is not significant compared to the budget of the maintenance contract and can also be utilized for other (maintenance) projects, therefore it can be stated that there are little to none asset specific investments required. The maintenance tasks can be described as mostly generic.

5.4.2 Step 2: Sourcing Selection
From the previous step we conclude that the total maintenance workload for the outer seawall is essential and generic in nature.
If we run these activities through the sourcing selection matrix (Figure 32), then the preferred strategy is Outtasking.

![Sourcing selection matrix]

**Figure 32 Sourcing selection matrix**

The generic aspect of the work involved is decisive in the selection of the sourcing strategy. Hardships that are too big a risk for a contractor should be excluded from the contract. This will be described in the implementation process of step 4.

### 5.4.3 Step 3: Adapting sourcing strategy to national and organizational context

The impact of the national and organizational situation in Indonesia influences the sourcing selection. The following aspects are considered for this framework step and will determine the local context in which the maintenance process takes place.

1. Maintenance culture;
2. Suitable legal administrative power to control long-term contracts;
3. Required management skills for complex contracts;
4. Life cycle approach to infrastructure maintenance.

The local context will be described for these aspects.

**Maintenance culture**

In Jakarta maintenance is not embedded in the infrastructure owning organizations. Evidence is provided through research of the financial and institutional capacity of the water resources management of the DKI Jakarta (van Nes & Vroege, 2010) and the Worldbank report on road expenditure in Indonesia (World Bank, 2012). The findings of these reports match when it comes to their conclusions on maintenance of infrastructure. Maintenance and preservation is often under-budgeted and of lower priority then new infrastructure. For instance for roads it is found that on average, district/city governments spend about 70 percent of road expenditure on new construction and development, while the remaining 30 percent is spent on maintenance and rehabilitation (World Bank, 2012). van Nes and Vroege (2010) argue that sustainable financing mechanisms are needed for adequate maintenance to keep the system in good condition continuously Presently, funds for O&M are dependent on
annual development budgets, which are highly fluctuating every year, based on actual events (disasters) and politics.

Having sufficient and experienced workforce is another problem maintenance departments face. According to van Nes and Vroege (2010) the “availability of adequate personnel is essential to implement adequate O&M (…) however, comparison with historic staff numbers for Jakarta and staffing in Water Resources Management services in other cities with comparable size shows that both Central and Provincial Services are extremely under-staffed, and, because experienced personnel is retiring, the situation is getting worse, and intimate knowledge on requirements and capabilities of the Water Resources System is diminishing”.

Due to the lack of funding and lack of skilled personnel a maintenance backlog is created that needs to be addressed. Infrastructure maintenance spending needs to be increased to close the maintenance gap.

These findings lead to the conclusions that adequate maintenance culture is not prevalent seeing that maintenance is given lower priority then new infrastructure and that maintenance departments of existing asset owning organizations are under-funded and under-staffed.

Suitable legal administrative power to control long-term contracts;
In an effort to attract private sector participation in infrastructure, the Government of Indonesia has revisited and revised many sector regulations and laws related to infrastructure service provision (including transport, electricity, telecommunication, and water and sanitation) and established regulatory and institutional framework for Public-Private Partnership (PPP) implementation. Under the new legal framework, the infrastructure sector and market are opened to the private sector. The private sector can invest in the development and operation of financially viable infrastructure projects, without being obliged to enter into joint ventures with State Owned Enterprises (SOEs). A revised Presidential Regulation (Perpres No. 13/2010, a revision of Perpres No. 67/2005) concerning public-private sector cooperation is a positive development as it provides better clarity and support for PPP framework and the provision of government support and guarantees.

Experience with Performance-Based Road Maintenance Contracts (PBMC) in Indonesia is discussed in (Greenwood & Henning, 2006) and (Sultana et al., 2012). Besides issues that are common for developed and developing countries, Sultana et al. (2012) also identifies some local issues which need special concern during the implementation of PBMC in a developing country. Of these issues political influence and corruption influence the legal setting of maintenance outsourcing. Supervision of the performance of contractors by the asset owning organization should be corruption free. Selection of contractors should be free of political influence in order to ensure a fair tendering process. Developed countries have less concern with theses legal issues.

The conclusion is that there is suitable formal legal foundation for maintenance outsourcing, however issues concerning corruption and political influence may form a barrier for private sector cooperation.

Required management skills for complex contracts
Both the asset owner and the private sector should have enough capacity to manage complex outsourcing contracts. Evidence of maintenance outsourcing contracts in Indonesia can be found in road infrastructure sector (Sultana et al., 2012; World Bank, 2012). The experience with these contracts can be used for the maintenance outsourcing
for flood defences. More data on management skills for complex contracts is not readily available and should be gathered to optimize the decision making process.

**Life cycle approach to infrastructure maintenance.**
In the segments mentioned above already some indication of a lack of life cycle approach is visible. Indicators of this are the lack of sustainable funding, the deficit in maintenance spending, the under-staffing of maintenance departments and the lack of long-term maintenance planning. New infrastructure has greater priority then maintenance and when it does concern maintenance short-term goals are mostly handled.
Table 11 National and organizational context results

<table>
<thead>
<tr>
<th>National or organizational aspect</th>
<th>Score</th>
<th>Effect</th>
<th>Undesirable sourcing strategy</th>
<th>Preferred sourcing strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance culture</td>
<td>Low maintenance culture in asset owning organization</td>
<td>Organization misses required knowledge and skills and funding to effectively maintain infrastructure</td>
<td>- In-house</td>
<td>- Outsourcing - Hybrid outsourcing - Outtasking</td>
</tr>
<tr>
<td>Legal structure</td>
<td>Legal structure that protects private sector investment in place. Potential corruption and political influence present</td>
<td>Short-term Maintenance contract (1-5 years) offer sufficient protection to</td>
<td>- Outsourcing</td>
<td>- Hybrid outsourcing - Outtasking - In-house</td>
</tr>
<tr>
<td>Maintenance management skills</td>
<td>Evidence of effective management of PPP contracts. Based on few cases in road infrastructure</td>
<td>Control of complex contracts is possible</td>
<td>- In-house</td>
<td>- Outsourcing - Hybrid outsourcing - Outtasking</td>
</tr>
<tr>
<td>Lifecycle approach</td>
<td>Mostly evidence of short-term approach to maintenance.</td>
<td>Design safety levels are not upheld during the entire life cycle</td>
<td>- In-house - Outtasking</td>
<td>- Outsourcing - Hybrid outsourcing</td>
</tr>
</tbody>
</table>

The outputs of this framework step are:
- Feedback on sourcing strategy selection
- Sourcing strategy adapted to national context

The feedback on the sourcing strategy selection can be seen in Table 11. Adapting the sourcing strategy to the local context, gives a preference towards Hybrid Outsourcing instead of Outtasking. This is because a more lifecycle approach to the design safety levels is preferred. Externalizing maintenance is preferred over in-house maintenance sourcing, since it can help the asset owning organization develop a maintenance culture and a better lifecycle approach.

The Hybrid Outsourcing strategy in the context of the outer seawall flood defence maintenance can be described the outsourcing of nonessential processes while retaining control over critical applications, utilizing the core competencies of the available
maintenance contractors, while focussing internal resources on the critical, strategic maintenance process steps.

![Diagram of maintenance strategies]

Figure 33 Sourcing strategy selection after step 3

Using the six-stage model of Schoenmaker the responsibilities of the supplier and client can be visualised. The black coloured blocks represent the contractor’s responsibilities and the white blocks are the client’s responsibilities.

![Diagram of maintenance process steps]

Figure 34 Hybrid outsourcing for seawall of NCICD
The maintenance process steps *Prioritisation* and *Work identification* are done by the client.

The practical interpretation of the framework is given in Table 12

**Table 12 Practical operation of sourcing strategy**

<table>
<thead>
<tr>
<th>Maintenance steps</th>
<th>process</th>
<th>Tasks involved</th>
<th>Responsible stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Work execution</strong></td>
<td>-</td>
<td>Inspection of outer seawall</td>
<td>External contractor</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Measurement of sand and rock layer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Suppletions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Shaping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Landscaping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Pest control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Heightening</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Repairs</td>
<td></td>
</tr>
<tr>
<td><strong>Work scheduling</strong></td>
<td>-</td>
<td>Work break down</td>
<td>External contractor</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>External contractor scheduling</td>
<td></td>
</tr>
<tr>
<td><strong>Planning/design</strong></td>
<td>-</td>
<td>Maintenance design</td>
<td>External contractor</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>-</td>
<td>Analysis of inspection and measurement results</td>
<td>External contractor</td>
</tr>
<tr>
<td><strong>Work identification</strong></td>
<td>-</td>
<td>Identification of suppletion, shaping, landscaping, pest control, heightening, or repair tasks.</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Prioritisation</strong></td>
<td>-</td>
<td>Order of execution of maintenance tasks</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Data management</strong></td>
<td>-</td>
<td>Information management for all relevant actors</td>
<td>External contractor</td>
</tr>
</tbody>
</table>

How the relationship between asset owner and the external contractor is arranged is defined in the 4th and final step of the framework; the implementation issues and risk mitigation.

