ASSET MANAGEMENT IN PUBLIC URBAN AREAS

A FRAMEWORK TO INCORPORATE VALUE IN MANAGING INNER-CITY QUAY WALLS

APPENDICES

MASTER THESIS - PHILINE GOLDBOHM - MARCH 2016

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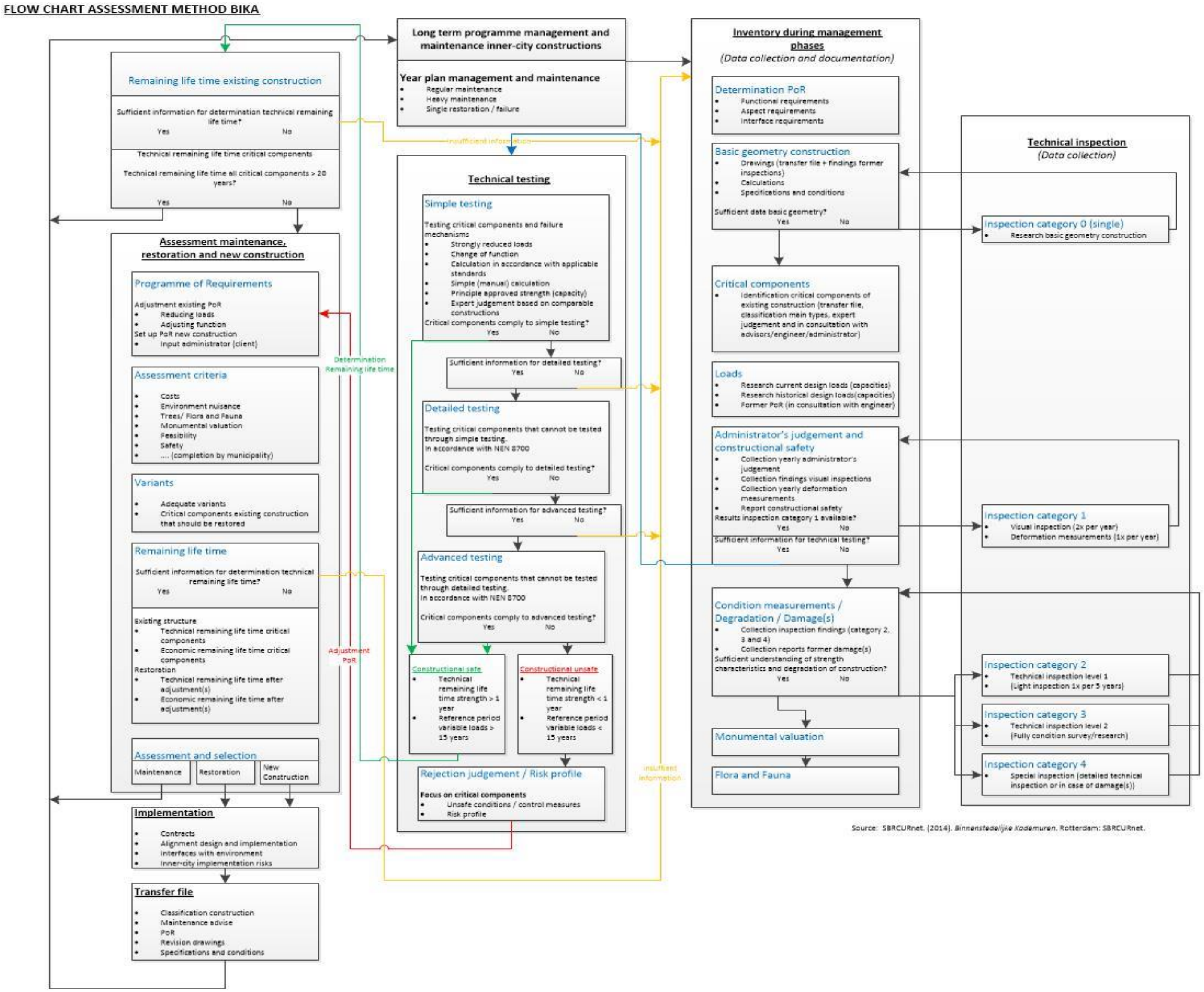


Source: SBRCURnet. (2014). *Binnenstedelijke Kademuren*. Rotterdam: SBRCURnet.

B. BACKGROUND

Value

Appendix 0 elaborates on the definition of value (B.1.1), functional (B.1.2) and technical value (B.1.3) and its mutual relationship (B.1.4). Furthermore, the principles of value capturing (B.1.5), opportunities and risks (B.1.6) are discussed. Additionally, methods to analyse and quantify this value in regard to managing inner-city quay walls as part of the public urban area are elaborated (B.1.7). This results in the answer to the following sub-question:

SQ1: What is understood by value in managing inner-city quay walls and how can it be quantified?

B.1.1 Value Definition

There are numerous descriptions of 'value'. Cohen (2005) defines value as "a fair return or equivalent in goods, services or money for something exchanged". Value is commonly proposed as the relationship presented in *Eq. 1* (A. Ramdien, 2012).

$$Value = \frac{Performance}{Cost} \qquad \textit{Eq. 1}$$

Value is a dynamic concept and is subjected to time and perception. Value attributes may be translated into performance criteria. Performance is measured by referring to clearly defined objectives (Tsang, 2002, p. 30). Furthermore, performance criteria are defined as a range of inherent characteristics (and functions) of an object that affects its value perception in the eyes of the client. Performance criteria are also used as selection criteria for management strategies. According to *Eq. 1*, several strategies to maintain or improve value can be formulated (A. Ramdien, 2012): adding function(s); increasing performance; and decreasing costs.

The best way to achieve more value of existing quay walls for local authorities is to improve their functionality while remaining or reducing the investments and (annual) maintenance cost (Li, 2008). This is why functionality, performance and cost should be well defined (A. Ramdien, 2012).

Systems Engineering (SE) focuses on customer requirements throughout the entire life cycle. Each process must contribute to optimisation taking into account the whole life cycle of a system. There is always an uncertainty on what will happen in this cycle. In order to decrease or anticipate this uncertainty, several methods or approaches can be used, for example Value Engineering (VE), Asset Management (AM) and Life Cycle Cost (LCC) (Michiels, 2003). In this context, value is defined as the misleading term 'cost effectiveness' (Grunsven, 2010; Juran, 1999). This definition describes also the relation between the system or asset effectiveness and the incurred costs: performance in relation to cost (FIGURE 1).

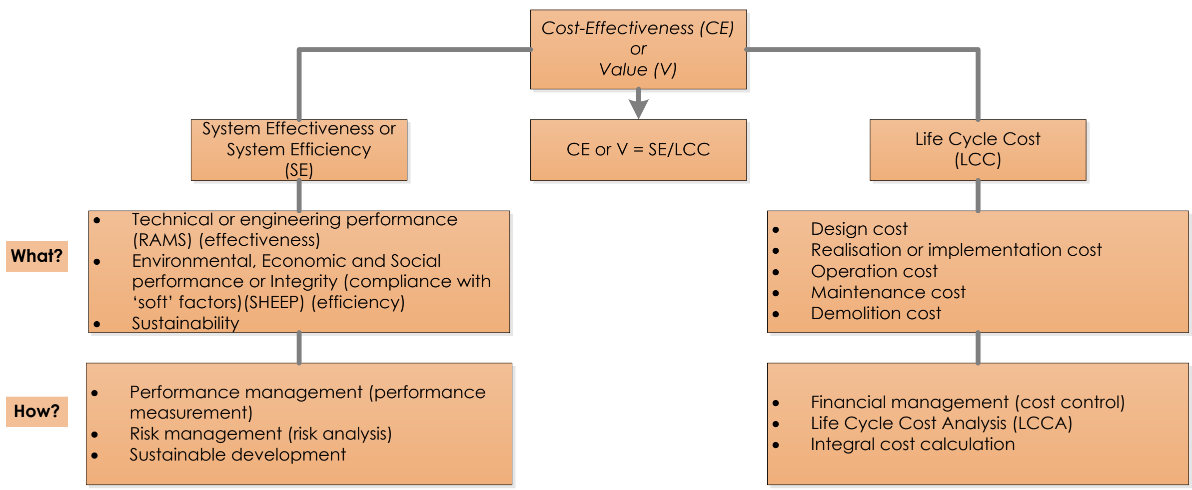


FIGURE 1: Value or cost-effectiveness (based on (Grunsven, 2010)).

The "Value and Cost-model" of H. A. J. De Ridder (2013) is also used to provide an understanding of the value concept. This model distinguishes a value creator and a value seeker. Within the scope of this research, the value creator (municipality) can be seen as the actor who facilitates in the need of the value seeker (users of public area and in this case inner-city quay walls). The value creator is the municipality who manages the public area in such way that it fulfils its functions regarding the need of its users (entrepreneurs, residents, customers, etc.).

The municipality is primarily responsible for the realisation and management of the public area and the inner-city quay walls. Directly after the realisation of a quay wall, this structure has a potential value. However, once the user function(s) of the public area are actually fulfilled, the desired value level becomes reality. The municipality incurs costs in order to facilitate the desired functions of the inner-city quay wall, as part of the public area. The combination of the estimated costs and a particular risk percentage results in a budget, determined by the municipality (FIGURE 2).

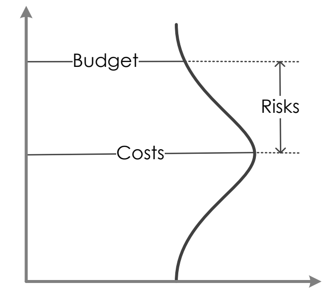


FIGURE 2: Budget.

Value is divided into amenity value, user value and future value (De Ridder, 2009, p. 13). Amenity value considers architecture and shape (aesthetics). User value relates to function (e.g. capacity) and future value to technical value (e.g. reliability, maintainability and safety). The costs consider investment costs, operation and maintenance costs and demolition costs. Benefits are generated when the perceived value exceeds the costs (FIGURE 3).

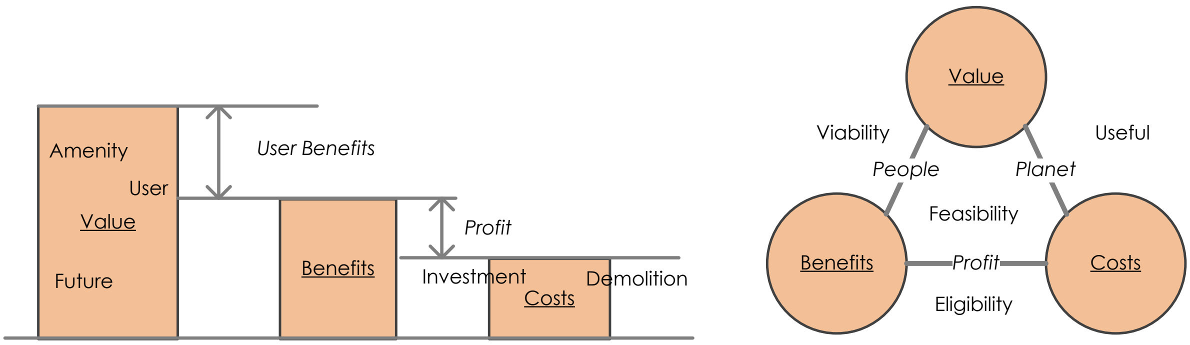


FIGURE 3: l) Value – Cost model considering r) People, Planet and Profit (De Ridder, 2009, p. 13)).

If the amenities, facilities and/or living properties in the surroundings of the inner-city quay wall are realised, the quay wall becomes part of the exploitation of the public area. This results in benefits or revenues for both the municipality and the users (entrepreneurs, residents, etc.)(FIGURE 4).

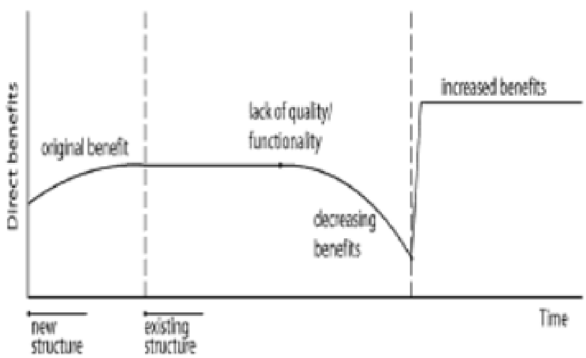


FIGURE 4: Benefits versus time (PIANC, 2008, p. 10).

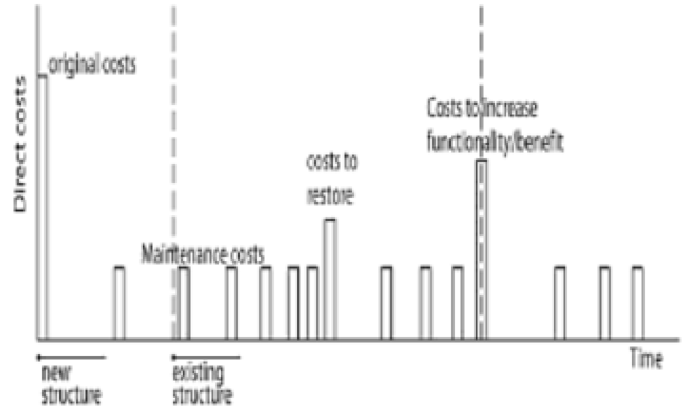


FIGURE 5: (Direct) Costs versus time (PIANC, 2008, p. 10).

D. J. Vanier (2001) mentions six terms that are used in asset management to describe the 'value' of an asset:

- *Historical value*: the original "book value" of the asset.
- *Appreciated historical value*: historical value calculated in the current currency, taking into account annual inflation or deflation.
- *Capital replacement value*: cost of replacing an asset in the current currency.
- *Performance-in-use value*: prescribed value of the actual asset for the user (Lemer, 1998).
- *Deprival cost*: cost that would be incurred by an entity if it were deprived of an asset and was required to continue delivering services using the asset.
  - Replacement cost of the benefits currently embodied in the asset.
  - Opportunity value which is the cost avoided as a result of having control of an asset (ANAO, 1996)
- *Market value*: value of the property if it were sold in the open market. However, in many cases, the market value cannot be used for municipal infrastructures (D. J. Vanier, 2001).

B.1.2 Functional Value

The desired functional value is determined by different actors in the initiative phase and recorded in the Functional Program of Requirements. Both present and future functionality of the inner-city quay wall is determined. The functionality is described as the complete description of operational activities, based on operational requirement regarding a particular object (Stavenuiter, 2002). These requirements consider among others the influence factors of the availability and capacity of the object.

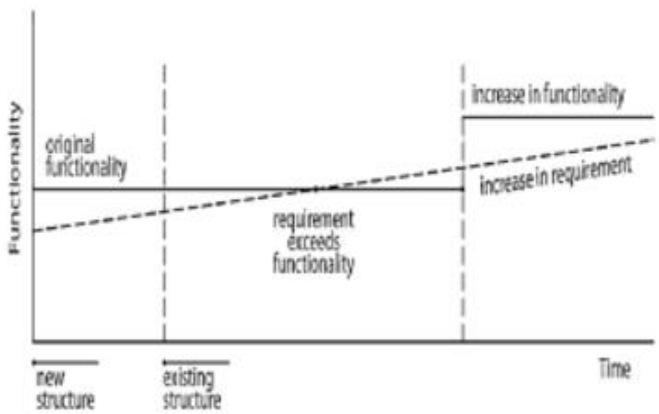


FIGURE 6: Functionality versus time (PIANC, 2008, p. 10).

However, a clear distinction is made between client (asset owner: municipality) and user perspectives. The user requires a functionality that is guaranteed during the exploitation period (minimum functional value). The client requires the guarantee of present and future functionality. He has a focus on a larger time horizon than the user; which could lead to a higher virtual functional value.

In the construction phase the virtual value is realised, resulting in a potential value of the particular object. In the operation and exploitation phase, the functional need will change over time. Therefore, the utility of the object should be evaluated during the entire period. The utility can be defined as the extent to which the object meets the operational requirements during the operation and exploitation phase. As the flexibility of an object is higher, the difference between the minimum desired functional level and the real functional level is also larger. In this way, the object can facilitate in in time occurring and changing needs (Weisz, 2006).

The consequence of changing need is a functionally obsolete object. Functional aging is not the consequence of technical aging, but of declining utility and obsolete functionality. In FIGURE 7, the functional value during the life cycle of an asset is schematised.

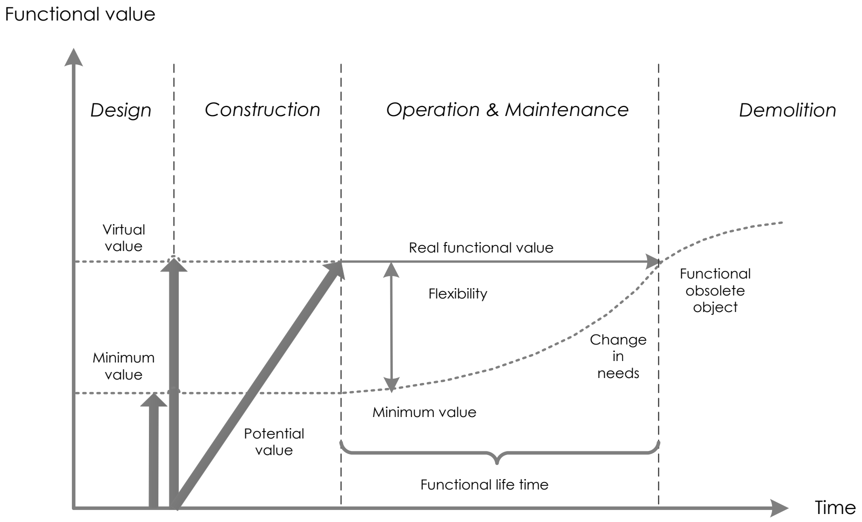


FIGURE 7: Functional value during the life cycle (based on (Weisz, 2006, p. 38)).