5.4.4 **Step 4: Implementation issues and risk mitigation**

In this section the implementation process for *Hybrid Outsourcing* will briefly be described. The issues that need to be addressed are mentioned in (Sultana et al., 2012) and (Hui & Tsang, 2004). These are listed in the Table 13.
<table>
<thead>
<tr>
<th>Implementation stage</th>
<th>Description</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning</strong></td>
<td>Determine resource requirements, prepare financial budget, plan for capital assets, manpower and materials</td>
<td>- Sustainable funding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Employee issues</td>
</tr>
<tr>
<td><strong>Service agreement</strong></td>
<td>Establish goals and objectives, service level, technical and commercial terms, as well as condition of service</td>
<td>- Performance specification and set up of performance standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Risk exposure (hardships)</td>
</tr>
<tr>
<td><strong>Work transaction</strong></td>
<td>Define task, scope and work specifications; provide method statements; and perform work using the chosen service provider</td>
<td>- Expertise of private sector</td>
</tr>
<tr>
<td><strong>Performance review</strong></td>
<td>Review results and check for compliance with service agreement. Introduce improvement in future transactions and, if necessary negotiate for amendment of performance standards.</td>
<td>- Performance monitoring</td>
</tr>
<tr>
<td><strong>Evaluation of strategy</strong></td>
<td>Revisit the strategy with due regard to change in the business environment; take corrective actions, and if necessary change strategy</td>
<td>- Payment and termination of contract</td>
</tr>
</tbody>
</table>

The issues will now be described shortly.
Planning
When planning the implementation of a sourcing strategy the focus is on establishing a sustainable funding scheme and resolving employee issues. Yearly funding should reflect a percentage of the construction cost of the infrastructure that corresponds with similar infrastructure in other countries. In the literature often a percentage between 1%-2% for the management and maintenance cost for flood defences is used (Jonkman et al., 2013). Employee issues are related to the need for employment of the asset owning organization when maintenance activities are externalized.

Service agreement
During the service agreement stage the performance specification and set up of performance standard is handled as well as risk exposure issues. The client’s ability to influence the maintenance process will be established in the service agreement stage. Risk exposure issues deal with the risks that the asset owning organization needs to bear in the contract. The contractor and client need to agree on what is meant by regular wear and tear, in other words which damages to the outer contour are included and which are not. Hardships that are not included in the contract are also known as Force Majeure or ‘acts of God’. The basic definition is that Force Majeure applies for events that could not have been reasonably predicted, are beyond the control and could not have been avoided by the asset owning authority and the contractor. These risks are too great to be borne by a company. The asset owning organization should reimburse the contractor after it performs maintenance or repair following such events.

The governance mode or contracting form that is best suited for the Hybrid Outsourcing strategy is either long-term contracting or a relational contract. In both cases contract management is mainly the responsibility of the asset owner. Relational contracting has a preference since this considers a contract to represent a relationship between the parties and introduces a degree of flexibility into the contract on the basis of understanding the other party’s objectives.

Work transaction
During the work transaction stage the expertise of the contractor is important. The work transaction should consist of transferring knowledge of seawall maintenance to the client and vice versa. Knowledge sharing on the maintenance process will lead to better maintenance management: The client will gain knowledge and experience on contract management and the contractor will improve its experience on specific asset maintenance.

Performance review
During the performance review stage, performance monitoring is the main issue. When monitoring the performance of the maintenance contractor it is important to align the strategic goals since this reduces the potential for opportunism. The correct indicators of performance should be enforced. A common typology for this is “You are what you measure”. Simply put it means that if a firm measures a, b, and c, but not x, y, and z, then managers begins to pay more attention to a, b, and c. According to (de la Garza et al., 2009) five components are needed to develop a framework to monitor performance, namely: level of service effectiveness, timeliness of response, safety procedures, quality of services, and cost-efficiency.
**Evaluation of strategy**

During the evaluation of the strategy phase, possible revision of the chosen strategy is considered. The chosen payment method and possible termination of contract are issues that need to be evaluated.
5.5 **Sourcing strategy for pump maintenance**

The revised framework can now be tested on the pumping stations for the NCICD project. The 4 steps of the framework will be followed to guide the decision making process.

5.5.1 **Step 1: Identification and assessment of maintenance for each separate asset type**

First off the workload must be identified. The input needed for this is:

1. A complete flood defence register; this contains all the flood defences that form the flood protection system.
2. The design safety levels; abstract design safety levels can be used to derive the performance requirements.
3. Failure modes of flood defences; the failure modes determine the maintenance activities that are needed for the asset.

1. **Flood defence register**

The pumping stations can be seen in Table 7 as asset type B3. There are 2 pumping stations planned, which in total will consist of 16-18 vertical axial flow pumps with a diameter of 3.2 [m], each with a design flow rate of 42 [m$^3$/s]. Since the upgraded pumping stations (asset A3) are similar in asset type to the new pumping stations, it is reasonable to say that the sourcing strategy for these assets will be similar as well. A preliminary design for one station can be seen in Figure 35.

![Figure 35 Pumping station cross-section and aerial view](image-url)
Define the safety levels
The pumping station has a required flow rate of 730 [m$^3$/s] to prevent flooding during peak inflow. The design head difference is specified as 7 [m]. How these more practical safety levels can be derived from this will be the subject of this section.

The abstract level of safety for the outer seawall can be formulated as follows:

- The pumping stations must always be able to produce a maximum flow rate of 730 [m$^3$/s] at peak inflow during

3. Failure modes of the flood defence
The failure modes that hydraulic pumps can endure have been research by (McKee et al., 2011) There are 13 main problems that afflict centrifugal pumps when in use. These problems, which include both mechanical and hydraulic problems, have been discussed in the literature over a number of years in a wide variety of industries. These problems are:

1. Hydraulic failures;
   a. Cavitation,
   b. Pressure pulsations,
   c. Radial thrust,
   d. Axial thrust,
   e. Suction and discharge recirculation
2. Mechanical failures;
   a. Bearing failure,
   b. Seal failure,
   c. Lubrication,
   d. Excessive vibrations,
   e. Fatigue
3. Other types of failure;
   a. Erosion,
   b. Corrosion,
   c. Excessive power consumption
4. Blockages

Maintenance workload for the pumping station
Maintenance of the pumping stations can be defined as:

- All the activities needed to ensure that the pumping station always has the availability a flow rate of 730 [m$^3$/s] during the asset lifecycle.

The maintenance work can be derived from the known failure modes of similar flood defences and wear and tear from normal operation.

The maintenance work is divided into three sections:
1. Monitoring;
2. Inspection;
3. Repair.

Table 14 shows the known failure modes and the maintenance work related to these failure modes. To determine the maintenance work we examined which type of maintenance influences a certain element of the pump installation. Subsequently we examined if that element plays a part in a certain failure mode.
The green coloured boxes indicate when a certain maintenance task is required to monitor, inspect or repair the corresponding failure mode.
### Table 14 Failure modes and maintenance workload for pumping stations

<table>
<thead>
<tr>
<th>Maintenance and inspection tasks</th>
<th>Failure modes induced by hydraulic loads</th>
<th>Mechanical failure</th>
<th>Other modes of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustic sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature gauge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximity sensors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replace</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impeller or other parts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair after calamity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove blockage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair/upgrade</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cavitation</th>
<th>Level of subarcy</th>
<th>Noise</th>
<th>Vibration</th>
<th>Reduction in pumping efficiency</th>
<th>Pressure pulsation</th>
<th>Axial thrust</th>
<th>Axial thrust and whirl</th>
<th>Axial whirl</th>
<th>Axial and whirl</th>
<th>Axial and whirl and whirl</th>
<th>Bearing failure</th>
<th>Seal failure</th>
<th>Lubrication failure</th>
<th>Sedimentation</th>
<th>Friction</th>
</tr>
</thead>
</table>

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Assessment of value and asset specificity of maintenance process steps

The maintenance work for the pumps can now be assessed on their value and asset specificity. The maintenance process steps will now separately be assessed on:
- The degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization.
- The asset specificity assessment involved per maintenance process step.

To determine the degree in which the maintenance process step is considered essential to the core strategic goals of the asset owning organization the maintenance process step should be assessed along the established criteria of an activity that is needed to ensure the design flow rate is readily available. The maintenance process steps will all be measured against this criterion. The results can be seen in Table 15.

Table 14 Value assessment of pump maintenance process steps

<table>
<thead>
<tr>
<th>Value assessment of maintenance process</th>
<th>Operational</th>
<th>Work execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work scheduling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influences essential work execution. Therefore also essential maintenance process step</td>
<td></td>
<td>Influences flow rate directly and therefore the flood safety as well. Essential process step</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tactical</th>
<th>Planning/design</th>
<th>Data management</th>
<th>Measurement inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since operational maintenance process step are essential, the tactical steps are also considered essential</td>
<td>Since operational maintenance process step are essential, the tactical steps are also considered essential</td>
<td>Since operational maintenance process step are essential, the tactical steps are also considered essential</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategic</th>
<th>Prioritisation</th>
<th>Work identification</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prioritisation of pump maintenance is considered essential to ensure availability of design flow rate</td>
<td>Work identification is considered a essential process step</td>
<td>Analysis of pump maintenance work is considered essential for asset owner</td>
<td></td>
</tr>
</tbody>
</table>

The operational maintenance process steps involved in the maintenance of the pumping station are seen as essential activities that is needed to ensure the availability of the design flow rate during the asset life cycle. In the framework description it is stated that if 1 or more maintenance process steps is essential, the entire workload is considered essential.
Asset specificity of maintenance process steps

The maintenance process steps for the pumps will now be assessed on their asset specificity. This is defined as ‘the degree of transaction-specific investments involved that cannot easily be put to other uses then for the maintenance of the flood defences if the Client/Contractor relationship breaks down’. The results can be seen in Table 16.