B.1.3 Technical Value

The functional requirements are translated into technical requirements, resulting in a technical design. The object should meet the minimum technical requirement regarding the quality of the object. In this case, the quality is defined as the extent in which the characteristics of the products and services meet the requirements and needs of the users.

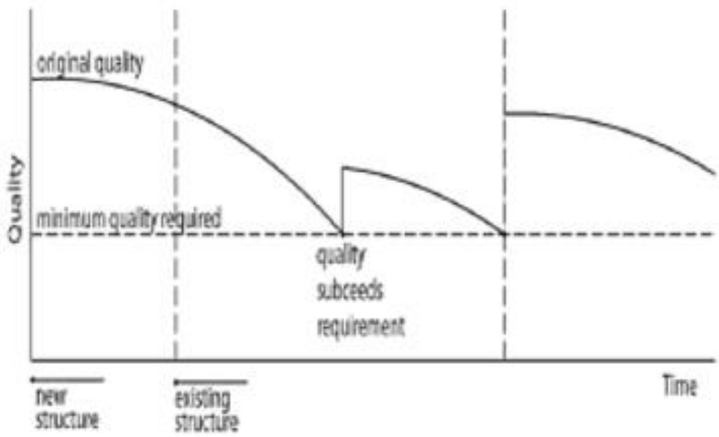


FIGURE 8: Quality versus time (PIANC, 2008, p. 10).

One of the most important quality objectives is ensuring safety for user and environment. This implies that the minimum technical value is defined as the moment that the object becomes unsafe. The virtual technical value is therefore always larger than the minimum technical value.

In the construction phase, the virtual value is realised in the potential value of the object. In the operation and exploitation phase, the technical value degrades. The degradation continues until the critical point there where the structure becomes unsafe. The sustainability is used to indicate the capacity of an object to function without much maintenance during a certain period. The larger the sustainability, the larger is the difference between the minimum technical value and the real technical value. To delay the degradation process, maintenance is performed in the operation and exploitation phase. In FIGURE 9, the technical value during the life cycle of an asset is shown.

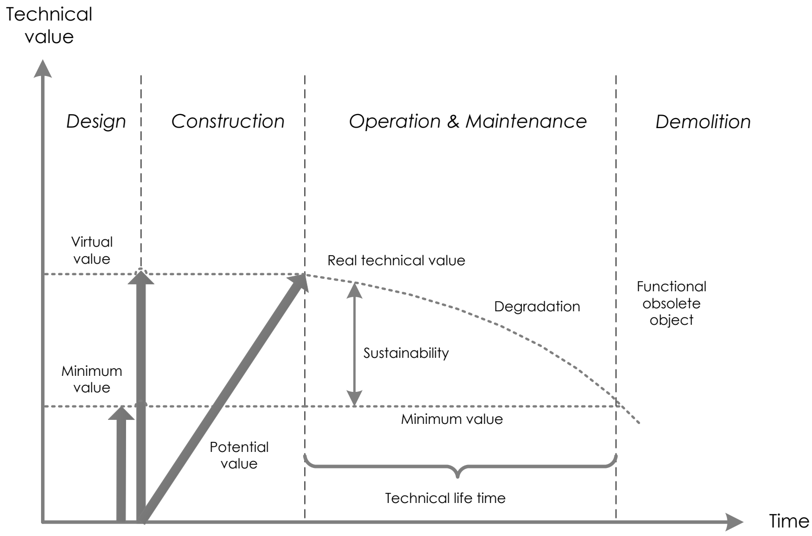


FIGURE 9: Technical value during life cycle (based on (Weisz, 2006, p. 40)).

The design life time is seen as the structural life time of the entire construction. During this period regular maintenance and reparation will be needed. The projected design life time of the assets should be in compliance with the municipal policy, described in the policy reports. The operation of infrastructures, including civil assets, can be seen as a continuous process in which the quality and functionality should be tested periodically, taking into account the requirements of the asset owner and the user-needs.

B.1.4 Relation Functional and Technical Value

It is often difficult to predict the development of needs, due to their dynamic characteristics. Therefore, providing an understanding of the functional life time of the inner-city quay wall is not easy. In the construction phase the functional value is realised. This represents the functional life time for years. As a consequence of an accelerated change in needs, the functional life time is shortened. This causes early functional obsolescence and a limited functional life time.

The real technical value is of such nature that the technical life time of years is established, which is equal to the expected functional life time. Due to the early functional obsolescence the life time of the inner-city quay wall is shortened. This results in a technical remaining value, due to the limited exploitation period of years. In terms of value, the inner-city quay wall is not used optimally.

Because of the limited exploitation period (shorter than expected), the predicted "break-even" point is never achieved. The benefits will never be equal to the costs and this leads to a loss on investment. Forecasted revenues will be missed. To prevent this undesired situation and to provide a solution for the difficult predictable development of needs, the following can be done:

- *Shorten design life time*: by shortening the design life time the development of needs in the exploitation period can be determined with more accuracy. The need will remain at a relatively stable level within the design life time. The real functional value can be diminished without the direct risk of functional obsolescence. A reduction of the virtual value results also in a shorter design life time. The real functional value should not be higher than the minimum value, because need is predictable during the exploitation period. As a consequence, the technical virtual value (and technical life time) is reduced. However, the effects of a limited design life time, e.g. a shorter exploitation period, on the benefits for asset owner and users should be taken into account.
- *Increase virtual value*: by including a larger flexibility in the inner-city quay wall design, this object facilitates in the changing needs without many adjustments in the operation and exploitation phase. When the functional virtual value is increased a potential life time increase is established: the difference between the maximum expected life time and the minimum expected life time. The technical value and technical life time should also be increased. Nevertheless, the technical virtual value and associated technical life time

could exceed the expected exploitation period. This could result in a technical remaining value. The benefits that are generated in the exploitation of the inner-city quay wall should be larger in order to recoup the investments. It is difficult to predict the exact duration of the exploitation period. It is therefore required that the break-even point regarding the inner-city quay wall eventually is achieved.

B.1.5 Value Capturing

The life cycle of an inner-city quay wall depends on the life cycle and economic development of the public area. In managing public urban areas, costs and benefits are important items. Investments in these areas should be reimbursed. A CBA is used to create an understanding of the financial framework. A public or private party invests in the public area to create value. Both positive as well as negative external effects for other parties occur. The positive external effects can be internalized and financially redistributed.

The concept of remaining value relates to a possible changed perception regarding the ownership of the public area. Public as well as private parties see the public area as an investment, with a net yield result. If a public or private asset owner generates returns, also opportunities for other parties occur. The remaining value is a function of the future utility. By investing in the public area, thereby adding value, the value of this area will increase. In order to create a mutual gain, it is essential to establish proper arrangements on the (re)distribution of this increased value (benefits – internal and external rates of return).

The willingness to pay of private parties indicates the extent to which their demands regarding the public area are met. These requirements of the municipality relate to previously stated quality aspects, such as safety, functionality, prestige and societal importance. For the willingness to invest of private parties, environment, project and organisational conditions are important. The environmental conditions relate to (Smeenk, 2007): managerial support; alignment with policy developments and urban ambition; policy objectives and substantive area concept; financial spatial resources or strategies. However, the essential conditions are related to project and organisational levels (Remmerswaal, 2010, p. 64).

B.1.6 Opportunity and Risk

Although it is possible to define cost objectively, defining performance is more complex. It is linked to more strategic, tactical and operational objectives. These objectives are influenced negatively by risks and positively by opportunities. According to the ISO Guide 73/ISO31000 a possible definition of risk is (Grunsven, 2010, p. 28): "the impact of uncertainty on objectives". Opportunities are defined as the "situations or conditions favourable for attainment of (performance) objectives" (Kähkönen, 2001). Resources are always limited, a trade-off between several objectives is often needed (Atkinson, Crawford, & Ward, 2006).

For this trade-off it is relevant to determine the value of civil assets. In the context of this research, the operation and maintenance of quay walls is seen as a management process to create added value for the municipality. This added value is derived by considering aspects that were not only initially stated in management and maintenance objectives. Opportunities are related to added value that is created for the client (Van der Wal, 2011, p. 12). This is shown in FIGURE 10. If properly managed, uncertainties represent risks and opportunities in adding value.

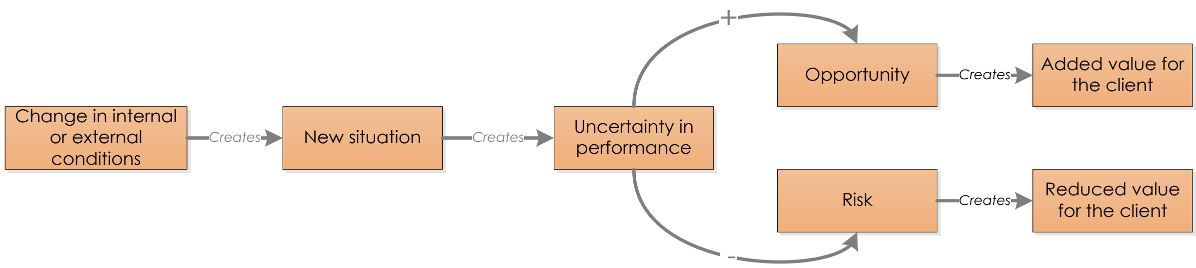


FIGURE 10: Decomposition of opportunity and risk (based on (Van der Wal, 2011, p. 12).

B.1.7 Decision-Making Instruments

The quantification of asset value is difficult and ambiguous. Many municipalities do not record the 'value' of a particular asset, but only the construction or replacement cost. Asset managers emphasise the role of both performance and cost to enable educated decision-making about maintenance and replacement. Two approaches to quantify asset value in order to facilitate the decision-making regarding management strategies are: a Social Cost Benefit Analysis (SCBA) or a Financial Economic Decision Supporting model (FEDS-model).

B.1.7.1 Social Cost Benefit Analysis

A SCBA visualises costs and benefits regarding social consequences of different variants for managing public areas and associated assets. It is still not common to take societal cost into account while managing assets in public areas. This management considers decision-making processes around planning and investment measures (Stowa & Stichting Rioned, 2014) (FIGURE 11).

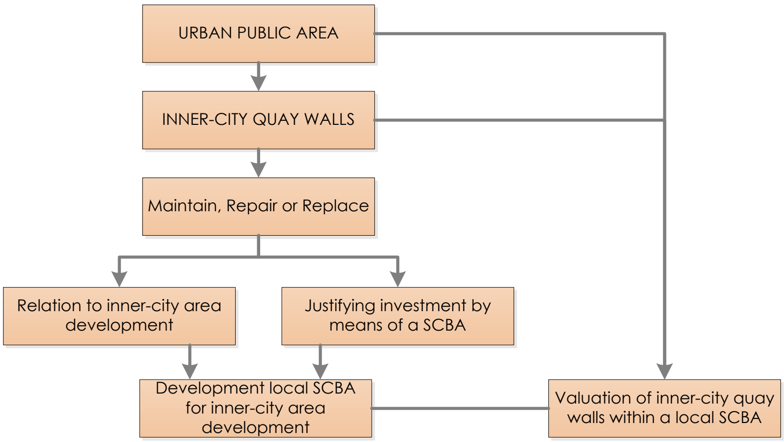


FIGURE 11: Inner-city quay walls and SCBA (based on (Van Velzen, 2009, p. 4).

The SCBA nuances management efforts in relation to social utility more proportionately. The analysis provides a deeper understanding of both direct and indirect costs and benefits for the municipality. Considering societal consequences of quay wall failure during management of the public area, a more substantiated final decision is needed. As stated previously, it is used to determine and assess (future) societal costs and benefits of prosperity effects in quantitative and monetary terms. A SCBA shows the feasibility of an investment-initiative regarding a particular development. It therefore serves political decision making (Beukers, Bertolini, & Te Brömmelstroet, 2011).

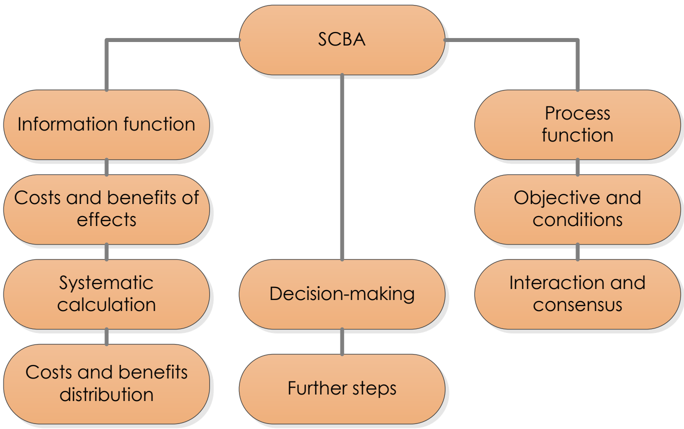


FIGURE 12: Functions of the SCBA regarding integral area development (van Batenburg, 2009).

The effects of project-alternatives or management strategies result in more than in direct repair costs. A social cost benefit analysis provides additional information. This research will consider a relatively simple (local) SCBA for which key figures are used (Jaap Bakker; Rijkswaterstaat, 2011); Stowa (2011); (Van Barneveld, De Moel, & Weeda, 2014).

B.1.7.2 Financial Economic Decision Support Model

Real cash flows such as turnover, profit, added value (in terms of WOZ-values) and taxes are retrieved using the Financial Economic Decision Supporting (FEDS-) model. This model identifies the current cash flows that are linked to cultural heritage, such as old inner-city quay walls, but also to assets in general. The basis of the FEDS-model is represented by real economic transactions, resulting in turnover, profit and added value (Bade, Smid, & Lardinois, 2007; Ramselaar & Keeris, 2011). These data are extrapolated to visualise future economic scenarios.

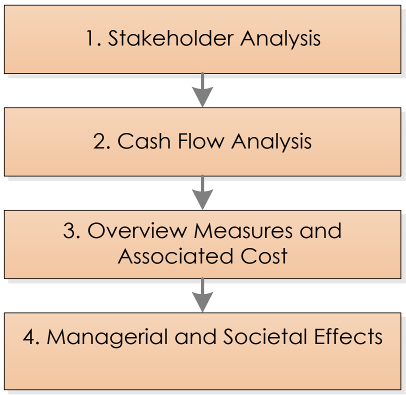


FIGURE 13: 4-step plan of Financial Economic Decision Support Model (FEDS).

The method considers a (monumental) inner-city, public area, and associated assets (of cultural heritage) to be an enterprise (economic entity). Revenues are made and costs are incurred; cultural heritage is seen as a capital asset. It is considered as a simplified and shortened SCBA (FIGURE 13).

B.2 ASSET MANAGEMENT

The specific components and methods that are integrated into an asset management framework for valuable maintenance of inner-city quay walls are not yet determined. In Appendix B.2 the discipline asset management is further elaborated (B.2.1) and the essential components and elements of an asset management system are discussed (B.2.2). Furthermore, reference is made to the asset management system that is developed by the Havenbedrijf Rotterdam for managing quay walls in harbours: Quay Wall Modelling System (KMS) (B.2.3). This section results in the answer on the following sub-question:

SQ2: Which factors should be taken into account when applying asset management in public areas and through which components are they integrated in the asset management framework?

B.2.1 Asset Management Principles

The management of constructions and civil infrastructures is often referred to as asset management. As mentioned previously, the main objective of asset management is achieving maximum value from an asset (portfolio) during its complete life cycle. To achieve desired outcome and value, asset management manages specifying, organising, planning and monitoring activities to achieve most cost-effective solutions throughout the entire life cycle (Blanchard, 1992).

There are different types of assets; tangible or physical assets, such as quay walls and intangible assets such as information, skills and money. Both types of assets need to be considered in decision-making processes related to management. An asset portfolio represents a combination of tangible and intangible assets, available to and owned by actors such as state or provincial governments and municipalities. Decisions regarding management of specific assets can be made based on, among others, the composition of the asset portfolio and taking into account their entire life-cycle.

Several principles are essential in the process of asset management. Manual (2010) summarizes asset management as policy driven, performance based, option and trade-off analysis based, decision-making based on quality information, and accountability and feedback related.

B.2.2 Asset Management Framework

An AMS-framework is presented in various ways, influenced by asset type, owner and work-organisation (Kaplan & Norton, 2004; Rodriguez, Munoz, Ramirez, & Andrade, 2006; D. D. Vanier, 2001). It remains difficult to establish a framework applicable for all types of assets and owners. Therefore, this research only focuses on the featu res and contents of the "modules" and sequences of steps in the decision-making process regarding the management of inner-city quay walls. The basis of this asset management framework is represented by the relation between strategic, tactical and operational level (FIGURE 14).

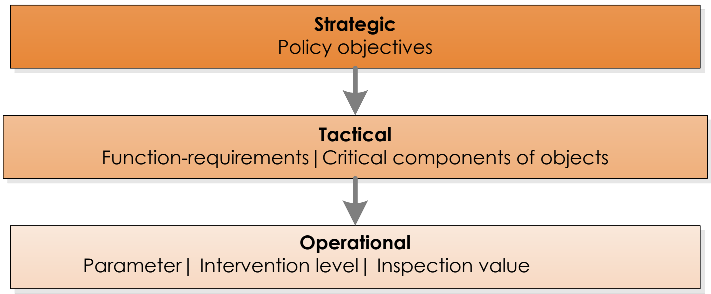


FIGURE 14: Relation between strategic, tactical and operational level.

FIGURE 15 provides an overview of several stages in the management of civil structures. However, particular modules and submodules may vary. Overall management relates to the maintenance or improvement of investment. Technical management focusses on maintaining or upgrading technical requirements, defined at the design phase of a structure.

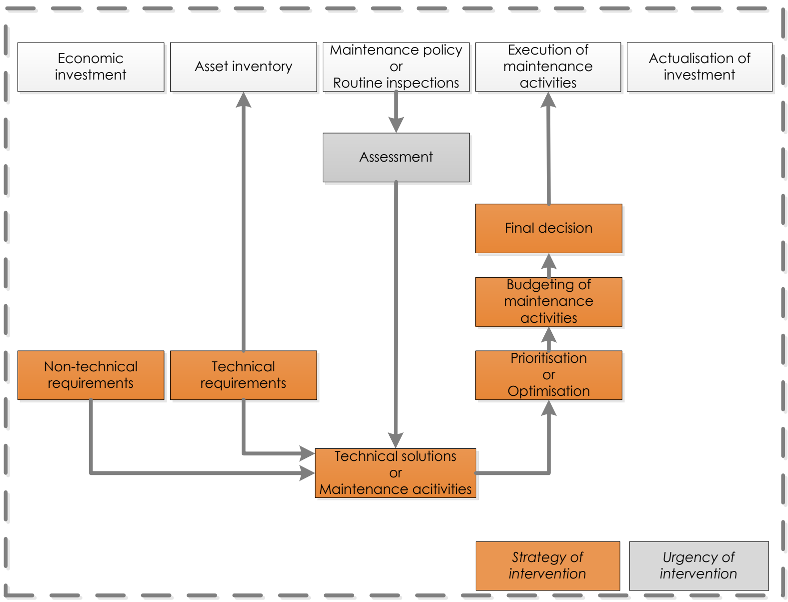


FIGURE 15: Elements of an Asset Management System (AMS) (Port of Rotterdam, 2012; Rodriguez et al., 2006, p. 12).

The processes of monitoring and recording, inspection, assessment, repair and replacement are essential components of an asset management system. This system includes cycles of inspection, assessment and interventions in terms of repair and replacement activities. These cycles depend on type, function, condition and value of the inner-city quay wall.

An economic investment is made when inner-city quay walls (or other civil structures) are built. In the design phase requirements regarding i.e. safety, functionality and aesthetics are defined. Both technical and non-technical requirements should be considered. Many of these structures are designed to have a long service life. This implies that requirements, legislations and exploitation-methods develop during the life time of a structure.

In order to maintain or improve the different functions of the inner-city quay wall throughout its expected service life, an inventory is made and a maintenance policy is established. Additionally, inspections are performed in order to assess the prevailing condition of the structure. If the inventory, inspection and subsequent assessment reveal that the inner-city quay wall does not meet the prevailing requirements, actions should be taken (*Binnenstedelijke Kademuren*, 2014; J.G. de Gijt, A. Roubos, & Grotegoed, 2015; Rodriguez et al., 2006, p. 13):

- *Change nothing (do nothing)* at present, i.e. postpone repair for a certain time and decide on supervision method and future inspection (regular maintenance).
- *Call for restricted use* (no maintenance).
- *Repair now* (major maintenance).
- *Demolish and renew* (replacement).

In further consideration, a selection of all previous actions is chosen and prioritised. Prioritisation is based on 'advantages and disadvantages', in terms of benefits and costs, risk and benchmarking through business values. The most accurate maintenance activities are evaluated. It determines whether their implementation enables the asset to meet the prevailing requirements.

Subsequently, the prioritised solutions are budgeted and a final decision is made. The procurement for the execution of the maintenance activities is the next step. It improves the structure to comply with the requirements and actualise the value of the initial investment (Mizusawa & McNeil, 2009; Piyatrapoomi, Kumar, & Setunge, 2004; Rodriguez et al., 2006) (FIGURE 16).

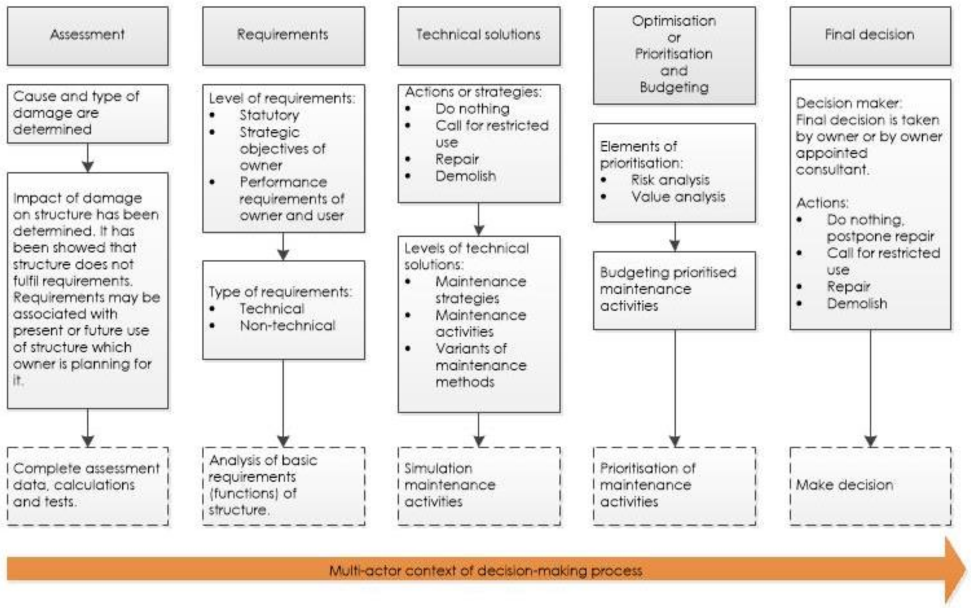


FIGURE 16: Maintenance process (based on (Rodriguez et al., 2006, p. 15)).

B.2.3 Quay Wall Modelling System or Kademuur Modellering Systeem (KMS)

The port of Rotterdam contains a large number of embankments, pipelines, buoys, poles and scaffolding (assets). The quays are very important assets. A port without loading facilities is no port. With more than 68 km (incl. Maasvlakte 2) of quay walls in ownership and management, the Port Authority needed a tool for efficiently managing and maintaining these structures. KMS was developed in collaboration with Simco Technologies, Traduco Asset Management and CH2M/Halcrow.

B.2.3.1 Prediction

The technical service life of a quay wall is mainly determined by the quality of the superstructure (concrete) and the substructure (steel). Thanks to concrete and steel degradation models, KMS predicts the quality of a quay wall during the entire contracted service life. The system provides graphs with the expected annual degradation, which enables the prediction of the time at which the quay wall structure needs to be inspected and when maintenance is necessary.

B.2.3.2 Simulation

KMS simulates different maintenance strategies for a quay wall. For each maintenance strategy KMS provides the consequences for the quality of the structure during the contract period. The maintenance effects on the quality of the quay wall are also illustrated by a graph. This enables the selection of the most efficient and cost effective inspection regime and maintenance scenario.

B.2.3.3 Analyses

It is important to have an understanding of the priority of the maintenance activities. This is caused by the limited time and budget, made available for maintenance. The priority is partly linked to the risks that influence the functionality of quay walls. The KMS takes these risks into account and considers possible maintenance tasks that reduce those risks. As a result, the system enables the calculation of a risk factor before and after the execution of maintenance activities. The difference between the two factors is the risk Δ. This number is assigned to a single maintenance task. A larger Δ implies a more effective maintenance task.

B.2.3.4 Prioritisation

The priority of a maintenance task depends not only on the risk factor. The use of the quay wall that is in need of maintenance is just as important. Therefore, a quality score is assigned to each quay wall. This score is based on commercial interests, availability requirements and contract period of the quay structure. This score is related to the possible maintenance tasks. In this way, each maintenance activity is coupled to both a risk factor and a quality score. A high quality score associated with a high risk factor indicates a maintenance activity with a top priority.

B.2.3.5 Budgeting

KMS proposes a total budget for the prioritized maintenance activities for upcoming years. This amount is based on the sum of the individual maintenance tasks. With a finite budget KMS provides an understanding in which maintenance tasks are within the annual budget and which ones are not. KMS translates the consequences of postponement immediately in the maintenance budget for the short and long term. The owner, or the owner's consultant, can then determine which maintenance tasks are performed in the coming year and what maintenance is deferred.

B.2.3.6 Planning

Once the prioritized maintenance tasks are finally determined, KMS plans these maintenance tasks efficiently and effectively. The efficiency is further increased by preparing work packages of multiple structures with similar tasks. Eventually, a prioritized list of maintenance tasks for the coming years, including the cost of this maintenance, is established.

KMS is developed for the management of quay walls in (commercial) ports. Recently, the system is also used for the management of other harbour assets. The surroundings of these quay walls are less ambiguous than those of (historic) inner-city quay walls, apart from the tide, wind and salt. It is therefore assumed that this system will not be adequate enough for the management of the quay walls in public urban areas. Nevertheless, the idea behind this Quay Wall Modelling System may be used for asset management of inner-city quay walls.

B.3 MANAGEMENT OF INNER-CITY QUAY WALLS IN PUBLIC URBAN AREAS

To manage the public area and its civil objects or works in future, a management plan should be made. This plan provides for a framework regarding all the input for the maintenance of civil structures for a certain period, mostly ten years. It represents the basis for determining the annual maintenance and replacement costs. Management has effect on three levels: strategic, tactical and operational (FIGURE 17). A management plan contributes to an efficient and transparent management process, as it decreases the probability that the asset owner encounters unexpected developments and costs. Furthermore, it offers a clear framework for desired developments and/ or scenarios.

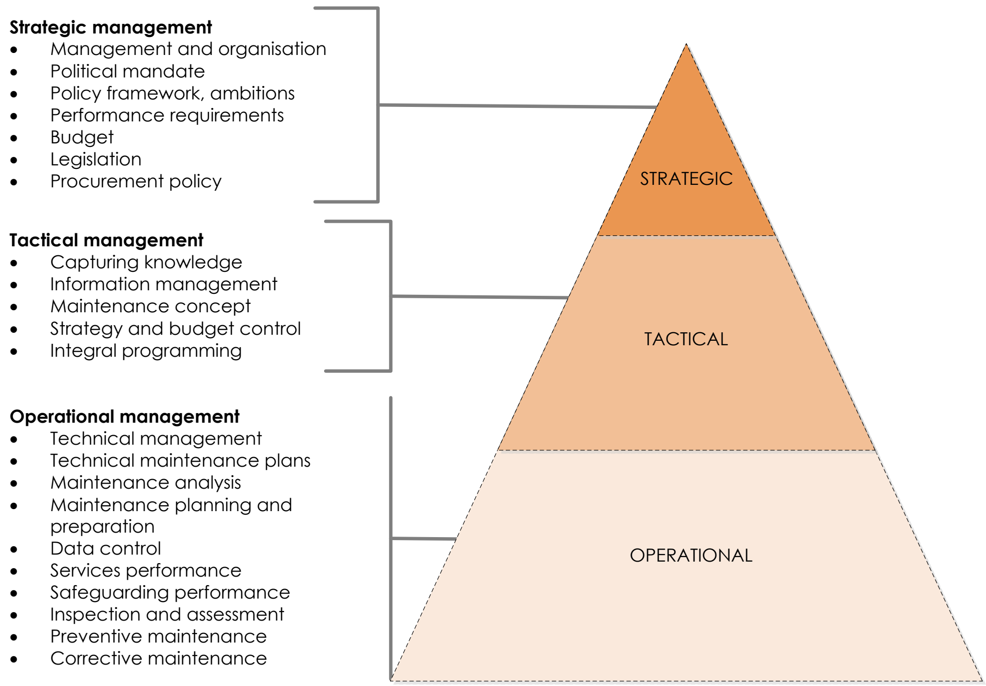


FIGURE 17: Process level management public area (based on (M.F. Lindner, B. Wolbers, & A. Schuh, 2013, p. 6).

Appendix B.3 provides an understanding of the management of inner-city quay walls as part of public urban areas. Firstly, different types of management in public urban areas are discussed: technical, functional and financial management (B.3.1) and risk-based management (B.3.2). Additionally, the municipal management philosophy (B.3.3), levels and roles (B.3.4) and tasks (B.3.5) are elaborated. Subsequently, inner-city quay walls are approached as part of the public urban area (B.3.6). The principles of failure B.3.7 and maintenance B.3.8 are elaborated. Among others, the influences from surrounding environment and possible interfaces are analysed B.3.9. This section answers the following sub-question:

SQ3: How are performance, cost and risk defined in respect to managing public urban areas and its assets, in particular inner-city quay walls?

B.3.1 Technical, Functional and Financial Management

In the eighties and nineties the demand for a management system increased. This resulted in the development of rational management and later on into integral management and participative management. The municipal primary management and maintenance processes consider 'construction and maintenance of public utilities and structures'. The current management of constructions and civil infrastructures tends to the principle of asset management ("Ports," 2014). As mentioned before, the purpose of this discipline is to have - within the boundaries of acceptable risks (performance uncertainties) and costs (budget) - the appropriate utilities and structures and to get the optimum performance from these facilities, measured over their entire service life.

B.3.1.1 Technical management

Technical management of inner-city quay walls can be defined as follows (*Binnenstedelijke Kademuren*, 2014, p. 16): "The, in consultation with all disciplines involved, definition of all activities that are necessary to maintain or achieve the agreed functions and qualities of objects during a longer period". This includes the preparation of conditions, agreements and performance of tasks assigned by the board to the technical manager. The ensuing activities are grouped under 'maintenance'.

The purpose of management and maintenance policy is preservation of the construction and maintaining the functionality throughout the life span. If economic and structural feasible, the life span can be extended. Safety is of major importance and should be guaranteed at all times. The manager should have an understanding of the entire area in order to determine the nature of the management applied. Old quay walls show obviously more deficiencies which might require more frequent monitoring and inspection. Furthermore, more frequent research regarding damage repair could be necessary.

B.3.1.2 Functional management

The responsibilities of a functional manager lie in the allocation of usage (contracting) and control regarding compliance with conditions and regulations. Environmental factors and requirements imposed on the quay structure should be considered. Over the past decennia, the nautical function of inner-city quay walls has shifted to a more recreational function. Functional changes are integrated in the functional management. However, they can influence technical management. Therefore, functional management and technical management should be coordinated. This is one of the responsibilities of the functional manager.

An integral vision regarding urban management, considering among others the Program of Requirements, includes the following aspects (*Binnenstedelijke Kademuren*, 2014, p. 17):

- Reserving area for future initiatives.
- Publicly accessible quays.
- Diversity in ships.
- Nautical functions.
- Recreational functions.
- Realisation of ports and quays that match profile and environment.
- Distinctive ports.
- Vivacity in the city centre.
- Water-related events predominantly in the city centre.
- Parking or traffic safety.
- Waterway management.
- Facilitating market initiatives.

B.3.1.3 Financial management

The financial system regarding the management (and maintenance) of civil works is based on three aspects:

- Exploitation: all costs related to regular maintenance, such as: standard maintenance actions, failure maintenance activities, corrective maintenance activities.
- Multi-annual investment budget: all costs related to project-based maintenance and replacement.
- Capital costs.

Management budgets to cover the costs regarding regular maintenance are relevant. This is reported in the annual maintenance plan. Defining a maintenance plan with action packages and financial substantiation is essential for transparent budgets and decisions. By providing an understanding of planned maintenance activities possible reductions of maintenance budgets and their consequences are anticipated. In many Dutch municipalities, the costs of operation and maintenance of civil works are financed by multiple budget items. A couple of Dutch municipalities do not provide maintenance plans related to the public area. In these cases it is difficult to evaluate if the available management budgets are sufficient. Research regarding optimisation of maintenance costs, analyses of maintenance strategies or participating in management-conscious development processes becomes difficult or even impossible.

After the technical life cycle of a civil object, replacement should be realised. This is an expensive project. Ideally, these costs are known for approximately ten years in advance and their progress relatively balanced. In reality however, expected life cycles are easily exceeded. The object still functions well and replacement is not yet an issue. Furthermore, the planned technical life time can also be not achieved, due to too high loads and/or other external influences. To create an understanding of the replacement moment the residual life time is determined. Based on relevant data and information regarding the replacement of civil objects, a multi-annual budget is prepared. Besides the decision whether or not to replace an object, also project-based maintenance is performed. These strategies should economically outweigh the eventual replacement-decision.

An indication of the replacement value is often difficult to provide, due to the lack of necessary information (M.F. Lindner et al., 2013, p. 19):

- Construction year
- Replacement cycle in years
- Residual life time
- Unit price replacement costs

In general, an object is replaced when the relation between the technical maintainability and maintenance investment becomes unfavourable (M.F. Lindner et al., 2013). This does not apply to monumental objects; which are maintained from a historical perspective. Based on their monumental status they are preserved. In a ten-year cycle a quality monitoring is performed which form the basis for a maintenance or restoration plan.

Maintaining monumental objects requires major investments for restoration purposes. Monuments and monumental objects should be assessed and tested by the National Office for Cultural Heritage (M.F. Lindner et al., 2013). When they are positively assessed – as potential Cultural Heritage – the opportunity arises to optimise costs related to these major investments: registration of the monumental object(s) as a national monument.

B.3.2 Risk-based Management

"The future development and the preservation and maintenance of the infrastructure of society will even more likely demand an intensified focus on risk. Risk is a rather commonly used notion and is used interchangeably with words like chance, likelihood and probability to indicate that we are uncertain about the state of the item, issue or activity under discussion. However, even though the context of discussion what is meant by the different words is understood, consistency and preciseness in the understanding of risk in the context of engineering decision-making are critical". (Faber & Stewart, 2003, p. 173)

The efficiency and effectiveness of the management of the public area and the associated assets, particularly inner-city quay walls, are directly connected to the question if the current efforts are 'targeted' and sufficient enough. The answer is found by considering risk-based social effects (damage, nuisance) and repetition times in the management system. A risk-driven management system provides an early understanding of the risks regarding societal effects in such a way that the management can be customised towards different situations. In addition, the municipalities do not ignore existing standards and guidelines, but they make an additional assessment before they implement the management strategy.

The current management process remains the same, but the municipality analyses the technical and societal risks beforehand. The frequencies of inspection and preventive maintenance can be adjusted to the results. Utility and necessity are thereby pre-determined. The municipality may limit (or intensify) inspection and preventive maintenance, in case of small (or large) societal and technical risks. A small risk is connected to an event that rarely occurs and/or of which the consequences are rarely noticeable. For a large risk, the opposite applies.