Table 16 Assessment of asset specificity of pump maintenance

<table>
<thead>
<tr>
<th>Maintenance process step</th>
<th>Asset specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Work execution</strong></td>
<td>Medium-High; specific equipment needed to repair and maintain the pumps.</td>
</tr>
<tr>
<td><strong>Work scheduling</strong></td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td><strong>Measurement inspection</strong></td>
<td>High; Pumps require many sensor to detect possible failures. These require asset specific investments and are not easily transferred to other maintenance projects.</td>
</tr>
<tr>
<td><strong>Data management</strong></td>
<td>Low; IT infrastructure required which could be utilized for other maintenance projects.</td>
</tr>
<tr>
<td><strong>Planning/design</strong></td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td><strong>Work identification</strong></td>
<td>Low; no specific equipment needed.</td>
</tr>
<tr>
<td><strong>Prioritisation</strong></td>
<td>Low; no specific equipment needed.</td>
</tr>
</tbody>
</table>

According to the assessment of asset specificity of the total maintenance workload, the asset specificity is considered to be medium to high. Especially work execution and measurement inspection needs asset specific investments.

Conclusion

The output of the first step of the framework is:

- A maintenance task register
- The value of maintenance activities
- The asset specificity involved with maintenance

The total maintenance workload can be considered essential and asset specific. The activities are essential because failure of the pumping system directly influences the ability of the asset owning organization to drain the basin and could lead to flooding of the city. Externalizing these risks is not preferred.

The investment in equipment that is required for the maintenance work can be considered significant. The asset specific maintenance costs compared to the construction cost is not clear, however the equipment needed is not easily transferred to other pump maintenance projects and can therefore be considered as asset specific.

5.5.2 Step 2: Sourcing Selection

From the previous step we conclude that the total maintenance workload for the pumping stations is essential and asset specific in nature.
If we run these activities through the sourcing selection matrix (Figure 36), then the preferred strategy is *In-house*.

![Sourcing selection matrix](image)

**Figure 36 Sourcing selection matrix**

### 5.5.3 Step 3: Adapting sourcing strategy to national and organizational context

The assessment of the national and organizational situation in Indonesia can be taken from the previous run of the framework for the outer seawall. The results can be seen in Table 17.

<table>
<thead>
<tr>
<th>National or organizational aspect</th>
<th>Score</th>
<th>Effect</th>
<th>Undesirable sourcing strategy</th>
<th>Preferred sourcing strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maintenance culture</strong></td>
<td>Low maintenance culture in asset owning organization</td>
<td>Organization misses required knowledge and skills and funding to effectively maintain infrastructure</td>
<td>- In-house</td>
<td>- Outsourcing - Hybrid outsourcing - Outtasking</td>
</tr>
<tr>
<td><strong>Legal structure</strong></td>
<td>Legal structure that protects private sector investment in place. Potential corruption and political influence present</td>
<td>Short-term Maintenance contract (1-5 years) offer sufficient protection to</td>
<td>- Outsourcing</td>
<td>- Hybrid outsourcing - Outtasking - In-house</td>
</tr>
</tbody>
</table>
Adapting the sourcing strategy to the local context, gives a slight preference towards Outtasking instead of In-house. This is because of the lack of maintenance culture and maintenance management skills in the organization. Externalizing maintenance execution is preferred over in-house maintenance sourcing, since it can provide the asset owning organization with expertise of the private sector on pump maintenance.

The Outtasking strategy in the context of flood pump maintenance can be described as outsourcing of nonessential operational processes while retaining control over essential applications, utilizing the core competencies of the available maintenance contractors in the execution of maintenance, while focussing internal resources on the critical, strategic and tactical maintenance process steps.

Using the six-stage model of Schoenmaker the responsibilities of the supplier and client can be visualised. The black coloured blocks represent the contractor’s responsibilities and the white blocks are the client’s responsibilities.
The maintenance process steps that are performed by the contractor are *Work scheduling* and *Work execution*. The asset owning organization can best perform the other maintenance process steps itself.

The practical interpretation of the framework is given in Table 18

<table>
<thead>
<tr>
<th>Maintenance steps</th>
<th>process</th>
<th>Tasks involved</th>
<th>Responsible stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Work execution</strong></td>
<td></td>
<td>1. Monitoring</td>
<td>External contractor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Inspection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Repair</td>
<td></td>
</tr>
<tr>
<td><strong>Work scheduling</strong></td>
<td></td>
<td>- Work break down scheduling</td>
<td>External contractor</td>
</tr>
<tr>
<td><strong>Planning/design</strong></td>
<td></td>
<td>- Maintenance design</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td></td>
<td>- Analysis of inspection and measurement results</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Work identification</strong></td>
<td></td>
<td>- Identification of suppletion, shaping, landscaping, pest control, heightening, or repair tasks.</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Prioritisation</strong></td>
<td></td>
<td>- Order of execution of maintenance tasks</td>
<td>Asset owner</td>
</tr>
<tr>
<td><strong>Data management</strong></td>
<td></td>
<td>- Information management for all relevant actors</td>
<td>Asset owner</td>
</tr>
</tbody>
</table>

How the relationship between asset owner and the external contractor is arranged is defined in the 4th and final step of the framework: the implementation issues and risk mitigation.
5.5.4 Step 4: Implementation issues and risk mitigation

Most of the implementation issues for the Outtasking strategy for pump maintenance is similar to that described in the section for the outer seawall (see page 112).

The governing mode or contracting form best suited for the Outtasking strategy is short-term contracting. Possibly long-term contracting if the experience is positive.
5.6 Reflection on framework application on NCICD case

The following paragraph contains a reflection on the application of the framework. The framework does help in deciding on a suitable sourcing strategy. It provides two different sourcing strategies for the outer seawall and the pumping station. For the outer seawall *Hybrid Outsourcing* is considered the best suited and for the pumping station *Outtasking* is considered as the best option. This particularly due to the asset specificity concerning pump maintenance and the part of pump maintenance considered as essential to the core strategic goals of asset owning organization.

The initial run of the framework however has also identified some issues that could be improved. These issues are:

1. **Identification and assessment of maintenance for each separate asset type:**
   - Verification of correct input parameters. Are the flood defence register and the design specifications complete and correct?
   - Failure modes of asset do not treat all influences on the flood defence, such as land subsidence, vandalism, encroachment, sea level rise. Should these be taken into account when deciding on a sourcing decision?
   - Quantitative assessment of value and asset specificity of maintenance process steps. A qualitative approach is now used, but can a quantitative approach improve sourcing strategy selection?

2. **Sourcing selection matrix:**
   - The sourcing strategy is not calibrated to ensure that the right sourcing strategy is selected with step 2. The strategy *Hybrid outsourcing* can’t really be selected if 1 or more maintenance process step is considered essential, however this should be possible. It is possible to select Hybrid outsourcing through step 3 however.

3. **Adaption of sourcing strategy to national and organizational context:**
   - Verification of completeness of context. Are all organizational and national factors that influence the sourcing selection taken into account?
   - Improved assessment of the context. Is the method of assessment correct or does the method need be changed?

4. **Implementation issues and risk mitigation**
   - Content of implementation issues and risk mitigation is not complete. What evidence can be provided to support the current list of implementation issues?

**5.6.1 Framework improvement points**

The issues that have been identified can now be used to improve the framework if possible.

1. **Identification and assessment of maintenance for each separate asset type:**
   - Verification of correct input parameters:

For the theoretical application of the framework the flood defence information and design parameters used are sufficient to produce results. When the framework is applied for real situation the information needs to be complete and correct.
Failure modes of asset do not treat all influences on the flood defences, such as land subsidence, vandalism, encroachment, sea level rise, long-term asset deterioration and external influences need to be taken into account when assessing the maintenance workload and responsibility for these influences need to be allocated appropriately.

- Quantitative assessment of value and asset specificity of maintenance process steps:
For theoretical sourcing strategy decision making the qualitative assessment provides adequate information. The detail level that quantitative assessment provides is not necessary for this research.

2. **Sourcing selection matrix;**
The selection matrix seems prone to generate a sourcing strategy that is not Hybrid outsourcing, due to the calibration of the matrix. This is mainly due to 2 reasons.
   a) 1 or more maintenance process steps for flood defences are very likely to be essential, if the asset owning organization is a public organization responsible for flood safety of inhabitants.
   b) The sourcing selection matrix is based on more commercial sourcing strategies and does not seem to translate well to public infrastructure.
This can be improved by adapting the axes or changing the definition of the value of the maintenance activities or asset specificity.