In case of repair or replacement of an asset it is possible to achieve efficiency gain, taken into consideration that the municipality only performs maintenance or replacement in an area with little societal risks and to a direct cause (e.g. complaints). More preventive maintenance will be performed in an area of greater social risks. Since inner-city quay walls are located in the centre of a municipality, societal risks are rather large due to building density.

In order to identify possible risks regarding inner-city quay walls as part of the public area a risk inventory can be performed. This inventory retrieves information from experts, managers and other interest-groups. Due to time and data limits in combination with the assumption that this inventory will be time consuming, this research retrieves possible risks regarding quay walls and public areas from documentations, literature and conversations with experts (A. Roubos & D. Grotegoed, 2014; J.G. de Gijt, 2010; J.G. de Gijt & Broeken, 2013).

Risks can be divided into (J. Bakker et al., 2010; Wagner & Van Gelder, 2013):

- Hardware: failure of the asset itself, constructional failure.
- Software: failure of computer software that controls of the performance of the hardware elements. Inner-city quay walls do not consist of electrical elements. In this research, these types of risk are therefore neglected.
- Human failure: failure caused by human activities, such as operational errors, negligence and maintenance faults.
- External risks: failure events caused by external uncertainties or uncertainties from outside the inner-city quay walls and also outside the public urban area. An example is ship collision (outside and affecting performance inner-city quay wall) and fire (outside and affecting performance public urban area). 'Acts of God' (e.g. tsunami), 'forces majeure' (e.g. war) and 'new risks' (e.g. changing legal and governance) are examples of external risk categories.

B.3.3 Management Philosophy

To substantiate a management plan, an accurate understanding of the functional requirements of the assets is needed. It is decided which functionalities are assigned to inner-city quay walls as part of the public urban area. In addition, the plans for their future destinations must be clear, including the associated desired maintenance levels. For each quay wall these performance aspects differ.

B.3.3.1 Quality ambitions

The quality level of quay walls is linked to organisation, management and usage. Furthermore, the maintenance level of the adjacent public space plays an important role. Several policy documents are input for development of the management vision (*Binnenstedelijke Kademuren*, 2014, p. 17).

As mentioned previously, civil structures should be safe and reliable and they should meet legislation and environment regulations ("NEN-EN1990. Eurocode - Grondslagen van het constructief ontwerp," 2002). These (performance) requirements are represented by RAMS-criteria (Jaap Bakker, Gerrit Bruggink, Gep Nagtzaam, & Jacco van der Worp, 2010; "NEN-EN1990. Eurocode - Grondslagen van het constructief ontwerp," 2002). Not only national standards and directives are applied, but also the municipal policy is taken into account. Often, this policy is translated into a management program with quality ambitions specific for a municipality. The quality framework for quay walls is formed by the performance aspects safety, functionality, image and societal importance (*Binnenstedelijke Kademuren*, 2014, p. 17).

- *Safety:* a quay wall and its components are able to operate in such a way as to provide an acceptable level of personal and material risk to users, owners and the general public.
    - User safety: the user may not suffer (physical) injury during normal work related activities.
    - Social safety or security: users should not feel unsafe in, on or at the proximity of civil work. There should be no confusing situations and structures should not look dilapidated.
- *Functionality:* a quay wall and its components have a quality level that meets the requirements of current use. Functionality can be defined as "the degree to which a structure can fulfil its intended functions as specified in the functional and operational requirements, which are primarily of user interest" (PIANC, 2008, p. 39). However, also some technical requirements which are more of interest to the asset owner and asset manager are also taken into account. Functionality is divided into certain acceptable levels of reliability, availability and maintainability.

- Reliability: the ability of a system or component to function under stated conditions for a specific period of time.
- Availability: "the ability of a structure to operate in such a way that there is an acceptable low level of down-time" (PIANC, 2008, p. 39).
- Maintainability: "a property of the structure to provide safe and efficient means to carry out future maintenance and repair, on both a regular and continuous basis or after a significant loading event"(PIANC, 2008, p. 40).

- *Image:* aesthetic requirements of a quay wall regarding the quality of living environment. Initially they are subjective and dependent on the location of the quay wall in the urban context and the accommodation and recreational functions. Aesthetics represent a factor in the development of an inner-city quay wall in relation to the area where the object is situated. It is also defined as the opportunity for an inner-city quay wall to be presented in such a way as to be pleasant to the eye and pleasant to stay around. The esthetical requirements of quay walls are initially subjective and among others dependent on the location, recreational functions and accommodation functions of and around the (inner-city) quay wall.
  - Living environment
  - Cultural heritage
- *Societal importance (accessibility):* gives the extent to which a work should be accessible for use. The loss of function of a work can have a greater or lesser impact on the use of public space. The loss of this function causes chaos and (economic) damages. One could think of decreased tourism and business activities.
- NB: It should be taken into account that 'Quality' (perceived benefits) is also related to '*Affordability*' (perceived costs). This affordability is expressed in the costs of corrective maintenance activities and consequence costs. Therefore, both quality aspects and costs aspects cannot be neglected.

These requirements are derived from the quality ambitions of the local authority regarding the public surroundings of the inner-city quay walls. As mentioned before, these are dependent of different policy documents, national standards and directives and municipal policies (*Binnenstedelijke Kademuren*, 2014, p. 17). If one or multiple previously described requirements are not met, maintenance measures should be performed. It is essential that it is determined whether investments in repair activities in relation to the intended residual life span of the structure are justified. In some cases, complete replacement or major renovation is considered necessary.

B.3.3.2 CROW quality levels

CROW (2013) provides the quality catalogue that offers national standards as guideline for the management of the public area. These standards consist of measurable criteria with clear descriptions and illustrations. In this way, provinces and municipalities capture desired quality levels of the public area. The catalogue only refers to quality regarding image and not to safety and functionality.

In general the following quality levels regarding image of the public area are distinguished:

- A+ Very good
- A Good
- B Basis
- C Low
- D Very low

This determination of these levels makes it possible to differentiate several desired quality levels for different public area, such as neighbourhoods, city centre areas, access routes and outdoor areas. Furthermore, the communication between owner and manager regarding the current and desired quality is simplified and made more transparent.

In some municipalities the policy framework, the maintenance strategies and/or implementation plan are inadequate or underdeveloped (CROW, 2013). This may result in:

- More complicated determination of an annual budget.
- Insufficient annual budget for regular and corrective and replacement investments.
- Difficult monitoring and controlling determined and agreed principles.
- Insufficient communication of policy related decisions with other parties in the process.

B.3.3.3 Integral management

The function of a quay wall is not limited to the water and earth retaining function (primary function). They also have an urban, cultural, historical and/or ecological value. Important secondary functions are accommodational functions, for example walking and recreating. A quay wall may also include cyclist paths, roads or parking spaces.

The management of (inner-city) quay walls had an integral nature. The water and earth retaining function should keep balance with the interests that can be derived from the user functions. Integral management is reflected in the coordination of various projects in the planning phase. Dual use of quays (and the surrounding area) may be the result of changing functions or area development.

Furthermore, cooperation opportunities with other programs and projects are taken into account. For example programs and projects of housing corporations and water boards, local resident initiatives, planned developments such as spatial interventions.

B.3.3.4 Systematic management

To create an understanding of the quality level and development of the manageable elements, systematic management is essential. This means that (*Binnenstedelijke Kademuren*, 2014, p. 18):

- Quality inspections should be executed according to pre-determined criteria.
- Quality inspections are the input for the assessment of the remaining life span.
- Residual strength and life span of quay walls is determined once per 10 years.
- Inspections take place according to a multiannual program.
- Quantity and quality data are stored in one system.
- Need for maintenance is determined based on identified quality criteria and residual life span.
- Based on inspections, the need for maintenance can be adjusted.
- Multi-year maintenance program, including financial substantiation, is taken into account.

B.3.3.5 Safe management

To prevent failure of structures, a management strategy for inner-city areas is prepared. The interests regarding safety (and sustainability) require timely maintenance of quay walls. Safe quay walls have the following characteristics (*Binnenstedelijke Kademuren*, 2014, p. 19; J.G. de Gijt & Broeken, 2003):

- Quay walls are in compliance with the legislation and regulations regarding the safety standards.
- No unacceptable displacements and washouts should occur nearby quay walls.
- Quay walls should not show any structural defects.
- Quay walls are in such a structural condition and associated management and maintenance are performed in such a way that protection against failure is guaranteed.
- Secondary functions should not have a disadvantageous impact on the water and earth retaining capacity (primary function) of the quay wall and should meet the Functional Program of Requirements.

Changing functionality and overload, structural degradation, new constructional directives or changing calculation methods in regard to quay walls increasingly result in non-compliance with current structural standards. If inspections show that loads on quay walls are larger than expected or that the structures are significantly deteriorated, recalculations should be performed. These are in accordance with constructional standards. The results of this assessment are the basis for the recommendation to the board regarding the measures that should be taken.

B.3.4 Management Levels and Roles

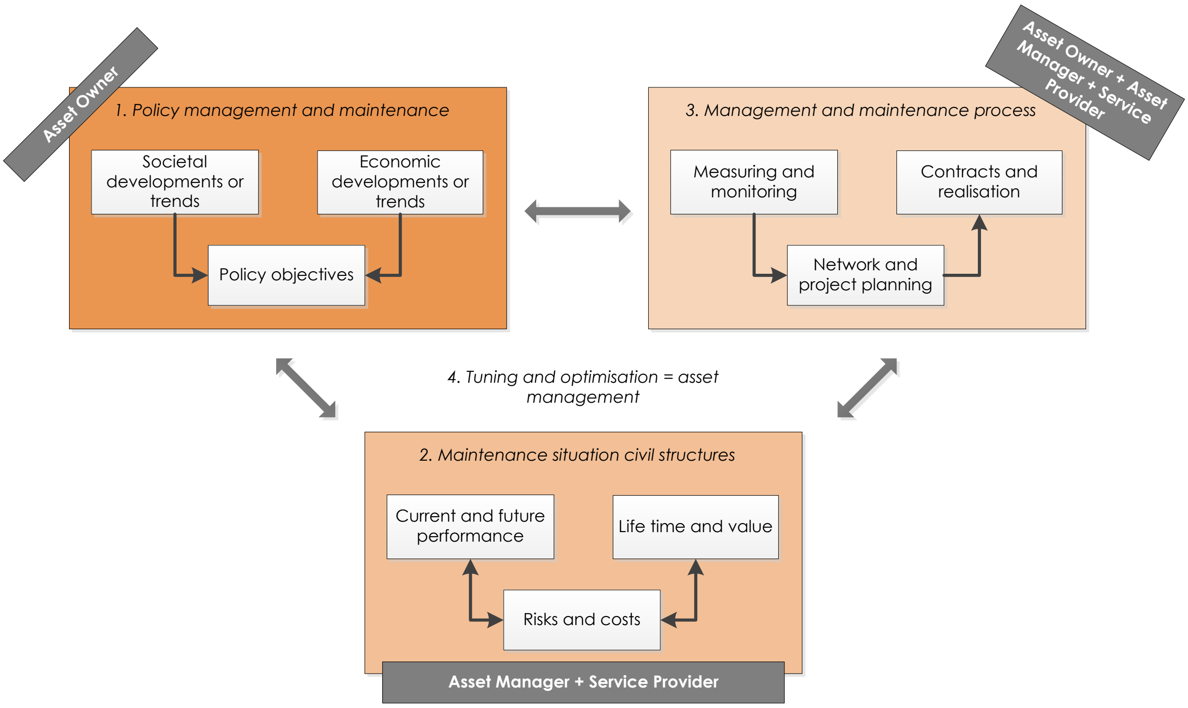


FIGURE 18: Simplified framework management of civil structures (based on (Rekenkamer Zeeland, 2009).

FIGURE 18 is a more simplified representation of those levels and considers the management of civil structures. It involves three main 'categories' that are taken into account (Rekenkamer Zeeland, 2009):

1. Policy regarding management and maintenance: municipal policy regarding management and maintenance of inner-city quay walls (and other civil works) is developed within a larger national policy framework. Therefore, societal and economic trends should be considered while establishing a management and maintenance policy objectives for the municipality.
2. Maintenance situation civil structures: the maintenance situation of civil structures is characterised by different aspects that can be used for prioritising maintenance activities. This involves the current and future performance level, life time, societal and economic value, costs and risks of the civil works. These aspects are closely interrelated. The purpose of policy is bringing the current situation towards the desired situation.
3. Management and maintenance process: when the policy is adopted and the current maintenance situation is determined, the policy may be performed. This process includes: measuring and monitoring of the performance level; determining and planning required maintenance activities; and the (procurement of) maintenance implementation.
4. Tuning and optimisation (asset management): the relation between previous three categories determines the effectiveness of the management and maintenance of civil structures. The maintenance situation and maintenance policy determine the nature of the maintenance process. Meanwhile, the performed maintenance affects the future maintenance situation and the compliance with policy objectives.
   The management and maintenance of civil structures can be considered effective if:
   - Policy objectives represent the framework for assessment of the maintenance situation.
   - Policy objectives are translated into maintenance plans and activities.
   - Maintenance plans and activities consider the current and future maintenance situation.
   - Maintenance plans and activities result into a maintenance situation that is in compliance with policy objectives.
   - Policy objectives are evaluated and if required adjusted based on performed maintenance activities and unexpected changes to the maintenance situation (as a consequence of exogenous circumstances).

B.3.5 Management Tasks

B.3.5.1 Advising

One of the most important responsibilities of the manager is providing a recommendation to the management regarding the establishment, use and management and maintenance of quay walls. For this, management plans, multi-year programs and year programs, including financial substantiation, are potential tools. The demands and constraints of the management, the needs of citizens and companies included in the Functional Program of Requirements should be taken into account as far as possible. Moreover, coordination takes place with projects of other managers, investors and owners.

B.3.5.2 Management plan

A management plan provides an understanding of planned maintenance and budgeted management and maintenance cost. Furthermore, technical measures needed for long-term functional preservation of quay walls are described. Besides, it creates policy-insight to other parties, as province, water authorities, private individuals, companies and other authorities. This contributes to effective coordination of activities and projects.

A strategic management plan provides a summary of the vision and organisation policy, including strategic organisational objectives and stakeholder interests. Furthermore, the relevant legislation and regulation are considered. Service Levels (SLs) and Key Performance Indicators (KPIs) are derived from the pre-defined organisational objectives and stakeholder interests. The Service Levels are translated into Asset Management Performance Indicators (AMPIs). The management and associated criteria used for the decision-making regarding assets is described, just as the expected budget development. Finally, a choice regarding in- or outsourcing is explained in more detail.

A management plan considers the following objectives (*Binnenstedelijke Kademuren*, 2014, p. 19):

- Preservation of properly functioning separations between land and water in an environmental friendly way and through efficient use of resources.
- Further professionalization of management and maintenance tasks.
- Preservation and repair of cultural values (heritage).

The management of quay walls has interfaces with other maintenance measure or activities such as (*Binnenstedelijke Kademuren*, 2014, pp. 19,20):

- Management water and water bed in regard to water quality, for example soil removal and dredging.
- Management of elements independent of quay walls, such as bollards, cramming mores and power generators on shore.
- Management and maintenance of berths, associated jetties and other objects.
- Nautical waterway management.
- Green (space) management.
- Maintenance regarding Flora and Fauna, as described in legislation and regulations.

B.3.5.3 Program of Requirements

In case of large maintenance projects and replacement the manager prepares a Program of Requirements with functional and technical requirements regarding the new quay wall.

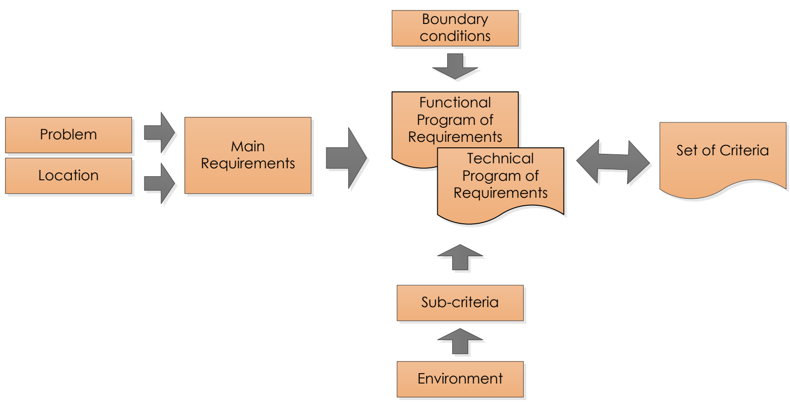


FIGURE 19: Structure Program of Requirements (based on (J.G. de Gijt & Broeken, 2003, p. 172).

The asset owner (client), in consultation with an engineering firm, identifies the issues regarding the inner-city quay wall structure(s) and to which extent a solution is expected. The different functions of the specific quay wall are indicated; this is the initiative for the Functional Program of Requirements. The quay wall structure performs the function(s) to meet the main requirements of its related systems: the public area and (water and motorway) infrastructure.

In the Technical Program of Requirements the technical issues and requirements regarding the quay wall structure are described in detail. The client indicates his Program of Functional Requirements; the engineer translates these into the Technical Program of Requirements. After approval of the client and user, this represents the basis for the design of the inner-city quay wall. The Technical Program of Requirements has a dynamic nature, due to changing circumstances and requirements. Therefore, it is defined and recorded more than once.

B.3.5.4 Claim settlement

The management tasks include also the settlement of claims or complaints that are related to core tasks, consulting and taking care of damage and client. Answering questions and desires of citizens in this respect is important. Meeting the service requirements is a key issue.

B.3.5.5 Data management

The management process requires up to date object data related to administration, size of area (also on detail level) and periodic inspections. Maintaining and keeping up to date of these data in a digital management system can be seen as data management. The aim is to include the multiple aspects (*Binnenstedelijke Kademuren*, 2014, p. 20).

When data is lacking, the manager (manager) encounters difficulties in offering a repair advice in case of damage(s). In such cases, there are often no other possibilities than to execute extensive and expensive research. Digitalising data into one management and information system enables transparent information. The information becomes accessible for multiple parties and there is no need to search into different systems and archives.