3. **Adaption of sourcing strategy to national and organizational context;**
   - Verification of completeness of context.
Until proven otherwise, the organizational and national context parameters seems to be sufficient to provide a sourcing strategy that is tailored to the national and organizational situation
   - Improved assessment of the context.
Assessment of the context factors is now qualitative in nature, however this should be improved with quantitative data if that is available.

4. **Implementation issues and risk mitigation**
   - Content of implementation issues and risk mitigation is not complete.
A detailed implementation scheme is beyond the scope of this research, since the main goal of this research is to produce a sourcing strategy. The implementation process however is of importance to ensure a successful introduction of a sourcing strategy.
6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The goal of this research was finding the best suited sourcing strategy for maintenance of flood defence structures planned in the Jakarta bay. A sourcing strategy was developed using a framework for maintenance sourcing selection. The current maintenance practices lead to inadequate performance of flood defence structures. Strategic sourcing of maintenance can help focus the core strategic goals of the asset owning organization and relinquish non-essential maintenance tasks to external contractors. This framework helps asset-owning organization in emerging countries structure their maintenance sourcing decision.

In Chapter 2 and 3 the elements needed to construct the framework are researched. In Chapter 2 the theories on flood risk management, infrastructure maintenance, and sourcing theory are discussed and the relevant aspects for maintenance sourcing selection are derived. In Chapter 3 three reference cases in the Netherlands are researched and the results from this is then used to optimize the framework. Chapter 4 describes the framework and its steps. The framework consists of 4 steps needed to develop a maintenance sourcing strategy for flood defence structures. Chapter 5 applies the framework to the case in Jakarta and develops the best-suited maintenance sourcing strategy for the seawall as well as the pumping station of the National Capitol Integrated Coastal Development (NCICD) project.

6.2 Research questions

The research was divided into sub questions that are answered in the following paragraphs.

Flood defence structures are designed to provide a certain flood safety level. This is based on probability extreme flood conditions. The flood defence structures are designed to withstand the corresponding hydraulic loads and failure modes if maintained properly.

The maintenance requirements follow from the design flood safety levels, the hydraulic loads and possible failure modes. The maintenance requirements can be inspection, measurement, testing, (re)shaping, repairing and upgrading the flood defence structures.

The conditions that influence the maintenance sourcing decision-making process can be divided in two parts. First, the degree in which outsourcing of maintenance of infrastructure is possible. This is determined by the asset specificity and the value of the maintenance activities to the core strategic goals of the asset owning organization. Secondly, the national and organizational conditions that influence the outsourcing decision. These are the maintenance culture of the organization, suitable legal administrative power to control long-term contracts, required management skills for complex contracts and, the life-cycle approach to infrastructure maintenance. These conditions need to be addressed when selecting a sourcing strategy.

Several maintenance outsourcing strategies options can be considered for flood defence structure maintenance. Four sourcing strategies for maintenance have been found, namely In-house, Outtasking, Hybrid Outsourcing and Outsourcing. The In-house sourcing strategy means that the asset owner performs all maintenance tasks with
its own personnel. Outtasking entails the outsourcing of non-essential operational maintenance task, with the asset owner performing critical strategic and tactical maintenance process steps. Hybrid Outsourcing entail the outsourcing of all non-essential activities, with the asset owner only performing the most critical strategic maintenance process steps. Outsourcing entails offloading the entire maintenance workload to an external contractor.

A theoretical decision-making framework for the selection of maintenance outsourcing strategy was constructed, because there were no existing frameworks available that are designed to structure the flood defence maintenance-sourcing dilemma. When flood defence maintenance is outsourced it is done at an ad hoc basis or based on models for infrastructure other then flood defences, such as road or power infrastructure or commercial applications.

The maintenance sourcing strategies for the flood defence structures of the NCICD case that follow from the framework are Hybrid outsourcing for the seawall type flood defence structures. For the pumping station maintenance an Outtasking strategy is advised for maintenance sourcing.

### 6.3 Framework

![Flood defence maintenance sourcing decision framework for NCICD case](image)

By combining a generic framework for maintenance sourcing with the sourcing strategies for flood defence structures and the results of the reference cases, a framework for flood defence maintenance sourcing can be made (see Figure 38). The framework can be used to develop flood defence maintenance sourcing strategies and is based on the technical asset requirements and incorporates relevant aspects concerning the maintenance culture.
of the asset owning organization, the legal administrative powers, management skills and lifecycle approach to maintenance of infrastructure.
6.4 Conclusions

The conclusion that the framework can work to produce a maintenance sourcing strategy for Jakarta is based on the evidence of flood risk maintenance sourcing in cases in the Netherlands where similar assets in similar conditions are maintained.

6.4.1 Conclusions concerning the Jakarta case

- A complete outsourcing strategy for the flood defence structures of the NCICD is not realistic, because it would not allow for the asset owning organization to effectively control the contractor and guarantee the design safety levels of the flood defence structures. The strategic goals of the asset owning organization will thereby not be met. This can be accomplished through Hybrid Outsourcing or Outtasking. Performing maintenance In-house is not advised seeing the relevant performance in the past.
- Asset management agencies lack the maintenance capability and capacity needed to perform all maintenance for the NCICD flood defence assets in-house and therefore are advised to utilize the expertise and skills of external service providers. The asset management organization needs to be based on a durable sourcing strategy that is realistic and cost-effective.
- The shift from providing maintenance of flood risk infrastructure in-house towards a hybrid outsourcing or outtasking strategy requires the organization to skip many steps and to quickly learn how to successfully implement such maintenance sourcing strategies. The organization needs to be dynamic for it will need to cope with changes in the environment. This can relate to technical requirements, changes in contractor, land subsidence or sea level rise.

6.4.2 Conclusions concerning the sourcing selection framework

- Flood defence maintenance sourcing selection requires a different approach than for maintenance of commercial assets. Flood protection agencies have different strategic goals then commercial organizations or semi-public agencies such as port authorities.
- Much of the maintenance work can be considered generic in nature, however traditionally maintenance is not often outsourced. Recently changes can be found in this attitude towards flood defence maintenance outsourcing. This is due to political influences, the development of the market mechanism in maintenance provision, and advances in maintenance techniques for flood defence structures.
- (Part of the) maintenance workload for flood defence assets can often be considered essential, thus making complete outsourcing of flood defence maintenance difficult. Outsourcing all of the flood defence maintenance process steps contradicts the overall strategic goals of an asset owning organization. This is due to the function that flood defence structures fulfil for society. Full outsourcing of maintenance is applied in some cases, where risks are deemed acceptable, such is the case at Maasvlakte 2.

Although the sourcing selection framework can produce a sourcing strategy for flood defence structures there are some limitations to the framework. The framework is now qualitative in nature and needs to be refined with improved quantitative analysis. The national and organizational context should be more specific and concrete. Also these
parameters have only been gathered by sampling the situation in Indonesia and the Netherlands. It is possible that other parameters can be identified in different countries.

Another limitation is the implementation process. The scope of this research did not include the implementation issues and risk mitigation measures that follow the sourcing selection. These issues relate to contracting, governance modes, risk mitigation, payment schemes and organizational structuring. The successful implementation of a sourcing strategy relies in great part on resolving implementation issues.

6.5 Recommendations

A 5-year maintenance sourcing evaluation cycle is recommended for the organization to learn from their experience and the ability to adapt to new maintenance sourcing strategies.

This framework is also intended to stretch managerial mental modes in emerging countries such as Indonesia. Maintenance engineering in developed countries can be considered more advanced, but also need to bridge a greater gap when applied to infrastructure maintenance in emerging countries. Advanced flood defence structures are constructed in emerging countries by engineering firms from developed countries. These designs often too advanced for the maintenance departments of the flood defence management organizations in emerging countries. This framework is a tool that is intended to accelerate an asset management organization’s learning potential. By focussing on its core competencies it can focus on its ability to fast track its flood defence maintenance management skills.

Financial evidence needs to be provided to demonstrate the value of alternative sourcing strategies and convince policy makers of the advantages of alternative sourcing strategies.

The framework might be adapted for use in other flood asset maintenance projects that seek to improve their maintenance sourcing strategies. With some adaptions it might also be suited to help other infrastructure providers, such as road or energy infrastructure, with their maintenance sourcing dilemmas.


CMEA see: Coordinating Ministry for Economic Affairs.


EIB see: Economisch Instituut voor de bouw.


GFMAM see: Global forum on Maintenance & Asset Management.


I&M see: Ministerie voor Infrastructuur en Milieu.

IAM see: Institute of Asset Management.


ITC. (2004), from http://www.itc.nl/ilwis/applications/application01.asp


OECD see: Organization for European Cooperation and Development.


RWS see: Rijkswaterstaat.


UNDRO: see Office of the United Nations Disaster Relief Organization Coordinator.


VONK. Vervangingsopgave Natte Kunstwerken; Meerwaarde van de Gevoeligheidstest Natte Kunstwerken voor Adaptief Deltamanagement Case Gemaal- en Spuicomplex Ijmuiden: Rijkswaterstaat, Water, Verkeer en Leefomgeving.


WBGU see: Wissenschaftlicher Beirat der Bundesregierung für Globale Umweltveränderungen.