After the completion of the new-build project or renovation project, the manager has to receive a completion file. This file should include items as mentioned in *Binnenstedelijke Kademuren* 2014, p. 20).

B.3.5.6 Inspection and testing

Regularly testing is essential and necessary for sustainability and safety of (inner-city) quay walls. There is an evident relation between testing and inspection. This assessment is based on data of inspections and measurements on development and obsolescence and gives a good indication of their theoretical residual life span It is determined if additional or accelerated measures are needed in order to repair the identified deficiencies.

B.3.6 Inner-city Quay Walls in Public Urban Areas

B.3.6.1 Functions

The functional value of inner-city quay walls is defined by its different functions and depends on user and asset owner perspectives of the users and asset owner. Each function is associated with risks, which are managed using different strategies.

"A function is a characteristic task, action or activity that must be performed to achieve a desired outcome. It is the desired system behaviour. A function may be accomplished by one or more system elements comprised of equipment (hardware), software, firmware, facilities, personnel, and procedural data" (Provincie Groningen, 2011).

The different functions assigned to an inner-city quay wall are (*Binnenstedelijke Kademuren*, 2014, p. 12):

- *Retaining function*: the construction is able to withstand the requisite soil and water pressure according to pre-defined safety levels for which the retaining height is the determining factor. The retaining height is the difference between the top surface of the quay and the design depth. This depth is primarily determined by the draught of ships and the water discharge requirements.
- *Load-bearing function:* the quay is able to safely transfer the vertical load caused by traffic, storage and temporary support constructions to the subsoil. Also temporary loads are of considerable impact.
- *Mooring function:* quays are able to resist shock and impact loads from ships as well as from mooring lines. Ships should be able to berth safely. Risks linked to winds and currents must not be underestimated. Waves however are of less influence. Sufficient mooring capacity for passing ships is a good sample of the quays mooring function, although most inner-city quay walls only have a limited nautical function. Their use is primarily recreational.

- *Traffic function:* Roads are constructed alongside many of the quaysides in inner-cities. The quay wall should be able to transfer loads caused by traffic and mobile cranes to the subsoil.
- *Storage function:* Quay walls are used for storage and transhipment activities. In order to support the weight caused by these goods this requires a rock-solid foundation.
- *Environment function:* In addition there are many challenges associated with the inner-city quay walls due to their urban function. Recreational aspects, monumental values and development plans as well as plan modifications are prime examples.

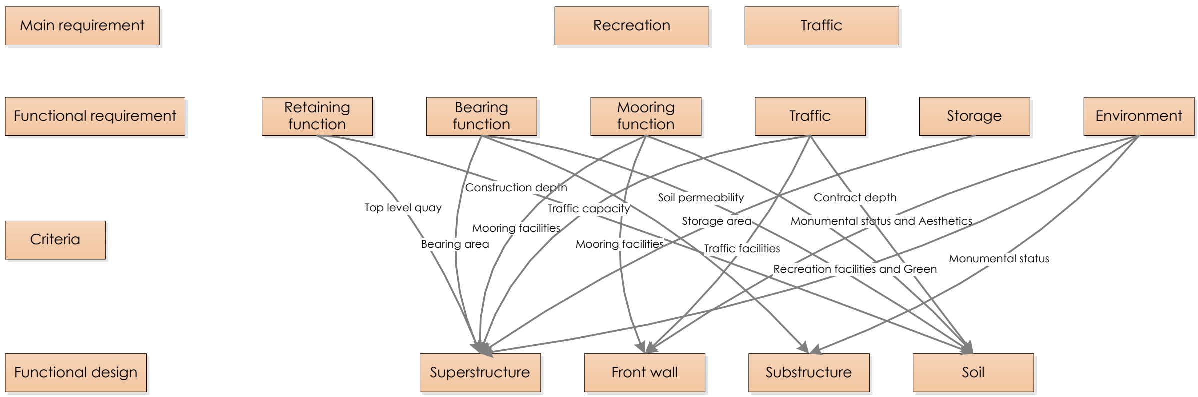


FIGURE 20: Functions inner-city quay walls (based on (J.G. de Gijt & Broeken, 2003).

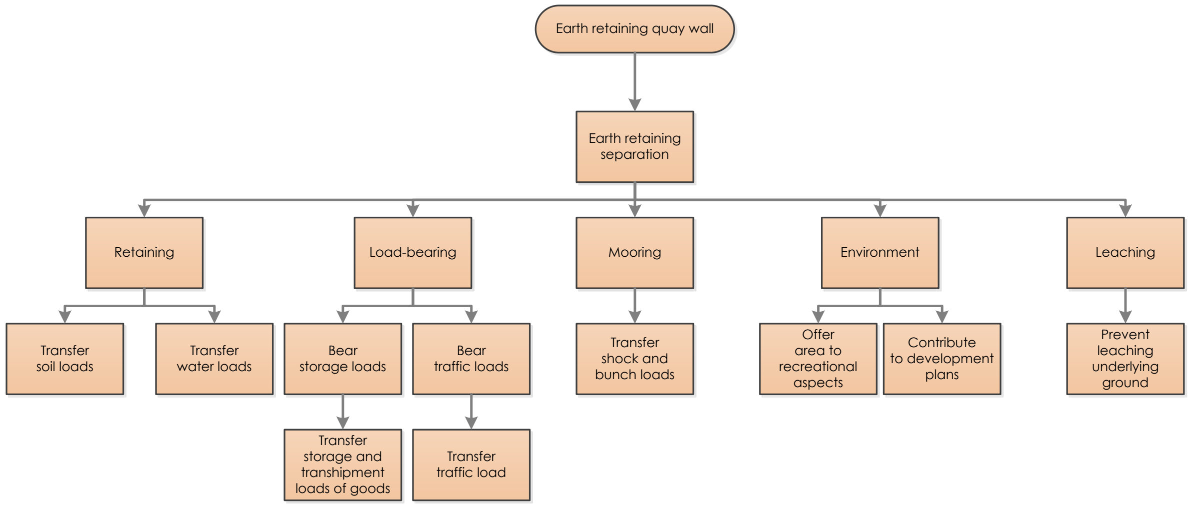


FIGURE 21: Function tree (urban) quay wall (based on (J.G. de Gijt, 2010).

B.3.6.2 Types

A distinction is made in the following types of inner-city quay walls (*Binnenstedelijke Kademuren*, 2014, p. 13). This distinction enables a better constructional assessment.

- Type 1: weight wall (gravity wall) founded on soil.
- Type 2: weight wall (gravity wall) founded on piles.
- Type 3: L-wall founded on piles.
- Type 4: steel or concrete sheet pile-wall.

Often, historic quay walls are no longer reconstructed but maintained because of the high costs. Some typical historic quay walls are (M. Meyer, 2015):

- Gravity wall with solid brick work or basalt from before 1920 and concrete with stamped lining after 1920.
- Gravity wall with wooden foundation for solid masonry or basalt of 1920 and concrete with stamped lining after 1920.
- L-wall on piles anchored un-anchored after 1960.
- Concrete sheet pile after 1950.

New constructed quay walls consist of steel ground retaining components with or without soil-anchors and a cover of desired ambition-level. Some typical new constructed quay wall types are (M. Meyer, 2015):

- Untreated steel with a steel covering plate.
- Untreated steel with a concrete apron.
- Brick work covering (stone strips) against concrete wall with stone edging.
- Basalt blocks (stone strips) against concrete wall and edging.

Weight types of quay structures are relatively robust and simple structures made of brick work, steel and/ or concrete. They derive their resistance from soil pressure caused by their own weight. However, sufficient bearing capacity of the subsoil is needed. Furthermore, this type is sensitive to erosion and when constructed on land, a deep excavation pit is required (Polder, 2011; Wu, Li, Gu, & Su, 2007).

Sheet pile walls perform their soil retaining function and stability through sheeting penetration, often in combination with anchors. This type of quay wall requires limited groundwork, is relatively simple and no construction pit is needed. Some disadvantages are (Polder, 2011; Wu et al., 2007): the relatively large deformation of the wall; anchoring requires a large amount of installation space; pile driving risks; risk of interlock openings.

B.3.7 Failure

In civil engineering, failure can often be defined as condition failure, which is a disability of a structure to perform its functions within constraints of legal safety margins. The consequences of failure can be divided into six 'damage categories' (CUR, 2010). This research emphasises the failure consequences or risk event consequences: money, nuisance, quality, safety and reputation or image.

B.3.7.1 Failure rate

During the use of an inner-city quay wall, the failure rate is not constant. Failure is characterized by different causes (FIGURE 22). The failure rate is divided into three typical periods, where the dominant failure cause shows similarities (Jaap Bakker et al., 2010, p. 16). Especially for modelling the remaining life span, collecting and analysing data and determining the most effective and efficient maintenance activity, understanding of (failure) behaviour as function of time is important.

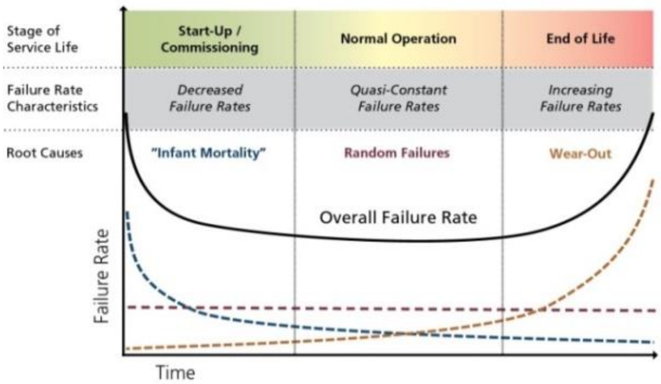


FIGURE 22: Hypothetical failure rate vs. time (IPO, 2015).

Failure is divided in several ways, such as 'noticeable' and 'non-noticeable' failure. In case of noticeable failure, the failure in functioning of a component can be noticed directly at that exact moment. Non-noticeable failure is only noticeable if the particular component is functionally tested or claimed. In order to detect non-noticeable failure in time, taking (adequate) measures is essential.

B.3.7.2 Failure mechanisms

The current condition of a quay wall can be assessed in compliance with the Eurocode, identifying the most important failure mechanisms. When the (sub) soil construction is suffering from major distortions, resulting in a failure mechanism, the ultimate boundary condition is met. These deformations are caused by (*Binnenstedelijke Kademuren*, 2014, p. 44): extreme loads, construction activities, degradation of materials or excavations. It should be noted that these aspects are variables that differ for each inner-city quay wall. For example, steel has other degradation and safety factors or boundary conditions than concrete or brick work. According to the Eurocode, the boundary condition is defined as the state where the construction just fulfils its function (*Binnenstedelijke Kademuren*, 2014, p. 66). Eurocode 7 distinguishes the following ultimate boundary conditions:

- GEO: 'collapsing or major disruption of the subsoil, in which the strength of the soil or rock contributes to the resistance' (carrying capacity foundations and retaining constructions, soil failure, soil loaded constructions).
- STR: 'internal failure or major disruption of the construction (components), including foundations on steel, piles or walls, in which the strength of the construction materials should contribute to the resistance' (failure of the construction).
- EQU: 'loss of equilibrium of the construction or subsoil, conceived as a rigid unit, in which the strength of the constructional materials and subsoil does not provide a contribution to the resistance'.
- UPL: 'loss of equilibrium of the construction or subsoil, as a consequence of floating due to water pressure or other vertical loads' (floating construction, failure tensile elements), in which the resistance of the subsoil can contribute.
- HYD: 'hydraulic soil fracture, internal erosion and erosion due to concentrated groundwater flow in the subsoil as a consequence of the hydraulic gradient' (piping, soil cracking).

Based on these ultimate boundary conditions, the geotechnical failure mechanisms for each type of quay wall are identified. Additionally, functionality failures due to major disruptions (in the usability boundary condition) may occur. A known failure mechanism, which is not geotechnical, is relevant for ancient quay wall structures and concerns the soil density of the construction. The run-off of sand or soil can cause the structure to collapse. Calculations on this failure mechanism are impossible to perform; these are often the negative consequence of the degradation of the construction. In TABLE 1, the failure mechanisms for each type of retaining wall are summarized. The failure mechanisms are described in more detail in the manual of SBRCURnet (2014) .

TABLE 1: Failure mechanisms for each type of retaining wall (SBRCURnet, 2014, p. 70).

Failure mechanisms (geotechnical and constructional)	Boundary condition	Retaining wall type 1	Retaining wall type 2	Retaining wall type 3	Retaining wall type 4
Vertical carrying capacity subsoil	GEO				
Vertical pile capacity (compressive)	GEO				
Vertical pile capacity (tensile)	GEO/UPL				
Horizontal carrying capacity subsoil	GEO				
Tensile strength anchorage	GEO/UPL				
Macro stability	GEO				
Tipping stability	EQU				
Kranz stability	GEO/EQU				
Constructional strength wall	STR				
Constructional strength piles	STR				
Constructional strength anchorage	STR				
Constructional strength residual elements	STR				
Collapse due to major displacements	STR				
Internal erosion	HYD				
Piping	HYD				

B.3.7.3 Uncertainty of failure probability

A good assessment of the failure mechanisms requires a good calculation model; the model should be an accurate resemblance of the reality. However, an ideal calculation model does not exist. The safety factors that are used for the design assessment are always subjected to uncertainties. The models should describe the constructional behaviour of a structure during certain circumstances. In this way, the compliance with the design and testing requirements is checked.

Models could vary from simple (empirical) relations towards advanced mathematical models, such as the Blum vs. FEM-analyses. Additionally, the behaviour of material can be assumed to be purely elastic or complex elasto-plastic. Despite the fact that a simple model requires a small amount of input parameters, the result will lie on the cautious side of reality. The complex models have an uncertainty that is the sum of all the uncertainties for each parameter. In the first case, the model uncertainty is high in respect to the second model. It can be expected that the complex model has a higher accuracy and a model uncertainty with a lower variation coefficient. The failure probability of an event is always associated with a probability distribution, which is based on the most suitable data set to measure the probable occurrence of a failure event.

B.3.8 Maintenance

The purpose of maintenance is to maximise system availability at minimum costs, by reducing the probability of system breakdowns (Rahman & Vanier, 2004). Maintenance is needed, due to quality losses and a lack of reliability. Maintenance can be seen as "a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform its required function(s)" (Frangopol & Liu, 2006). Last decades, traditional maintenance has developed towards performance-oriented maintenance (TABLE 2).

TABLE 2: Comparison traditional and performance-oriented maintenance.

Aspect	Traditional maintenance	Performance-oriented maintenance
Trigger for maintenance is based on	Technical specifications Budgets	Risks, costs and benefits in relation to business objectives and values
Considerations are based on	Experience, knowledge and skills	Objective performances with knowledge and skills
Methods and techniques	Work flow control	RCM and FMECA
Expectation	Simple measurable output such as maintenance costs	More complex information such as life cycle extension
Responsibility	Operational level	Strategic, tactical and operational level
Control	Operational level through budgets and based on simple measurable KPIs	Strategic, tactical and operational level based on KPIs
Staff	Operational staff is sufficient	Higher educated staff is required

Maintenance in general consists of (D. J. Vanier, 2001):

- Inspections that are performed periodically to monitor and record the performance of systems.
- Preventive maintenance that ensures that systems or components continue to perform their intended functions throughout their service life.
- Repairs that are required in case defects occur and unplanned intervention is required.
- Rehabilitation that replaces one major component of a system when the system reaches the end of its service life cycle.
- Capital renewal is often considered outside the maintenance definition, as renewal replaces a system at the end of its service or because of technical, economic, obsolescence, modernisation or compatibility issues.

Maintenance is often regarded as a necessary expense that falls under the operational budget. It is a common item on the hit list of cost-reduction programs (Tsang, 2002). In the Netherlands, management and maintenance of civil structures is controlled through performance management and project control ("Beheer en onderhoud hoofdwatersystemen, rijkswegen en hoofdvaarwegen," 2007; Jaap Bakker et al., 2010).

The maintenance level of civil structures is based on the following aspects ("Beheer en onderhoud hoofdwatersystemen, rijkswegen en hoofdvaarwegen," 2007):

- Legislation and regulation: these are not just to meet frameworks such as the "Nota Mobiliteit", but also health and safety legislation (see chapter 'Legislation and Regulation').
- User Service Levels: desired service levels that may relate to safety or user comfort in temporary or permanent conditions.
- Civil engineering functionality: continuously meeting the quality standards regarding the functionality of the infrastructure. These requirements are prescribed as preconditions in guidelines or manuals and are often derived from experience.
- (Business) Economic optimisation: the pursuit of optimisation (lowest possible cost) and to guarantee certain functionality.

B.3.8.1 Maintenance management

Maintenance management, including the implementation of a management plan (not legally obliged), plays an essential role in achieving client satisfaction or optimum value through providing effective maintenance to meet or even exceed client's expectations in the most cost effective manner and to improve the quay wall sustainability concurrently (Othman et al., 2007, p. 151). Furthermore, it enables timely reservations of resources for regular maintenance and necessary replacements.

Maintenance management used to be experience based and highly depending on implicit, qualitative local knowledge. Nowadays, it moves towards a more scientific approach, based on explicit, quantitative general knowledge (F3O, 2011). Within maintenance management, maintenance performance measurement (MPM) is perceived as essential in the performance of a civil structure. In order to achieve this, maintenance managers should have a clear overview of maintenance process performance. This can be established by defining a performance measurement system (PMS) and indicators (MPI) that enable measurement of maintenance function performance.

The current management of maintenance of inner-city quay walls is schematically illustrated in FIGURE 23. Based on inventory and inspection data, it is determined if the actual aging process of the structure(s) matches the theoretical remaining life time and which (additional) maintenance measures are required.