**APPENDIX**

**A. Flood risk management & Water Governance**

The Water Governance Centre (WGC) uses a three-layer model of water governance as a framework to clarify how the relevant elements of water governance can be distinguished and how they are interrelated.

![Three layer model of water governance](image)

The content layer consists of the knowledge of the water systems and the nature of the problems. In addition to that a good information position and the experience and skills required to solve the problems are essential. Water management practices can only be performed in the right way if the institutional layer is in order. The fundamental requirements for successful integrated water resources management means an adequate organizational framework together with the necessary legal instruments and a good financing structure. In addition, in order to successfully solve persistent water problems, attention to what is called the relational layer is required. Important elements of this layer are communication and cooperation between different actors and with the public, stakeholder participation, transparency and trust. Water governance focuses most explicitly on the institutional and relational layer, without neglecting the importance of and relations with the content layer.

The three-layered model is meant to create a framework that can be used to compare the different approaches and to be employed as a checklist. The WGC has compared the three layer model with the approaches of the OECD, which has identified seven gaps that need attention in good water governance and the ‘Building Blocks’ and ‘Academic panel assessment model of the WGC itself.
### Table 19 Comparison of Three layer model with other approaches

<table>
<thead>
<tr>
<th>THREE-LAYER MODEL</th>
<th>OECD GAP ANALYSIS</th>
<th>WGC ACADEMIC PANEL METHOD</th>
<th>BUILDING BLOCKS WGC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content Layer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear policy</td>
<td>Policy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge and skills</td>
<td>Capacity</td>
<td>Knowledge quality</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Administration</td>
<td>Institutional quality</td>
<td>Administrative organization</td>
</tr>
<tr>
<td>Legislation</td>
<td></td>
<td>Juridical quality</td>
<td>Water planning law</td>
</tr>
<tr>
<td>Financing</td>
<td>Funding</td>
<td>Economic quality</td>
<td>Financing system</td>
</tr>
<tr>
<td><strong>Institutional Layer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culture and ethics with Objectives (motivational)</td>
<td>Act ing and interacting capacities</td>
<td>Stakeholder participation</td>
<td></td>
</tr>
<tr>
<td>Communication and cooperation</td>
<td>Accountability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maintenance and the organization of maintenance within the field of integrated water management have linkages with the content layer and institutional layer. The outsourcing of maintenance can be linked to elements of the content layer, institutional layer and relational layer.
B. Asset Management & Maintenance

Asset management principles

The fundamental principles of asset management have been found to be (Davis, 2007; McGovern et al., 2013):

• **Who owns what and who is responsible and accountable?** – Each organisation should be aware of the assets it owns, and the assets it uses that are owned by others. The organisation should also be clear about who is the custodian of each asset, including who is responsible for the asset’s operation and maintenance and its management.

• **Know your assets** – Each organisation should have a full and accurate inventory and maintenance knowledge of all assets – date of ‘birth’, location, building contract documents, records of regular maintenance, breakdowns and repairs, replacements, upgrading, refurbishments, and details of disaster crises and remedies. This data is centralised in an asset register. Leong states: “only with the availability of accurate data of assets can asset management begin” (Leong, 2004).

• **Asset objectives** – What is the asset for? An organisation must have in place objectives for each and every asset, the services they provide to the public and the standard of service they are designed to deliver. These are the agreed levels of service.

• **Service criteria** – Every asset is designed to perform a social or environmental function. A monument celebrating a historical event provides an urban or community identity. Complex assets, like infrastructure, perform larger and more complex services. All service objectives must be clearly defined, with service criteria established for each asset or system of assets. When objectives change, the criteria for managing the asset also change. For example, an asset may be renovated, upgraded, refurbished, redeveloped of adapted to deliver the new levels of service or asset objectives.

• **Asset functions, conditions and performance** – Assets must be in a condition to deliver the agreed levels of service for which they are designed. For example, a water canal is designed to drain water from the city and protect inhabitants from flooding. But is that canal cluttered with waste or other blockages are present, water may flow over the banks and into the streets and houses. This may result in loss of economic activities and health risks such as electrocution.

• **User expectations** – Infrastructure is often designed for many types of users with different needs. For example, a road is used by cyclists, pedestrians, taxi drivers, and government cars; as well as trucks transporting produce to markets, petrol tankers, mining equipment, visitors, and school buses. An organisation that is the owner or custodian of infrastructure must know:
  • The levels of service the community wants and is willing to pay for.
• The community’s acceptance of the trade-offs between the asset and other social benefits.
• Levels of costs that are within the community’s capacity.
• The types of assets vital to the well being of a community. This may include the interaction between infrastructure and local environmental assets.
• Data on user expectations, usually obtained from local area plans, to be recorded and used in making decisions.

• **Asset stakeholders** – Assets are managed using a government’s or an organisation’s governance structure. These structures should also ensure that services meet the needs and demands of users and other groups affected by service delivery.

• **Environmental impact** – Natural ecosystems provide constraints within which organisations must function. The management of infrastructure can affect global, regional and local ecosystems. For example, if ports are not designed to isolate international ships from the local ecosystem, foreign flora and fauna may invade and destroy local habitats. Infrastructure service providers should have an ongoing relationship with stakeholders responsible for the management of the local, regional and global ecosystems.

The principles above guide infrastructure asset management, but their implementation requires work. Each organisation has a system through which staff manages assets. This can be either a simple or a complex asset management system.

**Asset management system**

A **simple asset management system** enables an organisation to ‘know’ its assets; including how much they cost, who is responsible for maintaining them, their condition and functionality and when they require rehabilitation. A simple asset management system focuses on each asset, independent of the system in which they function.

A **complex asset management system** is one in which a simple system is expanded to include photographs and plans of all assets, their component parts, their maintenance schedules and details of all activities on the asset since it was designed. It documents the system(s) in which the infrastructure delivers services. A complex asset management system includes an estimate of the life-cycle costs of an asset, the actual depreciation each year, amortisation details, and possible adaption/development to better align the current components to the changing needs of users and their clients. It identifies the related infrastructure systems that affect its ability to deliver the services required, the contact people, and details of collaborative maintenance (McGovern et al., 2013).

**Reliability Centered Maintenance**

A common methodology to determine the right maintenance strategy is Reliability Centered Maintenance (RCM). RCM is suited to an item and provides a structure for determining the maintenance requirement of any physical asset in its operating context, with the primary objective of preserving system function cost effectively (IEC, 2009; Moubray, 1997; Smith, 1993). Identification of system functions and functional failures, as well as failure mode and effects analysis, are important
elements in RCM. The RCM process entails seven basic questions to analyse a system, namely:

- What are the functions and the performance requirements of the infrastructure?
- In which ways can the infrastructure fail?
- What is the cause of failure?
- What are the impacts / effects of failure?
- What are the consequences of failure?
- What can be done to prevent failure?
- What needs to be done when no suitable preventive solutions can be found?

There are other methods to determine the right maintenance strategy such as Total Productive Maintenance (Tsang, 2002) and Value Management (Schoenmaker, 2011). Further research into the methodologies to determine maintenance strategy is not required. For this research it is important to realize there are objective methods available to determine the needed maintenance interventions.
### C. Six stage model

![Six Stage model](image)

**Figure 40 Six Stage model (Schoenmaker, 2013)**

<table>
<thead>
<tr>
<th>Process step</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals, objectives</td>
<td>Produce, implement, review and update the requirements, aims and objectives of the (regional) road agency</td>
</tr>
<tr>
<td>Develop organizational goals and objectives</td>
<td>Translate the objectives into SMART objectives that describe the requirements of the network and the requirements of the supporting processes</td>
</tr>
<tr>
<td>Performance requirements</td>
<td>Provide an accurate record of the condition and performance of the assets, recommend and undertake surveys to support analysis and work identification</td>
</tr>
<tr>
<td>Measure and inspect the assets</td>
<td>Establish and maintain an accurate and up to date asset inventory and associated condition and performance data to support use of this data by the other processes</td>
</tr>
<tr>
<td>Manage the data</td>
<td>Establish and maintain an accurate and up to date asset inventory and associated condition and performance data to support use of this data by the other processes</td>
</tr>
<tr>
<td>Analysis</td>
<td>Analyse data and intelligence gathered and documented to identify trends, faults, intervention levels that are in conflict or future conflict with the requirements</td>
</tr>
<tr>
<td>Identify the needs</td>
<td>Produce effective solutions that satisfy the identified needs to keep the assets in line with the requirements</td>
</tr>
<tr>
<td>Identify the solutions</td>
<td>Produce effective solutions that satisfy the identified needs to keep the assets in line with the requirements</td>
</tr>
<tr>
<td>Plan and design the intervention</td>
<td>Deliver maintenance plans and preliminary designs of the solutions</td>
</tr>
<tr>
<td>Prioritise the interventions</td>
<td>Weigh the proposed interventions on preset criteria, the available budgets and impact on requirements. If necessary propose changes in requirements if available budgets do not cover the identified needs</td>
</tr>
<tr>
<td>Schedule for delivery</td>
<td>Prepare for construction to ensure the delivery is to pre-determined cost and time</td>
</tr>
<tr>
<td>Work execution</td>
<td>Efficiently deliver the maintenance work and deliver input for the data</td>
</tr>
<tr>
<td>Deliver the work</td>
<td>management systems</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Approve</td>
<td>Advice</td>
</tr>
<tr>
<td>Approve - 0-inspection</td>
<td>Advice - before contract</td>
</tr>
<tr>
<td>Deliver</td>
<td>Advice - during contract</td>
</tr>
<tr>
<td>Deliver - before contract</td>
<td>Approve</td>
</tr>
<tr>
<td>Deliver - before contract</td>
<td>Approve &amp; input</td>
</tr>
<tr>
<td>Deliver - corporate</td>
<td>Collect &amp; provide</td>
</tr>
<tr>
<td>Deliver - corporate/regional</td>
<td>Deliver</td>
</tr>
<tr>
<td>Deliver - partially</td>
<td>Deliver 0 - inspection</td>
</tr>
<tr>
<td>Develop &amp; deliver</td>
<td>Deliver - partially</td>
</tr>
<tr>
<td>Independent audit</td>
<td>Develop</td>
</tr>
<tr>
<td>N/A</td>
<td>Develop &amp; deliver</td>
</tr>
<tr>
<td>Own, review</td>
<td>Maintain</td>
</tr>
<tr>
<td>Review</td>
<td>N/A</td>
</tr>
<tr>
<td>Review &amp; approve</td>
<td>Review &amp; approve</td>
</tr>
<tr>
<td>Review &amp; deliver</td>
<td>Supply &amp; maintain</td>
</tr>
<tr>
<td>Review &amp; deliver - during contr</td>
<td>Understand and apply</td>
</tr>
<tr>
<td></td>
<td>Understand and comply</td>
</tr>
<tr>
<td></td>
<td>Understand, apply &amp; comply</td>
</tr>
<tr>
<td></td>
<td>Advice</td>
</tr>
<tr>
<td></td>
<td>Deliver</td>
</tr>
<tr>
<td></td>
<td>Develop &amp; deliver</td>
</tr>
<tr>
<td></td>
<td>Supply data</td>
</tr>
</tbody>
</table>
D. Transaction cost economics

The paradigm of transaction cost economics states that the organization of transactions between providers and users should be designed to maximize net value of the sum of production and transaction costs, based on the characteristics of the transactions (Baldwin, 1997). Transactions differ in asset specificity—the extent to which investments made to support particular transactions can be put to other uses if the buyer/seller relationship ends. Governance structures—markets, contracts, and internal hierarchies—differ in their incentives to maximize net value of costs and in their ability to protect investments in transaction-specific assets. For example, markets provide strong incentives to maximize net value, but little protection for transaction-specific investments, because it is easy for buyers or sellers to walk away from the relationship. Therefore, transactions that involve a high level of asset specificity can often be more effectively organized internally, since the organization has an incentive to protect its own investment in the transaction. Transactions using relatively generic assets can be outsourced more easily. For maintenance outsourcing this implies that more common, non-unique flood defences are relatively easier to maintain then a ‘one-off’ flood defence.

Figure 41 Spectrum of Governance structures (Baldwin, 1997)

Transactions can be organized under a spectrum of governance structures ranging from pure, anonymous spot markets – where the good or service is generic and identities of buyers and sellers are unimportant to the transaction – to fully integrated firms or organizations, where both the trading parties are under unified ownership and control, and the transaction can be modified by managerial permission. This can be seen in Figure 41. Between the two poles of spot markets and vertical integration are contracts of increasing duration and complexity, which can include partnerships that are owners of assets. Simple, short-term contracts involve customization that requires an exchange of information and terms of payment. For more complex customization, longer-term contracts may be required, including adjustment clauses to respond to contingencies over the life of the contract. When the goods or services cannot be well defined in advance, relational contracts may be used. These contracts focus on the terms of the relationship rather than the scope of work, which may be renegotiated as needed.

Within this context, outsourcing represents a move away from vertical integration to one of the contracting options. The optimal governance structure for a particular good or service or how far one should move to the left of the spectrum depends on the characteristics of the transactions involved.

Transaction characteristics

Some goods and service can be produced more efficiently if one of the parties invests in “transaction-specific” assets that cannot easily be put to other uses if the buyer/seller relationship breaks down. Asset specificity can take a variety of forms including (Baldwin, 1997; Schoenmaker, 2011):
• *Site or location specificity* – a buyer or seller locates its facilities next to the other to economize on inventories or transportation costs;
• *Physical asset specificity* – investments are made in specialized equipment or tooling designed for a particular customer;
• *Human capital specificity* – one or both of the parties develop skills or knowledge specific to the buyer-seller relationship;
• *Dedicated capacity* – capacity is created to serve a customer who is large relative to market size, so that it would be difficult to find alternative customers; and
• *Brand name capital* – when the parties must maintain the reputation of shared brand, as is the case with franchise relationships. This usually does not apply to maintenance contracting.

Because the value of the transaction-specific assets depends on the continued existence of the buyer/seller relationship, the party that has not invested may expropriate some of the value of the investment by threatening to walk away from the relationship. If the investor cannot be assured of realizing the full value of the transaction-specific investment, efficient investments that reduce the cost of production may not be made, resulting in higher costs to both parties.

Bounded rationality may also interfere with the efficient operation of transactions. Because of limited managerial time and span of control, organizations cannot effectively manage an unlimited or even a limited number of transactions internally. In addition, bounded rationality limits the capability of markets and simple contracts to handle asset specificity, because the parties cannot foresee and contract for all possible contingencies (Baldwin, 1997).

**Governance structures characteristics**

<table>
<thead>
<tr>
<th>Governance Structure</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markets</td>
<td>Strong incentive to maximize net value</td>
<td>Can’t protect transaction-specific investments</td>
</tr>
<tr>
<td>Contracts</td>
<td>Some protection for investments; market-like incentives</td>
<td>Can’t contract for all possibilities</td>
</tr>
<tr>
<td>Vertical Integration</td>
<td>Internalizes value of transaction specific investments</td>
<td>Can’t control costs as well as market</td>
</tr>
</tbody>
</table>

*Figure 42 Governance structure characteristics*

For many types of transactions, markets are the preferred governance structure because they provide “high-powered incentives”. That is, the supplier reaps the full benefits or bears the full costs of its own activities, and thus has a strong incentive to
maximize value net of production costs, and to respond quickly to changes in the market prices of inputs or outputs. However, transaction cost economics argues that markets have difficulty dealing with some transactions because of asset specificity, bounded rationality, and opportunistic behavior by the parties to the transaction (Schoenmaker, 2011). Since buyers and sellers can easily walk away from pure, spot market transactions, they offer no protection against opportunism when transaction-specific assets are involved.

Contracts offer some protection for transaction-specific assets by tying the buyer and seller together for a specified period. However, bounded rationality precludes comprehensive ex ante contracting that specifies how the parties will behave in all possible circumstances. If contracts are inherently incomplete, parties may perceive potential gains from opportunistic behavior. As a result, attention must be focused on more complex (or internalized) governance mechanisms to fill gaps in the contract, settle disputes, and adapt to new conditions. Contracting parties may also make ex ante efforts to screen counterparties in terms of reliability or reputation, and/or designing ex post safeguards to protect transaction-specific investments.

When asset specificity, bounded rationality, and opportunism make contracting problem severe, vertical integration may be needed to ensure that the value of transaction-specific assets is internalized. It can also follow for flexible redeployment of assets and personnel when the conditions surrounding the transaction change. However, bounded rationality limits the span of effective managerial control. Lower-level managers and employees may engage in suboptimizing behavior, or they may have insufficient incentives to minimize production costs.

If it is feasible to have more than one source of supply, organizations can mitigate some of the negative effects of markets and vertical integration by maintaining both internal and external providers. Outsourcing part of the workload to an external provider or allowing internal customers the option to buy externally can create incentives for the internal provider to control costs and improve performance by exposing it to market pressures. Conversely, retaining some capability to produce in-house can allow organizations to maintain management competencies needed to make more effective sourcing decisions; retain some leverage over the external provider, particularly when there are only a few potential suppliers; and maintain surge capacity (Baldwin, 1997).

**Relationship between transaction and governance**

Because markets provide stronger incentives to maximize value net of production costs, whereas vertical integration may be a more cost-effective governance structure for transactions involving asset specificity, the central recommendation of TCE is that the governance structure for a particular transaction should be chosen to maximize value net of both production and governance costs. This is reflected by the Dutch public works agency Rijkswaterstaat approach “Markt, tenzij...” meaning “Market, unless...” (RWS, 2008). Thus, in making outsourcing decisions, it is important to consider not only the internal and external costs of providing the good or service but also the cost of managing the transaction internally and externally.
To summarize the predictions of TCE, market governance of transactions may impede efficient investment in transaction-specific assets because of the potential for opportunistic behaviour. Contracts can protect transaction-specific investments to some extent, but bounded rationality prevents contracts from specifying all possible contingencies. As contracts become more flexible, they allow more potential for opportunism. Thus asset specificity, combined with the potential for opportunism and bounded rationality, tends to move the efficient governance structure to the right on the spectrum. However, bounded rationality also places a limit on the number of activities that can be controlled within a single organization, so firms should only internalize transactions that they can govern more effectively than through markets or contracts. Thus, the arrows in the diagram indicate that bounded rationality tends to preclude organizations based entirely on markets or on vertical integration. In addition, production costs are likely to be lower as one moves toward the market end of the spectrum because of market incentives to maximize value net of costs and because of the potential for greater economies of scale with an external provider that serves multiple customers.