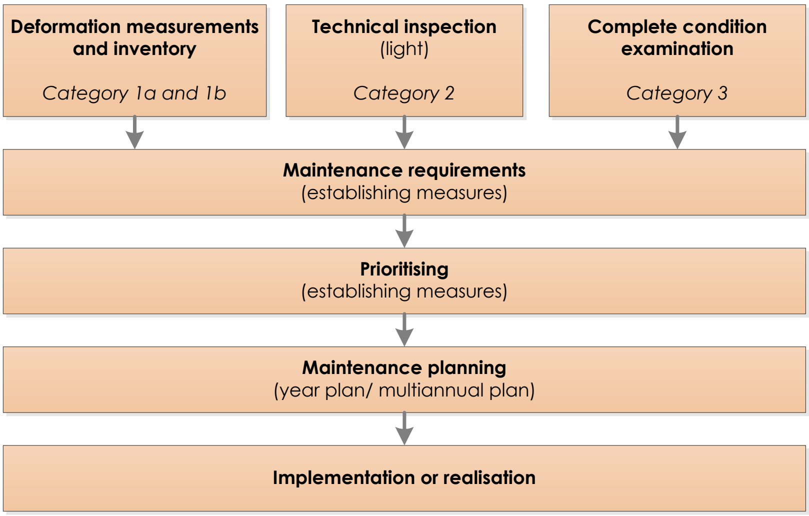


FIGURE 23: Maintenance management process inner-city quay walls (*Binnenstedelijke Kademuren*, 2014, p. 21).

Performance measurement increases performance (and competitiveness) of organisations by providing more balanced metrics. However, there are several implementation issues regarding human involvement; integration and linkage of strategic goals and vision to the operational level; and development of effective indicators (Parida & Kumar, 2006). Neely, Bourne, Mills, Platts, and Richards (2002) discuss the following encountered difficulties:

- A highly developed information system is called for.
- The process can be time-consuming and expensive.
- Management involvement and commitment is required.
- Resistance to change.
- Vision and mission are not actionable.
- Strategy may not be linked to resource allocation.
- Goals may be negotiated rather than based on stakeholder requirements.
- State of the art improvement methods are not always used.
- Striving for perfection can undermine success.
- Strategy is not always linked to department, team and individual goals.
- A large number of measures dilute the overall impact.
- Indicators are often poorly defined.
- There is a need to quantify results in areas that are more qualitative in nature.

The common mistakes that are made in the measurement of performance can be summarised under (Parida & Kumar, 2006):

- Not linking and aligning performance measurement to strategy.
- Not validating the links.
- Not setting the right performance targets.
- Measuring incorrectly.
- Lack of information for decision-making.
- Focus on past and failure to predict.

B.3.8.2 Maintenance strategies

Maintenance is an essential operation for keeping the quay wall and its components running in a condition that enables it to perform its intended function(s) and satisfy its clients and users (Othman et al., 2007, p. 149). Therefore, actions and policies should be established – at early stages of the project life cycle – to maintain the inner-city quay wall in optimum operating mode (FIGURE 24 and FIGURE 25). Possible maintenance actions are inspections, replacements, perfect repairs and life time extending measures (or partial repairs) ("NEN-EN1990. Eurocode - Grondslagen van het constructief ontwerp," 2002, p. 2; Van Noortwijk, 1998, p. 1). There are two types of maintenance: corrective maintenance and preventive maintenance (FIGURE 24).

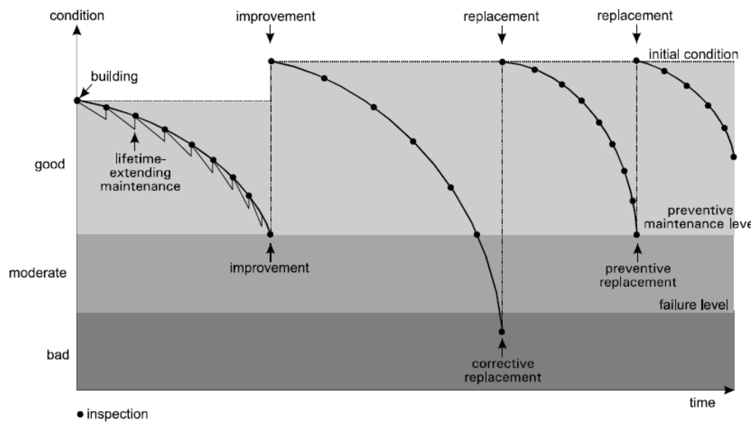


FIGURE 24: Condition of a component (JD Bakker, Van Der Graaf, & Van Noortwijk, 1999).

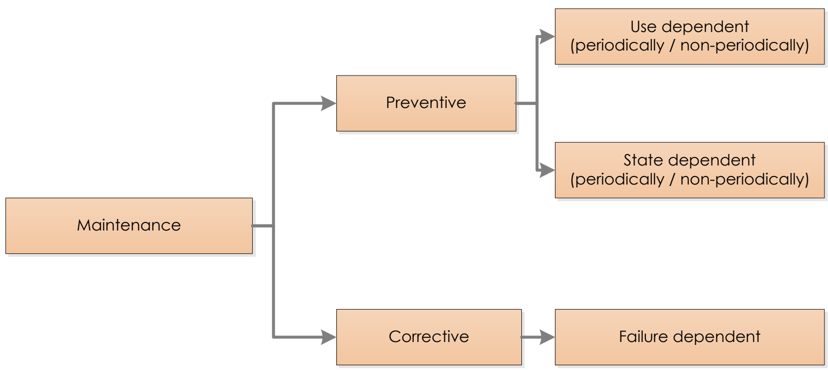


FIGURE 25: Maintenance types (*Binnenstedelijke Kademuren*, 2014, p. 21).

The difference between preventive and corrective maintenance is characterized by the failure limit of a construction (component) (FIGURE 25). Failure is defined as "no longer meeting the requirements regarding the functionalities of the construction" (*Binnenstedelijke Kademuren*, 2014, p. 21). Actions in respect of preventive and corrective maintenance are weighed in a risk analysis. A corrective action aims at the repair of the required level of functionality and safety, after the occurrence of failure. A preventive action aims at the maintenance of construction parts, before the occurrence of failure.

Preventive maintenance is divided into use dependent and state dependent maintenance.

- *Use dependent:* construction (element) is repaired after a fixed number of 'usage units'. The state of the construction is not important. The fixed amount of 'usage units' is sub-divided into periodically and non-periodically maintenance.
- *State dependent:* in time stochastic characteristics. Prior to the reparation or replacement of the construction (part), it will be inspected. Dependent on the state and the expected maintenance behaviour it is decided if repair is needed and when the next inspection should take place. Also this type distinguishes periodically and non-periodically state dependent maintenance.

In practice is appears that the maintenance of inner-city quay walls is particularly preventive. Prior to the maintenance, criteria are established that should be met. If the criteria are exceeded, repair will be necessary. The criteria should be set below the failure limit. Corrective maintenance will be possible if the chance of failure is quickly established. Due to the fact that this is complicated with regard to inner-city quay walls, as of thee submerged parts, this type of maintenance is rarely executed. The safety and availability of the construction may be adversely affected by corrective actions.

It is relatively difficult to predict the exact occurrence of failure and therefore, state dependent maintenance is often used. The length of an inspection interval is adapted during the life cycle of the construction. In the beginning, in the design life cycle, the inspection interval is approximately consistent. After the exceedance of the design life cycle, this interval is modified in relation to the degradation of the construction material or the change in usage.

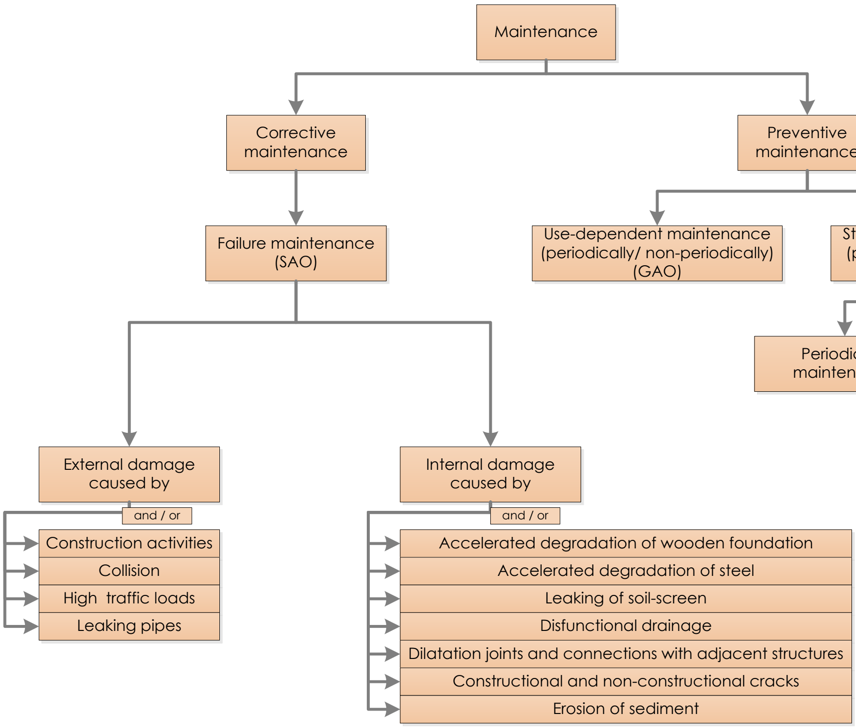


FIGURE 26: Maintenance strategies.

The maintenance regarding civil works is divided into (JD Bakker et al., 1999):

- Regular maintenance: e.g. reparation minor damage(s), cleaning surfaces, yearly maintenance.
- Major maintenance: life time extending maintenance, to postpone replacement moment.
- Replacement: demolishing and renewing existing civil work.
- Maintenance backlogs (combination of previous types of maintenance).

B.3.9 Interfaces and Environment

Urban areas are dynamic environments, in which individuals and organisations have their own requirements, desires and interests. Over the years, stakeholders expect to have more influence on organisations, decisions and construction projects. Recognizing the different requirements, interests and potential implications for stakeholders facilitates the decision-making of appropriate communication and noise reduction measures. Construction or maintenance activities may have a negative impact (nuisance risk) on objects in the environment. For example on individuals, (water) way users, houses, industrial buildings, infrastructural works, public spaces and flora and fauna.

B.3.9.1 Monumental appreciation

Some inner-city quay structures are covered by a protected city area, some are monumental or connected to a historic Listed building or bridge. There could also be municipal, provincial or national monument in the sphere of influence of the quay structure. This is an important factor in the execution of maintenance activities or replacement projects. For example, in renovation projects the re-use of materials can be required to maintain their original character. Dependent on the monumental status, a different path is followed regarding a new quay wall construction. The appreciation and preparation of repair activities of historic quay structures requires a certain amount of knowledge and experience. In particular the preparation phase and the definition phase, shaped through a restoration plan, are often preceded by a feasibility study and construction-historical archive research.

A monument license is required, which is based on a restoration plan. The lead time for such a project is much longer than a regular project. The application time for a monument license through the State Service for Cultural Heritage can easily reach six months. Besides obtaining a monument license, a grant application is often part of the restoration process. The restoration of a quay structure should be combined with the current requirements regarding safety and operation. In general, restoration is more expensive than repair or new construction.

To assess the feasibility of a restoration, an accurate determination of the current state is of great importance. This is certainly the case for a monumental quay structure. The profundity of the investigation should be assessed for each component and it is dependent on the monumental value and the assigned status of the construction.

In order to determine the way of repair of the quay wall, sufficient information on history and definition of the civil work is required. These data can be obtained through archive research: specifications and conditions, drawings, previous executed maintenance, and historical and geographical context. The construction-historical archive investigation has a larger societal level than research on a quay wall structure without a monumental status. To establish an objective assessment and a responsible decision an appreciation matrix may be used. All aspects related to valuation are addressed.

During the assessment and adjustments of monumental constructions, a balance is reached between the possibilities regarding the preservation of the current and future function and the possibilities regarding the preservation of the particularities and specific values (FIGURE 27).

In case of a monument and associated components, preservation takes precedence over new construction. The restoration of components during the life span of the monument is required occasionally. The desires of the user are weighted against the possibilities that are offered by the monumental construction. Intervention remains customisation; acting sustainable and responsible is essential. The restoration vision consists of a description that is based on the functional requirements. The authentic character of (monumental) inner-city quay walls is preserved. In case of restoration, it is of great importance that planning is well designed and consistent with the urban plans in the area. Consultation between the different parties involved is therefore essential.

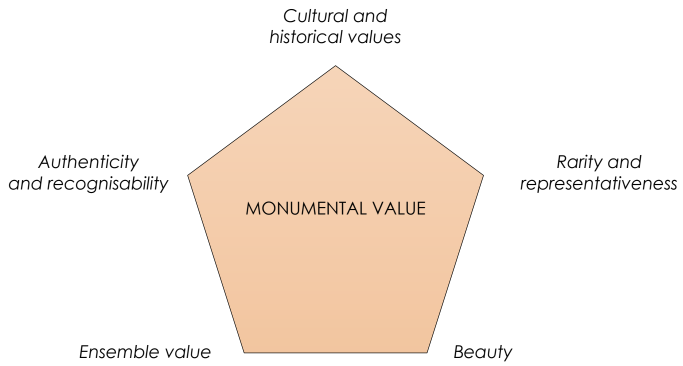


FIGURE 27: Monumental value.

B.3.9.1.1 Extra: Valuation of Cultural Heritage

In this research cultural heritage is defined as the following (Van Velzen, 2009, p. 26): "the constructions and buildings that are constructed by previous generations and which should stimulate the historical and/or cultural awareness of a society or which are important for the identity of a society". It considers all physical remains in the living and working environment, such as houses, churches, quay walls and archaeological remains and geographical elements, such as roads, ditches and green elements with a historical significance. Cultural heritage is more human than scientific; however it can be approached from a scientific perspective.

Valuing cultural heritage always implies that different interests of particular stakeholders should be mutually compared. A SCBA provides an understanding of these comparisons, by creating transparency through an unambiguous way of (cultural heritage) appreciation. The SCBA is used for the evaluation of alternatives by expressing different costs and benefits in monetary terms. Not all costs and benefits are monetised directly. Dammers, Hornis, Heemskerk, and Planbureau (2005); Ruijgrok, Brouwer, and Verbruggen (2004) demonstrate in their researches that the economic value of cultural heritage lies hidden in a higher market value of real estate and increased turnovers for the retail and hospitality sector (tourism). These are the components for which a market value is retrieved. However, a part of this societal or economic value is covered by human perception for which no market value is instantly available.

According to Van Velzen (2009) the existing literature, which is related to appreciation of cultural heritage, is mainly focussed on the valuation of public 'goods' nature and environment. Both are available for all individuals and their value will not (significantly) decrease when more individuals make use of them. To provide a proper indication of the total economic value of the environment, the model developed by Turner (1999) represents the basis: all human motives to value an object (FIGURE 28). Utility values relate to the current or future use of cultural heritage. These values are elaborated in Appendix F.

Total Economic Value Cultural Heritage		*Real estate value*	*Most important stakeholder*
Utility value	Settlement value	Yes	Owner real estate
	Recreation value	Yes	Owner retail/hospitality facility
	Living comfort value	Yes	Owner house
	Recreational amenity value	No	Visitor
	Functional value	No	Real estate and public area within effect radius
	Safety and Health value	No	Real estate and public area within effect radius
	Other	Yes / No	
	Option value	No	Entire society
Non-utility value	Philantrophic value	No	Entire society
	Inheritance value	No	Entire society
	Existence value	No	Entire society

FIGURE 28: Economic value cultural heritage (based on (Turner, 1999; Van Velzen, 2009)).

In order to valuate (cultural heritage) objects, multiple valuation methods are used to monetise the effects that could add value to a project. In practical applications these methods are complicated to execute, due to missing data, time or financial measures. Furthermore, the methods are divided into stated preference and revealed preference. Stated preference refers to data based on statements of people, represented as questions on a survey. Revealed preference refers to actual behaviour of people, for example by studying the purchase of market goods. TABLE 3 provides an overview of the different methods that can be used for the valuation of cultural heritage and in particular inner-city (historic) quay walls as part of the public urban area.

TABLE 3: Valuation methods (based on (Van Velzen, 2009)).

Economic value of (cultural, historic) heritage	Method for valuation	Advantages	Disadvantages
User values			
Living comfort value	Hedonic pricing method	Based on revealed preference	Time and money consuming
Settlement value			Only regressive relations
Recreational value			Cannot be generalised
Recreational experience	Travel cost method	Based on revealed preference	Survey or observation
			Time and money consuming
Safety values	Control cost method and Recovery cost method	Based on revealed preference	Key figures are not always reliable
Other values		Key figures available	
		Fast and inexpensive	
Non-user values			
Philanthropic value	Contingent valuation method	Applicable to most different elements	Stated preference
Inheritance value			Cannot be generalised
Existence value			Wide bandwidth
	Cost effectiveness analysis	References of subsidies or other investments in (cultural, historic) heritage	Value cannot be included into balance
			Can only be used as reference

B.3.9.2 Non-constructional elements

Non-constructional elements do not have a direct impact on the constructional function of the quay wall; however, these could have negative effects. These objects influence the quay wall construction in different ways: load, foundation and root process.

B.3.9.3 Flora and Fauna

During the maintenance of the quay structure, the present flora should be respected within the safety boundaries of the construction. To meet the regulations regarding the flora and fauna, the quay walls are inspected by acknowledged ecologist. In case of the presence of protected plant species, the report includes mitigating measures. Furthermore, a monitor programme and report are established to verify the protected state of the flora during and after the restoration. Flora includes (SBRCURnet, 2014, p. 28):

- Grass and woody vegetation ("Kwaliteitsinstrument voor Onderhoud van de Openbare Ruimte" (Ki-OOR) can be used to determine the desired maintenance and quality level).
- Moss ("Kwaliteitsinstrument voor Onderhoud van de Openbare Ruimte" (Ki-OOR) can be used to determine the desired maintenance and quality level).
- Trees (Virtual Tree Assessment (VTA) can be used to determine the desired maintenance level).