The empirical evidence on transaction cost theory seems to substantiate the predictions. In a study into the evidence on transaction cost theory Baldwin (1997) observed the following:

- **Asset specificity makes outsourcing more difficult**: asset specificity, uncertainty and thin market are more efficiently managed by vertical integration, but outsourcing can still be feasible if the buyer owns transaction-specific assets.

- **Contracts can be tailored to fit the characteristics of transactions**: Increasing contract length can reduce potential for opportunism, but limits adjustments to changing circumstances. Other contract provisions than can be used to manage uncertainty and opportunism are minimum purchase requirements, price adjustment provisions and opportunities for renegotiation.

- **Timing and reputation can influence outsourcing decisions**: if timing in delivery is crucial, vertical integration may allow more flexible and responsive scheduling. Reputation effects are important for both buyers and sellers. When
used in source selection it can reduce opportunism by sellers and opportunism by buyers can drive potential sellers away.

It seems that transaction cost theory can be used not only to explain why organizations source their activities the way they do, but also show how sourcing decisions are made in a structured manner. Sourcing selection tools have been developed by authors such as Kraljic (1983) and Hui and Tsang (2004).
E. Literature study summary and conclusion

Flood risk management
Communities that are at risk from floods need flood risk management interventions to analyse, assess and reduce the risk of floods. Floods can never fully be prevented, however the risk of flood must be treated through technical and non-technical measures. The performance of flood defences is based on design water level, probability of failure and availability of service and adequate maintenance of flood defences is needed to ensure flood safety levels are kept during the asset life cycle. Maintenance of flood defences should be considered as an integral part of the development of flood defences. Port cities need to adapt to future socio-economic changes as well as sea level rise and land subsidence. Cities that experience subsidence, such as Jakarta, relatively are among the most exposed to flood damage. Neglected maintenance often results in aggravated costs of flooding.

Governments are moving from government to governance, transferring water management tasks, such as maintenance, to the markets. Water governance concerns the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society. The five principles of sound organization for water management prescribes the conditions needed for good water governance. The maintenance organization in water governance of Indonesia has been shown to have opportunities for improvement according to the WGC.

The questions from this chapter and their answers are:

(1) **What are the basic principles of flood risk management and how are flood safety levels determined?**

Flood risk management is the holistic and continuous societal analysis, assessment and reduction of flood risk. Flood safety provided by flood defences is determined by the design water level, probability of failure and availability of the asset. Maintenance requirements flow from these floods safety levels.

(2) **What flood risk challenges do coastal cities in emerging countries face in the future?**

Coastal cities are increasingly exposed to floods due to growth of population and wealth, sea level rise and land subsidence. Even if investments to adapt current flood defences remain the same flood probability, subsidence and sea-level rise will increase the global losses due to flood. If cities want to maintain present flood risk, they will need adaption to reduce flood probabilities below current values. In this case, the magnitude of losses when floods do occur would still increase, often by more than 50%, making it critical to also prepare for larger disasters than are experienced today. Jakarta is one of the cities that experiences land subsidence and of which it is expected that flood losses would increase significantly even when maintaining present flood risk.

(3) **In what degree can maintenance contribute to attaining flood risk management goals?**
Maintenance of flood defences is needed to maintain the design flood safety levels and to adapt the flood defences to changes in the safety level. Failure of maintenance execution will deteriorate safety levels. Flood defences need to be raised to counter the effects of sea level rise and land subsidence. This needs to be inspected and tested or otherwise flood safety will decline. Asset owners that neglect maintenance will have to suffer added losses during floods. In Jakarta neglected maintenance resulted in aggravated flood losses after the 2007 floods. It is estimated that 40% reduction of flood risk could be reached if regular maintenance had been carried out. Based on experience approximately 2% of the initial investment cost should be spent annually on operation and maintenance. Maintenance should be considered as an integral part of flood defence development.

(4) What are considered to be the water governance opportunities for maintenance in the NCICD project Indonesia?

According to the WGC the water governance opportunities for maintenance for the NCICD are:

1. **Adopting a lifecycle approach to ensure maintenance and operation cost are provided for the entire life cycle of the project.** A life cycle approach might lead to higher initial investments, if that means lower lifecycle costs on the long term.

2. **Institutional development and capacity building.** The programme management of the NCICD will have new responsibilities. The institutional design, embedment, budget and legal framework for the organization needs to be established. Maintenance should have an important role in this new organization.

3. **Public private partnerships, innovative contract management and alternative financing mechanisms.** Private sector involvement is essential and there should be incentives that engage the private sector. Maintenance for the NCICD should also offer private sector incentives such as innovative contracts, with more emphasis on quality and long-term objectives than only procurement based on price.

**Infrastructure maintenance**

Infrastructure asset management is a more complete approach to asset governance than just asset maintenance. It involves all the activities that ensure assets help fulfil the objectives of an organisation, and is therefore concerned with asset performance, risks and expenditures. The principles of asset management give guidance on how to structure infrastructure asset management.

For this research it is important to see the position of maintenance within the larger field of asset management. For this research it is important to focus in maintenance of flood risk infrastructure that is located in emerging countries.

Implementing asset management requires a lifecycle approach that involves the entire organization and not just the maintenance department. Life-cycle costs can be much higher than initial construction and supply costs when operation, maintenance and disposal of infrastructure are considered. Rough estimates imply that annually
maintenance spending should be approximately five to six per cent of the non-depreciated value of the asset.

Maintenance is the combination of all technical and administrative actions, including supervision and monitoring, intended to retain an item in, or restore it to a state in which it can perform a required function. The different types of maintenance are preventative maintenance, corrective maintenance, condition-based maintenance and design improvement. Maintenance planning horizons that illustrate the conflicting nature of long-term decision-making for asset managers are the operational, tactical, and strategic horizons. Maintenance managers need to execute the right maintenance tasks (operational), find the right mix between fixed and variable maintenance (tactical) and choose the right maintenance strategy (strategic).

Maintenance can be seen as a cyclical process. The six-stage model encapsulates the three cyclical processes and offers a visual tool that can help allocate the responsibilities of contractor and client in a maintenance outsourcing situation.

In emerging countries often barriers are in place that block the delivery of good asset management. These barriers can be categorized in resource constraints, organisational constraints and incentives. The result is an infrastructure maintenance gap that must be closed. Since preventative maintenance is what is most lacking in these countries each opportunity to break the Build-Neglect-Rebuild paradigm must be seized and applied if proposed change offers improvement in infrastructure maintenance delivery.

The questions from this chapter and their answers are:

(1.) **What is asset management and how does it help organizations?**

Asset management is the process of guiding the acquisition, use and disposal of assets, to make the most of their service delivery potential and manage the related risks and costs over the full life of the assets. Adopting an asset management approach helps organizations better manage their asset over the entire life cycle of the asset. Asset management concerns the entire organization and not just the maintenance department. Asset management can help organizations reduce costs over the entire life cycle by providing a coherent framework between the different disciplines in an organization.

(2.) **What is maintenance and what maintenance strategies are suited for flood risk management?**

Maintenance concerns all technical and non-technical actions, including supervision and monitoring, intended to retain an item in, or restore it to a state in which it can perform a required function. Determining a suitable maintenance strategy often concerns a cost benefit analysis. Since failure of flood protection might lead to unacceptable costs, a preventative maintenance strategy is best suited for flood risk management. This is in line with the greater philosophy behind flood risk management, namely to prevent damage from floods.

(3.) **How is maintenance of infrastructure performed by emerging countries?**
Preventative infrastructure maintenance in emerging countries is often neglected. There seems to be a Build-Neglect-Rebuild paradigm that prevents the delivery of adequate infrastructure maintenance. The factors responsible for poor asset management and lack of maintenance are:

- Organisational constraints;
  - Lack of required information
  - Lack of required skills
  - Roles and responsibilities not clear
  - Lack of accountability
  - Limited private sector capacity
- Resource constraints;
  - Inadequate government budgeting for maintenance due to lack of revenue or other priorities
  - State Owned Enterprises (SOEs) may not have resources for maintenance, given pricing regimes
- Incentives:
  - Moral hazard arising from development assistance
  - Political incentives lead to prioritization of new infrastructure
  - No culture of maintenance
  - Service not valued by customer

Some of these factors need to be taken into account when determining a sourcing strategy. Which factors that should be might follow from the sourcing theory literature study.

**Sourcing of maintenance**

Outsourcing is the process where the client offloads a certain task or set of tasks to an external service provider. The advantages of outsourcing are amongst others a better focus on core activities and a reduction of workforce. Some disadvantages are the possibility of losing a critical skill and losing control over the supplier. Outsourcing is guided by the theoretical underpinnings of Transaction cost economics. This theory states that market transactions are not free of costs. Even though firms present a more efficient way of exchange, costs are incurred to structure the organization. The organization of transactions between providers and users should be designed to maximize net value of the sum of production and transaction costs, based on the characteristics of the transactions. Transactions differ in asset specificity. Governance structures differ in their incentives to maximize net value of costs and in their ability to protect investments in transaction-specific assets. Transactions using relatively generic assets can be outsourced more easily.

The governance spectrum varies from the two poles spot markets and vertical integration with in between them contracts of increasing duration and complexity. When asset specificity, bounded rationality, and opportunism make contracting problem severe, vertical integration may be needed to ensure that the value of transaction-specific assets is internalized. These predictions are supported by empirical evidence. Selecting an outsourcing strategy should be done with care, as there are numerous examples of outsourcing gone wrong. Numerous scholars have adapted Kraljic’s decision matrix for supply management. A sourcing strategy decision matrix for maintenance of facilities was
developed by Tsang and could be adapted for this thesis. There are 4 sourcing strategies have been identified namely in-sourcing, outsourcing for cost efficiency, outsourcing for capability and out-tasking. Selection between these strategies is done by taking into account the scope and purpose of sourcing. Implementing a sourcing strategy often lead to issues that must be addressed or failure of the new sourcing strategy may follow.

The questions from the beginning of this chapter can now be answered.

(1.) What are the principles of sourcing theory and how can it help organizations?

The pillars where sourcing theory is based on are (1) the use of domestic resources mainly for the core competencies of the company; and (2) the outsourcing of all other (support) activities that are not considered strategic necessities and/or whenever the company does not possesses the adequate competencies and skills. Applying the right sourcing for services allows organizations to focus on their core tasks. It can help organizations reduce costs, and staff, while becoming more flexible and importing specialist skills that were not present in the organization. There are risks involved with unloading tasks to the market. If outsourcing is to be considered these need to be treated by applying the right governance structure.

(2.) Which are important factors to consider with outsourcing according to transaction cost economics?

The factors that influence outsourcing can be found in transaction cost theory. These are:

- **Asset specificity**: the more generic an asset is considered the more it can be outsourced to the market. Increasing specificity adds more transaction specific costs for a potential contractor and these might be better integrated in the client organization.

- **Duration and complexity**: long term contracts and/or more complex contracts require more attention to the type of contract that is used.

- **Bounded rationality**: because of limited managerial time and span of control, organizations cannot effectively manage an unlimited or even a limited number of transactions internally. This however also works the other way around since bounded rationality limits the capability of markets and simple contracts to handle asset specificity, because the parties cannot foresee and contract for all possible contingencies.

- **Potential opportunism**: if the risk of potential opportunism is severe, vertical integration of the service may be preferred instead of outsourcing.

Findings from the field seem to confirm the predictions of transaction cost economics.

(3.) When is maintenance outsourcing beneficial for a governing organization?
Maintenance sourcing can help organizations that manage public infrastructure reduce cost and staff, focus on their core activity and allow for more transparency. Specialist skills that are needed can be accessed through outsourcing.

(4.) How can an asset management authority select a sourcing strategy for maintenance in a structured manner

There are outsourcing strategy decision support models available. These are often designed for private organizations that are in search of maximizing their net profit. Public or non-profit organizations can also use these models, although they need to be adapted to suit the specific needs. In general sourcing strategy selection requires technical analysis of the functions or services that are considered for outsourcing and an analysis of the organization and its capabilities and objectives. Sourcing strategies can be developed beforehand and selection can take place based on the results of the first two steps. Implementation of the chosen strategy is important, since different strategies may have different issues that may arise.

(5.) Is outsourcing of infrastructure maintenance a viable alternative for emerging countries?

Outsourcing of infrastructure maintenance is becoming standard practice in western countries, but is still in development in emerging countries. It is suggested that force account labour, which is a barrier to good infrastructure maintenance, might be resolved through outsourcing strategies. If new approaches to maintenance and asset management are to be introduced, new project offer better opportunities then existing infrastructure. Considering outsourcing of maintenance for the NCICD project seems to be a viable and worthy undertaking.
F. Maintenance Analysis

The maintenance requirements follow from:

1. Performance requirements and design safety levels of the flood defences.
2. Known failure modes of the flood defences.
3. Risks involved with the failure modes;
4. Specific design aspects of the flood defences.
5. Usage of the flood defence.

From these requirements the maintenance tasks are derived. The result is a list of the required maintenance activities per asset and a description of the work involved. For each of these tasks several aspects are of interest:

1. Maintenance requirement derived from the safety level;
2. Predictability of maintenance tasks;
3. Specificity involved with the maintenance task, and;

After the maintenance work tasks have been researched, the maintenance management tasks will be assessed on their criticality to the strategic goals of the asset owning organization.

For the sourcing strategy selection it is important to determine the expected specificity of the maintenance work and criticality for all maintenance activities. The specificity determines in significant degree the suitability for outsourcing. The more specific the tasks are, the more risk the contractor has with the maintenance transaction.

The critical maintenance activities flow from the strategic goals of the water management organization. Activities that are critical for the asset owner are rather not left to the market, since this exposes the asset owning organization to undesirable risks. The asset owning organization must ask themselves: “What parts of maintenance management and maintenance execution form a critical part for the fulfilment of our strategic goals?”
G. Implementation issues

Figure 44 shows a flow chart of the process. There are three feedback loops in the process – the feedback to “work transaction” refers to repeated cycles of work execution, the feedback to “service agreement” may entail modifying the level of service delivered to customers, and the feedback to “choice of strategy” may result in change of sourcing strategy in response to a new business environment.

Figure 44 Implementation process steps

According to Hui and Tsang (2004) when ensuring that a chosen sourcing strategy is effective, one needs to be aware of the related strategic and operational issues that arise at various stages of the implementation process. See Tables 20 and 21 for a list of these issues. Usually, the strategic issues take priority over operational issues.
### Table 20 Strategic implementation issues (Hui & Tsang, 2004)

<table>
<thead>
<tr>
<th>Key stages of implementation</th>
<th>In-sourcing</th>
<th>Outsourcing for cost efficiency</th>
<th>Outsourcing for capability</th>
<th>Out-tasking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Integration with business plan</td>
<td>Budgeting</td>
<td>Benchmarking</td>
<td>Supply chain</td>
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<tr>
<td>Service agreement</td>
<td>Investment justification</td>
<td>Zero sum game</td>
<td>Relative power between supplier and buyer</td>
<td>Win-win game</td>
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<tr>
<td></td>
<td>Knowledge management</td>
<td>Market mechanism</td>
<td></td>
<td>Power balance</td>
</tr>
<tr>
<td>Work transaction</td>
<td>Process management</td>
<td>Control of opportunism</td>
<td>Know-how transfer</td>
<td>Reducing information asymmetry</td>
</tr>
<tr>
<td>Performance review</td>
<td>Performance management system</td>
<td>Budget control</td>
<td>Alignment of partners' strategic objectives</td>
<td>Alignment of partners' performance goals</td>
</tr>
</tbody>
</table>

### Table 21 Operational implementation issues (Hui & Tsang, 2004)

<table>
<thead>
<tr>
<th>Key stages of implementation</th>
<th>In-sourcing</th>
<th>Outsourcing for cost efficiency</th>
<th>Outsourcing for capability</th>
<th>Out-tasking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Process capability</td>
<td>Open tender</td>
<td>Invitation for tender</td>
<td>Task specification</td>
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<td></td>
<td>Skill inventory</td>
<td>Competitive offers</td>
<td>Prequalification</td>
<td>List of approved contractors</td>
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<td></td>
<td>Organization structure</td>
<td></td>
<td>Competitive offers</td>
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<td></td>
<td>Budget</td>
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<tr>
<td>Service agreement</td>
<td>System/technology</td>
<td>Define service level</td>
<td>Due diligence</td>
<td>Define service level</td>
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<tr>
<td></td>
<td>Employment contract</td>
<td>Expectations</td>
<td>Define service level</td>
<td>Risk and contingencies</td>
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<tr>
<td></td>
<td>Training</td>
<td>Accountability</td>
<td></td>
<td>Incentives and penalties</td>
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<tr>
<td>Work transaction</td>
<td>Task assignment</td>
<td>Autonomous</td>
<td>Autonomous</td>
<td>Job order for task</td>
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<td></td>
<td>Program schedule</td>
<td>Procedure control</td>
<td>Procedure driven</td>
<td>Permit to work</td>
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<tr>
<td></td>
<td>Risk and contingencies</td>
<td>Monitoring</td>
<td>Participation</td>
<td>Joint action</td>
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<td>Quality assurance</td>
<td>Quality control/audit</td>
<td>Documentation</td>
<td>Monitoring</td>
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<td>Procedure</td>
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<td>Coordination</td>
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<td>Coaching</td>
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<td>Stakeholder coordination</td>
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<td>Performance review</td>
<td>Performance appraisal</td>
<td>Reporting</td>
<td>Performance feedback</td>
<td>Information sharing</td>
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<td>Stakeholder satisfaction</td>
<td>Corrective actions</td>
<td>Effective control</td>
<td>Productivity</td>
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<td>Learning from experience</td>
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<td>Stakeholder satisfaction</td>
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<td>Proactive approach to issues</td>
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