B.3.9.4 Adjacent structures

Quay walls are in many cases connected to other works, such as bridges, locks, parking garages and buildings. It is necessary to establish an evident separation in ownership and management. Undeveloped areas remain undeveloped. In weighty (social) interests building within the sphere of influence of the quay walls can be conditionally allowed. However, the maintenance of the quay is executed without additional measures to prevent damage to adjacent buildings.

B.3.9.5 Cables and pipes

Space limitations result in the presence of cables and pipes in the sphere of influence (subsurface) of quay walls. Especially in the compaction these elements play an essential role. During maintenance activities, present cables and pipes have often cost-increasing effects. The application process incorporates the assessment of the risks associated with excavations in the surrounding area of the quay wall. After the placement of cables and pipes or drillings, a review on their location and depth is established.

B.3.9.6 Preventive precautionary measures

As stated before, during the execution of construction or maintenance activities, damage can be done to flora, fauna or the environment in general, surrounding buildings, roads, bridges, quays, shores or public facilities (objects). Damage may be caused by (*Binnenstedelijke Kademuren*, 2014): vibrations or hitting of cables and pipes, collisions with vessels or workboats, lifting- and other manoeuvres at, on or near objects or execution methods. Additionally, many inner-city construction activities take place on areas that are easy accessible for passers, tourists or playing children. This is accompanied by additional safety risks.

B.3.9.7 Communication with third parties

For an accurate public communication the following recommendations is done (*Binnenstedelijke Kademuren*, 2014, p. 111):

- Client (municipality) and contractor (co-)create a communication and information plan in which the (method of) consultation, frequency and participants are determined, just as which information and when is communicated between third parties, contractor and client.
- Client and contractor have periodic consultation to organise the responsibilities regarding the communications with third parties (residents and companies). The method and content of communication are finally determined and contact points are designated.
- On time and prior to the construction activities third parties receive information on the purpose (nature), duration and period of the activities that can cause nuisance. Additionally, the measures that are taken to reduce the nuisance, damage(s) and risks are elaborated.
- Organising information meetings.
- Client and contractor use websites to inform interested parties for the purpose, duration, progress and nuisance of the construction activities.
- Use of Social Media.
- Establishing a procedure to deal with complaints, suggestions and/or questions of residents.

The traffic safety on inner-city water- and motorways requires special attention. To guarantee the safety level intensive communication (and collaboration) with the water- and motorway operators is needed.

B.4 LEGAL AND GOVERNANCE

Considering asset management in the public area, legal obligations, municipal policy guidelines and external regulation (B.4.1 and B.4.2) should be taken into account at all times. Furthermore, policy reports and documents provide guidance but also limitations regarding the management of the public area and its associated objects. Since the stakeholders' interests do affect the 'business value' of these assets, the different roles of public and private parties involved in the management process of inner-city quay walls as part of the public area are discussed (B.4.3). Finally, this section provides a short elaboration on different types of contracts and associated contract-considerations when managing inner-city quay walls (B.4.4).

B.4.1 Regulatory

In order to create an understanding of the regulatory level of control within the construction sector, the relevant regulations, standards and guidelines are elaborated. In order to deal with the deterioration of quay wall structures, several options as previously described could be considered. The selection of these maintenance strategies depends on the type and cause of damage and their impact on meeting the (functional) requirements of the quay wall structure (Rodriguez et al., 2006, p. 18).

In addition, several (national) guidelines and standards have been developed by among others the Centrum voor Regelgeving en Onderzoek in de Wegenbouw (CROW), the Ministry of Infrastructure and Environment and the International Organisation for Standardisation (ISO).

B.4.1.1 Dutch Civil Code

A civil engineering work, such as an inner-city quay wall, must be safe for all users. Users should not suffer any injury or damage and, if this is the case, the owner of the work is liable. This liability can be divided into risk liability (Art. 6:174) and debt liability (Art 6:162).

B.4.1.2 Building Degree or Building Act

A building, including a civil work, must at all times comply with the requirements in the Building Act: NEN standards (Netherlands) and EN standards (Europe). The Building Degree is a 'General Administrative' that is established at the highest political levels. The Building Degree is a legal set of rules, based on the 'Housing Act'. The Degree includes all technical regulations considering safety, health, utility and energy efficiency.

B.4.1.3 Eurocode Standards

The Building Degree requires compliance with NEN standards and EN standards. The European standards are represented by the Eurocodes that are used for testing the structural safety of the constructions. Legislation regarding civil constructions considers the EN 1990 series (EN 1990 – EN 1999): the Structural Eurocodes (FIGURE 29). In the Netherlands, the NEN-EN 1990 series are applicable. They replace the Dutch NEN 6700 and NEN 6702.

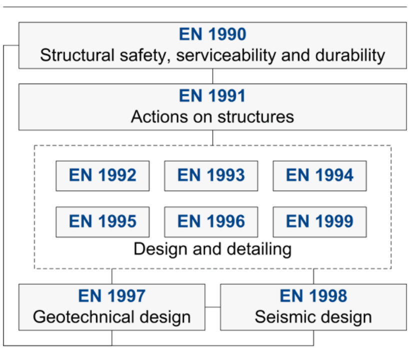


FIGURE 29: Links between Eurocodes ("EN Eurocode Parts," 2015).

The NEN-EN 1990 series cover the basics requirements of safety, usability and durability regarding civil constructions. They are meant to be used by standardising commissions, designers and contractors and supervising governmental institutions. Within the EN 1990 standard the requirements regarding the system reliability, the design life category, durability and quality represent the fundamental basis of the entire structural design. The standard provides also specific information considering among others limit states and load calculations.

When it is determined to renovate or replace the existing quay structure by a new construction, the respective structural parts should be re-designed and re-dimensioned in compliance with applicable safety criteria. The design philosophy regarding renovation, rebuilding or new construction is in line with European standards, such as (*Binnenstedelijke Kademuren*, 2014, p. 77): Eurocode 0 (NEN-EN 1990 Algemeen (General)); Eurocode 1 (NEN-EN 1991 Belastingen (Loads)); Eurocode 7 (NEN-EN 1997 Geotechniek (Geotechnics)); and NEN 8700. The conditions in respect to defensive constructions are described in chapter 9 of NEN 1997-1. The corresponding documents are the Nationale Bijlage (National annex) NEN-EN1997-1/NB and the Aanvullende bepalingen (Additional conditions) NEN 9097-1 in combination with NEN-EN1997-1 (= Eurocode 7). The National annex covers many CUR 166-elements (J.G. de Gijt et al., 2015) (*Binnenstedelijke Kademuren*, 2014, p. 72).

B.4.1.4 Safety consideration

The former regulatory framework NEN 6700 distinguished three safety categories 1, 2 and 3 with reliability indices of 3,2; 3,4; and 3,6 (*Binnenstedelijke Kademuren*, 2014, p. 71). The unwritten policy, related to civil works owned by RWS, is that primary water retaining works are covered by the highest safety category. This implies that the previous regulatory framework a minimum reliability index of $\beta N = 3{,}6$ requires, with an standard reference period of $N = 50$ years.

Reliability indices for new constructions

The Eurocode distinguishes safety categories or reliability classes. In accordance with these design regulations, the calculations in respect to the safety assessment of a design can be based on a methodology with characteristic loads, strength parameters and partial safety factors (load and material factors) (SBRCURnet, 2014, p. 77). The required reliability level in the EN-standards differs from the reliability level in the CUR-guides and the former Dutch NEN-standards. The safety requirements, in terms of minimum required reliability indices (β-values) are shown in TABLE 4.

TABLE 4: Safety categories reference period of 50 years (new construction) (SBRCURnet, 2014, p. 77).

Probability		EN 1990		CUR 162 + 166		NEN 6700	
Economic damage(s)	Casualties	Category	β_{50}	Category	β_{50}	Category	β_{50}
Negligible	Low				2,5 – 2,6		
Negligible Low	Negligible Significant	RC1	3,3	II	3,4	1 2	3,2 3,4
Significant	High	RC2	3,8			3	3,6
Very high	High	RC3	4,3	III	4,2 – 4,3		

Reliability indices for existing constructions

In case of existing constructions reference is made to the 'Bouwbesluit 2012' (Building Act 2012) for the assessment in accordance with the Nationale Bijlage (Eurocode). For the renovation or reconstruction of existing structures, the β-values should lie between the minimum values of the existing and new constructions. The safety requirements, in terms of minimum required reliability indices (β-values) are summarised in TABLE 5.

TABLE 5: Safety categories for existing and new constructions (SBRCURnet, 2014, p. 78).

NEN 8700 Assessment existing constructions		Renovation/ reconstruction existing constructions		EN 1990 new constructions	
Category	β_{50}	Category	β_{50}	Category	β_{50}
RC1	1,8	RC1	2,8	RC1	3,3
RC2	2,5	RC2	3,3	RC2	3,8
RC3	3,3	RC3	3,8	RC3	4,3

The renovation of existing structures requires a target level of the new construction level. The legally allowed deviation to the reconstruction level is only used in case of disproportional cost for reaching the new construction level (monumental or special constructions). During the renovation, the implementation of the observation of the constructional behaviour is considered. Especially for the assessment of the existing constructions and constructions in renovation, the standard NEN 8700 is established. The standard is composed, because of the fact that the assessment of the existing structure differs essentially from new construction. First of all, the consideration of the desired safety level in regard to the cost effectiveness is generally different. In case of renovation, an increase in the safety level and the realisation of a new construction entails more additional costs than in case of a new design. Furthermore, the remaining life time of an existing structure is often less than 50 or 100 years. Finally, possible measurements can be performed to acquire more information on a construction.

The NEN 8700 distinguishes three reliability categories (*Binnenstedelijke Kademuren*, 2014, p. 71) (TABLE 6).

TABLE 6: Reliability categories.

Reliability category	Safety category	Reliability index	Minimum reliability index existing constructions	Minimum reliability index new constructions	Minimum reference period (year)
RC1	1 and 2	3,3	1,8	3,3	15
RC2	3	3,8	2,5	3,8	15
RC3 Constructions with large social impact(s)	-	4,3	3,3	4,3	15

The assessment of an area with existing constructions, for the identification of the safety level, a value between the new construction level and rejection level is assumed. The reconstruction level represents the maximum value. It is recommended to re-assess the area with existing structures, based on the reconstruction level. In case of extreme costs, in some cases (monumental constructions), the rejection level is allowed. However this level is only allowed provided that in near future measures will be taken and constructions are permanently loaded. The behaviour of the structure is monitored during non-compliance with the reconstruction level (*Binnenstedelijke Kademuren*, 2014, p. 71).

In anticipation of NEN 8707 it is recommended to use load factors that are derived from NEN 8700 (existing buildings). Situations and loads that do not appear by buildings (soil pressures). In these cases, the standards from the Eurocode, annex B and C (including the Nationale Bijlage) are used. In accordance with the Nationale Bijlage of the Eurocode, the constructional components may be classified into a lower consequence category if it is assumed that the consequence of failure is relatively small.

B.4.1.5 Roads Act
The legal framework for the management of civil works is recorded in the Roads Act of 1930. The government, the province, the municipality and the water is required to maintain a road, when the public sector body that is intended to reveal road (Art. 15:1). Bridges are also defined as road (Art. 1:2).

B.4.1.6 Law General Provisions for Environmental Law (Wabo)
The municipality has the task to monitor civil engineering works within its territory. This also applies for-works owned by third parties. This monitoring task rests with the Department of Building and Housing. Damage claims not resolved in the foreseeable future are reported to the supervisor.

B.4.2 Guidelines and recommendations
Inner-city quay walls are part of a primary or secondary flood defence. Primary flood defences comply with stricter safety requirements than secondary flood defences. For the assessment of primary flood defences reference can be made to the Leidraad Kunstwerken (Guideline Works) and the reports of Deltares in regard to 'Afstemming Leidraad Kunstwerken en Eurocode' (Alignment Guideline Works and Eurocode) (*Binnenstedelijke Kademuren*, 2014, p. 71).

B.4.2.1 RWS-guidelines
The developments in legislation have also led to changes in the guidelines prescribed by Rijkswaterstaat (RWS). In addition to the 'Richtlijnen Ontwerp Betonnen Kunstwerken' (ROBK) for the assessment of new constructions, the 'Richtlijnen Ontwerp Kunstwerken' (ROK) established. The ROK elaborates on demands, actions and recommendation additional to the Eurocodes.

The safety of existing infrastructures was for a long period assessed using standards meant for new constructions. In 2004, RWS presented the 'Richtlijnen Beoordeling Bestaande Kunstwerken' (RBBK), which served as a first directive for the assessment of existing civil structures. RWS developed the 'Richtlijnen Bestaande Kunstwerken'(RBK) with requirements regarding the safety and usability of existing structures and these directives to uniformly assess the overall structural safety. The RBK consists of guidelines and additional requirements for the assessment of existing structures (Dieteren, Veen, & Sliedrecht, 2012).

For the assessment of the structural safety three reliability levels are distinguished:

- New construction: new structures (components or elements) that are physically altered and reconstructed should meet the requirements for new constructions.
- Reconstruction: new structures (components or elements) that are physically altered and reconstructed should meet the requirements for new constructions.
- Disapproval: structures (components or elements) that are not altered or reconstructed should minimally meet the safety level of disapproval. This level is significantly lower than for new construction. However, it should be provided that:
  - No structural damage is present.
  - During the remaining life time the traffic load does not increase beyond the design level.
  - The strength or resistance of the structure does not decrease.
  - The maintenance management guarantees the structural safety.

B.4.2.2 CUR-recommendations

Besides legislation, standards and guidelines developed by the Dutch Government (especially RWS) other guidelines are used. The CUR recommendations represent agreements between parties in the construction sector: communicative documents. The following CUR recommendations are applicable to management and maintenance of inner-city quay walls in the Netherlands:

- CUR Recommendation 72: Inspection and investigation of concrete structures (CUR, 2011).
- CUR Recommendation 73: Stability of brick constructions (CUR, 2000).
- CUR Recommendation 117: Inspection and recommendation civil works (CUR, 2015).

B.4.3 Actors

Asset owners, asset managers and service providers play an important role in the implementation of and compliance to legislation and regulation regarding the maintenance of inner-city quay wall structures. In performing or applying asset management, the different roles of asset owner, manager and service provider are represented in an asset management team.

B.4.3.1 Role development in maintenance

Over recent years, maintenance organisations or departments of (local) authorities have been forced to reduce cost or increase the flexibility of both resources and cost (L. Euser 2001; M. Seifert & T. Harmon, 2009).

The management department of a local authority fulfils no longer the role of internal service provider, but that of a governance organisation: the client for external service providers (Kuipers, Kronenburg, & Leenen, 2010). Therefore, the governance of sourcing relationships is increasingly considered to be more important than the preparation and execution of operational maintenance tasks. The asset owner no longer executes the maintenance of assets; it is performed more and more in cooperation with suppliers. In this way, chain dependencies are introduced; maintaining an asset is the responsibility of multiple parties and their mutual relationships (S.D.J. van Leeuwen, 2012, p. 30). Asset owners have to keep the maintenance costs under control by managing and controlling the external parties in the maintenance chain (L. Euser 2001). All parties that are involved should work together, because they are - to a greater or lesser extent - mutually dependent.

B.4.3.2 National Government (asset owner and asset manager)

The National Government consists of the Dutch government, departments and the First and Second Chamber. Rijkswaterstaat (RWS) is an agency of the Dutch Department of Infrastructure and Environment (asset owner) and works daily towards a safe, liveable and accessible Netherlands (Rijkswaterstaat, 2015). Therefore, RWS involves the civil society in the design and development of their living environment and cooperates with water boards, municipalities, companies and research institutes. RWS plays roles as regulator (standards), client and (Dutch) government party.

RWS is responsible for the management and maintenance of national highways, waterways and waters and the realisation of a sustainable living environment. RWS states that asset management is their main policy that should be implemented top-down (van der Velde, Klatter, & Bakker, 2013). RWS can be seen as the asset manager in the asset management process implemented in 2012. The three main objectives of the implementation of asset management are: establishment of good and reliable data for decision-making; prioritisation of activities within a limited budget; and setting clear goals and requirements that allow good contracting.

B.4.3.3 Provinces (asset owner)

The provinces represent the regional level of administration between the national government and the local municipalities. They translate national objectives into regional policy. The provinces are responsible for the secondary flood defences and issuing permits in case of extraction of groundwater (Havekes & De Putter, 2009; Rijksoverheid, 2015). The Dutch provinces are to a large extent financed by the national government. In the Netherlands, there are twelve provinces with a responsibility of subnational and regional important matters.

Municipalities or local authorities (asset owner and asset manager)

The municipality is, apart from a governmental organisation under public law, also owner of the majority of the common public space. She requires a private payment in exchange for use of municipal land. This is based on her position as owner. This payment is performed in terms of rent or lease. Despite the fact that the municipality has the same rights and obligations as other legal entities (civil law) her position as a contracting party differs fundamentally from that of a private entity. The municipality (authority) is supposed to represent the public interest. For the municipal acting under private law other rules apply than for private parties. This local authority has a dominant role in the management of the public area.

The municipality has some specific tasks regarding water management. She is responsible for surface and groundwater in urban areas. The municipality takes care of the disposal of sewage and rainwater from the sewer system (Havekes & De Putter, 2009; Michiels, 2003; Rijksoverheid, 2015). In urban areas, a large part of the canals, ponds, ditches and other waterways is managed and maintained by the municipality. However, often this is done by the water board.

The municipality is responsible for the water banks and other civil structures such as bridges and culverts. Within the municipal organisation, the board of mayor and aldermen establishes a budget for the management and maintenance of civil works in their area ownership. Public inner-city quay walls represent a major replacement task and financial time bomb for municipalities (Gaalen, 2013; "Historische kademuren in slechte conditie," 2015; J.G. de Gijt et al., 2015).

B.4.3.4 Consultancy and engineering firms (service providers)

Since the management and maintenance of inner-city quay walls have been given a higher priority on the public agenda, consultancy and engineering firms are consulted. They use their knowledge and expertise to provide technical advice on constructional calculations, feasibility and safety. They propose solutions regarding rehabilitation or new construction of "unsafe" quay wall structures. The input for these solutions is the performance of inspections and assessments. Therefore, they should act in compliance with certain preconditions, standards and legal obligations.

They also engage specialists for further evaluation of the civil structure. Furthermore, based on the findings of the engineering firm(s), the (local) government will take a decision regarding the maintenance of the civil structures. The engineering firm's objective is to provide reliable constructional advice to improve or maintain their image. Currently, they encounter constructional uncertainties due to a lack of data of existing structures. They could benefit from a more unified maintenance approach. When an engineering firm is considered to be leading in his approach regarding inner-city quay walls, it may result in more orders in the future.

B.4.3.5 Contracting firms (service providers)

The contractor takes the responsibility for realisation and coordination of construction activities. The contractor takes care of, within a contracted price and agreed time. Often, the client ((local) government) engages an engineering firm as a third party for inspection, assessment and technical solutions related activities. Subsequently, the by the client selected constructional solution, will be tendered to one or more contractors. Then, it will be executed or implemented by the selected contractor(s) and (sub) contractors.

The contractor's objective is successfully realising and coordinating maintenance projects, through delivering constructional quality, to improve or maintain their image. Quality is directly related to value and therefore contractors could benefit from a more unambiguous maintenance approach. When a contractor is considered to be leading in his approach regarding inner-city quay walls, it could result in more orders in the future.

B.4.3.6 Knowledge or research institutes

Knowledge or research institutes are organisations that are focussed on the development of science and execution of academic research, such as TNO and SBRCURnet. Some institutes are institutionalised because of a research program. They have specialised knowledge and skills regarding specific issues or topics. They act as researcher, developer and/ or consultant. The organisations are continuously working on new solutions for societal and technical problems. The acquired knowledge is shared and made applicable for the (Dutch) market. Current issues are put on the agenda, innovation is stimulated and knowledge is documented in standards. In case of the management and maintenance of inner-city quay walls, research is done towards more effective and efficient methods for inventory, inspection, assessment and constructional improvements of these structures.

B.4.3.7 Other

- *Citizens* are the stakeholders in the public area in the form of users, initiators and/or entrepreneurs:
    - *Residents* (inhabitants inner-city): users and initiators of the public area;
    - *Entrepreneurs*: users and initiators of the public area. They get their earnings partially from their location nearby or within the (historic) inner-city.

  In order to make use of (municipal (public) and private) services they should pay in terms of taxes, charges and fees.
- *Transport services* are also users of the public area in terms of transport service providers.
- *Environmental organisations* who advocate the importance of nature (flora and fauna) and environment. They are engaged with items such as flora and fauna protection, pollution, (noise) nuisance, cultural heritage, archaeology and traffic with the general purpose of achieving a nature- and environment- friendly society.
- *Property corporations and property owners* are owners of managers of real estate and thereby of (a part of) the property value.
- *Visitors and tourists* are users of the public area, its associated civil assets and adjacent businesses such as the recreational facilities, restaurants, cafes, hotels and shops around the municipal (cultural historic) attractions. They benefit, besides from the different (cultural historic) attractions from the amenity value of the inner-city public area. They pay the municipality for services they use in terms of taxes and charges (e.g. tourist tax, parking and mooring charges).

B.4.4 Contracting

An accurate type of contract between client and contractor is essential for an optimum risk allocation during the execution of a project. The operational aspects should be covered as effectively as possible in the design of the construction. In general, the client or in this case the municipality can be held responsible for the risks that occur during operation and maintenance; if and only if the contractor is "not attributable to his own act or omission in more than a negligible extent" (Dutch Civil Code Article 6:258 paragraph 2).

The way the process will be organised, plays a critical role. It determines the distribution, the nature and size of the tasks which should be performed by different parties that are participating in the construction process. The tasks are dependent on the client's objectives regarding the process. The choice for the organisation form is highly affected by the content of the problem specification. A problem specification should be a resemblance of the nature and size of the influence that the client addresses to himself and the market participants (*Binnenstedelijke Kademuren*, 2014, p. 101). The size of the solution space is defined by the problem specification. In FIGURE 30 the dimensions of the solution space, in terms of performance, cost and time, are displayed.

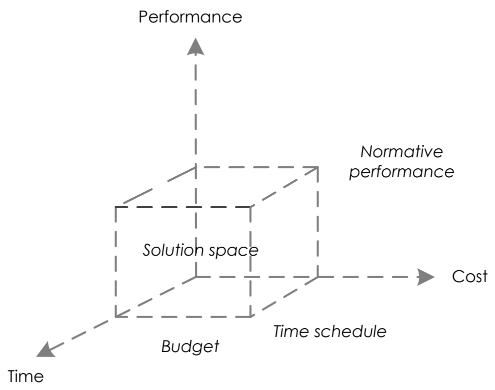


FIGURE 30: Dimensions solution space (Ridder, 2013, p. 13).

The type of contract can be seen as a consistent and legal translation of the combination of the construction process' influence and the associated solution space into the contractual distribution of responsibilities and risks (*Binnenstedelijke Kademuren*, 2014, p. 101). Not only the consistency between the organisation form and problem specification is decisive for the contractual conditions, but also the decision prospects regarding the procurement process.

The intended performance will benefit from a well-thought-contract type, because (*Binnenstedelijke Kademuren*, 2014):

- The contractual distribution of responsibilities and risks are economically resembled in the tender level.
- The contractual distribution of responsibilities and risks determines the client's recover possibilities.

In TABLE 7 the responsibility distribution regarding different types of procurement and collaboration is shown.

TABLE 7: Responsibilities regarding procurement and collaboration concepts (*Binnenstedelijke Kademuren*, 2014, p. 102).

Construction phases	Traditional collaboration concept			(Multi-year) Maintenance concept	Integrated collaboration concept	
	Direction	*UAV/RAW*	*Building Team*	*Framework Contract*	*Design & Construct*	*Turnkey*
Initiative	Responsibility client					
Research						
Definition						
PoR						
Preliminary Design						
Final Design						
Implementation Design						
Work Preparation						
Implementation				Responsibility contractor		
Maintenance						
Frameworks						
Procurement	Procurement procedure in compliance with applicable procurement regulation or directive					
Implementation	UAV	UAV	RVOI/UAV	UAVgc	UAVgc	UAVgc

In traditional contracts, the responsibilities and risks lie mainly with the client. In integrated contracts, such as D&C contracts, almost all responsibilities and risks are assigned to the contractor. The contractor is responsible for both design and realisation of the construction. An integrated contract enables an optimum alignment between both phases. This may result in possible time and cost savings. More risk shifts towards the contractor. Differentiation between contracting parties in the procurement process will be increasingly established by looking at value (quality) and not only at cost. Clients believe that using new contract types would encourage a value-based mind-set; however these new contracts are still not applied everywhere.

As stated before, the shift in responsibility of executing maintenance activities from asset owner towards supplier or service provider results in a transition in the levels of ownership and risk between both parties. The level of ownership is defined as the extent to which resources are owned by the asset owner (S.D.J. van Leeuwen, 2012). The different strategic options of sourcing (make, buy or ally) maintenance activities and associated contract types are visualised in FIGURE 31.

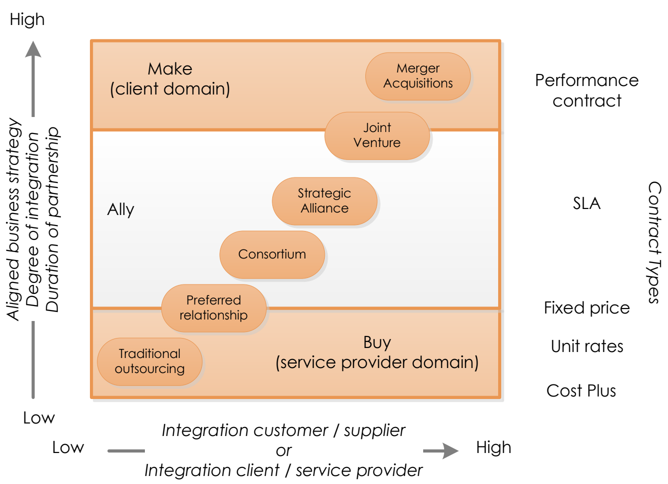


FIGURE 31: Sourcing options related to some contract types (S.D.J. van Leeuwen, 2012, p. 33).

In managing inner-city quay walls as part of the public (urban) area, the contracting regarding these objects is subject for further research. Until now, mainly because of the age of these structures, few innovative contracting methods are used for their management. Contracting based on both value (performance) and costs contributes to a larger amount of information which should be anticipated by contracting parties. Value-orientation should not result in a minimised number of tenderers, due to a fear for too much information.

Besides, engineering and contracting companies could improve their marketing by acquiring and using their skills in client-consultancy. They could convince the client by emphasising their expertise on added value of projects. Tenders are prepared in relation to integral life cycle approaches. This is impossible without a value-orientated mind-set. Because of the expected repair and replacement tasks in the future, the contracting of urban assets such as inner-city quay walls will become increasingly important for all actors involved.

B.5 DECISION-MAKING PROCESS: MAINTAIN, REPAIR OR REPLACE?

Regarding inner-city quay walls, an asset management framework or value-defining model should integrate multiple modules, such as:

- Asset inventory
- Inspections
- Requirements (functional and technical performance)
- Assessment
- Reference period or remaining life time
- Technical solutions or alternatives
- Prioritisation
- Budgeting
- Final decision.
- (Execution of management strategies and monitoring)

Following this process step by step a large amount of information regarding inner-city quay walls in respect to its surroundings (public urban area) is acquired. One of the final steps of this flowchart is that the municipality makes her final decision: should the inner-city quay wall be maintained (change nothing or restrict use), repaired (repair) or replaced (demolish and renew)?

C. REALISATION

C.1 ALIGNMENT DESIGN AND EXECUTION

TABLE 8: Focus points regarding alignment between design and execution (SBRCURnet, 2014, p. 103)

Focus point	Possible bottlenecks (or risks) during execution	Measures in design
Environment objects (buildings, cables and pipelines, roads, trees, etc.)	Damage(s) due to vibrations	- Components should be installed vibrations-free
	Damage(s) due to conflicts between new construction components and existing environment objects	- Prematurely inventory existing environment objects and adjustment design - Prescription inclusion
	Damage(s) due to manoeuvre equipment	- Components nearby damage-sensitive environment objects should be installed with minimum manoeuvres of equipment
	Damage(s) due to pumping	- Such a design that there is no or limited pumping needed during execution (brick-, concrete- and welding work above the waterline) - Controlled pumping (construction pit)
Residents	Construction nuisance (noise, vibrations, etc.)	- Components should be installed vibrations-free - Minimising pile driving - Minimising construction time on location / maximising prefab components
	Safety and security for residents during construction activities	- Such a design that dangerous (lifting) manoeuvres can be limited
(Waterway) traffic	Obstruction / nuisance motorway traffic	- Performing construction activities primarily from water side - Maximising prefab components
	Obstruction / nuisance waterway traffic	- Performing construction activities primarily from land side - Maximising prefab components
Transport route	Limited dimensions (height, width, length overall, draught) and permissible axle loads transport vehicles	- Taking into account maximum dimensions and weights of components to be transported
Available construction area	Limited manoeuvre-space equipment	- Components should be installed using space-restricted equipment
	Limitations allowable construction loads	- Components should be installed using equipment which meets maximum load requirements
	Limited space auxiliary constructions	- Taking into account available auxiliary constructions in respect of limited space
Water levels	No or limited pumping possibilities due to settlement risk	- Such a design that no or limited pumping is needed during execution - Controlled pumping (construction pit)
	Construction components below/ around the waterline	- Brick-, concrete- and welding work above waterline
Delivery times	Materials out of stock	- Taking into account delivery times equipment

C.2 EXECUTION ASPECTS

TABLE 9: Focus points during execution (SBRCURnet, 2014, pp. 104-105).

Section	Activities	Specific focus points during execution
Ground work	Excavation	- Cables and pipes - Flora and Fauna - Archaeological objects - Not UXO (not detonated explosives) - Stability surrounding objects - Soil quality
	Temporary storage ground	- Area and permit for storage - Soil transport through city centre
	Supplement	- Compaction ratio soil - Soil quality - Damage(s) due to vibration settlements
Dredging work	Excavation waterway in front of quay	- Flora and Fauna - Maximum allowable dredging depth (regarding stability of quay wall) - Soil quality
	Dispose released sludge	- Soil transport through city centre - Disposal unit liberated soil or sludge
Demolition work	Removal brick work	- Flora and Fauna - Debris in water
	Removal anchorage	- Stability quay structure
	Removal concrete construction	- Noise production - Debris in water - Vibrations
	Removal sheet pile construction	- Vibration impact on surrounding objects (settlements) - Vibration nuisance (individuals, sensitive equipment) - Not UXO - Manoeuvre space equipment
	Removal foundation piles	- Vibration impact on surrounding objects (settlements) - Vibration nuisance (individuals, sensitive equipment) - Not UXO - Cables and pipes-manoeuvre space equipment - Obstructions in subsoil
Pile driving work	Installation foundation piles	- Vibration impact on surrounding objects (settlements) - Vibration nuisance (individuals, sensitive equipment) - Not UXO - Cables and pipes-manoeuvre space equipment o Obstructions in subsoil
	Installation sheet pile construction	- Vibration impact on surrounding objects (settlements) - Vibration nuisance (individuals, sensitive equipment) - Not UXO - Cables and pipes-manoeuvre space equipment

		- Manoeuvre space equipment - Obstructions in subsoil
Anchorage	Installation anchors	- Archaeological objects - Not UXO - Cables and pipes - Existing (subsoil) environment objects - Manoeuvre space equipment - Property frontiers across entire anchorage area
Concrete work	Installation in-situ concrete construction	- Water levels - Outdoor temperature - Auxiliary constructions - Supply concrete
	Installation prefab concrete construction	- Transport prefab elements - In-situ handling prefab elements
Steel work	Installation anchor plates, cap and/ or quay equipment	- Water levels - Conservation (limitation underwater)
Brick work	Bricklaying retention wall	- Water levels - Outdoor temperature
Transport	Supply and discharge equipment and materials	- By water or by land - Limitations dimensions and weights - Permits - Traffic regulations (measures)
	In-situ transhipment	- Capacity lifting facilities vs. available space - Storage space
Auxiliary constructions	Construction pit	- Position stamping - Pumping - Stability surrounding objects - See installation sheet pile construction
	Concrete forms	- Water levels
	Slot forms	- Stability surrounding objects

C.3 EXECUTION RISKS

TABLE 10: Execution risks (SBRCURnet, 2014, p. 105).

Event	(Possible) Causes	Measures
Damage(s) to surrounding objects (buildings, cables and pipes, roads, works)	Vibrations due to foundation activities (pulsation and pile driving)	- Precautionary measures vibration- and deformation damage(s)
	Manoeuvres equipment	- Measures Cables and Pipes - Applying protective structures
Unallowable nuisance residents	Nuisance construction activities exceed maximum allowable boundaries	- Precautionary measures noise nuisance
	Residents are insufficiently informed regarding construction activities	- Communication with third parties (public communication)
Unallowable nuisance (waterway) traffic	Insufficient communication with (waterway or motorway) operators	- Communication with third parties
Accidents in public space	Dangerous or unsafe situations in public space, due to construction activities	- Precautionary measures public space
Damage(s) to Environment, Flora and Fauna	Insufficient consideration for Environment, Flora and Fauna during construction work	- Precautionary measures nuisance Environment, Flora and Fauna
Instability quay wall during construction phase	Exceedance maximum acceptable construction load behind quay wall	- Inventory upper loads equipment behind quay wall for each construction phase - Identification maximum allowable upper load behind quay wall for each construction phase - Adjustment execution method in case occurred upper load is larger than maximum allowable upper load
	To deep excavation of water soil in front of quay wall	- Determination maximum allowable dredging depth (incl. dredging tolerances)
	Inaccurate construction phasing	- Construction phasing design = construction phasing execution - Alignment construction phasing between design and execution
Construction components cannot be installed	Subsoil obstructions	- Measures Cables and Pipes - Archive research regarding former and existing constructions in subsoil - In-situ research or investigation
	Transport of components to the construction site is impossible	- Inventory limitations of transport routes - Taking limitations of transport routes into account during design - Collaboration and agreements with (water- and motorway) operators: communication with third parties
	In-situ transhipment of components is impossible	- Inventory possibilities for in-situ transhipment (required lifting capacity in respect to available space) - Taking transhipment possibilities into account during design - Alignment between lifting facilities and available space
	Equipment for installation of components is unavailable	- Inventory available equipment - Taking available equipment into account during design
	Insufficient space for equipment to install components	- Inventory available space for equipment - Taking available space and equipment into account during design
	Construction location is suspected to be not UXO	- Historical and exploratory research

D. DESIGN

D.1 PERFORMANCE

TABLE 11: 'Performance-ruler' inner-city quay walls in public urban areas (Gemeente Delft, 2012).

Very Good (A^+ / A)	Good (B)	Medium (C)	Bad (D)
			
Safety and Health			
• Construction in perfect condition • No damage • No safety risk	• Construction in good condition • Negligible damage • No safety risk	• Doubts about safety • Further investigation is desired • Attention required • 'Warning' phase	• Loose components • Threat of collapsing • Threat of accidents • Damage • Safety risk • 'Alarm phase'
Functionality			
• Conservation in good condition • Foundation in good condition • No cracks or damage	• Conservation is missing in some places • Minor damage without consequence • Minor cracks in brick work • Local patching may be effective	• Some leaching • No threat of collapsing • Conservation is missing in some places • Damage without consequence • Minor cracks in brick work • Beginning decay, deterioration • Preventive actions should be taken • Further investigation required	• Extreme leaching • Threat of collapsing • Conservation is missing in multiple places • Damage with possible consequence • Cracks in brick work • Decay, deterioration • Preventive and corrective actions should be taken • Further investigation required
Image			
• Clean, no pollution or contamination • No deformations • Brick work in perfect condition	• Minimum pollution or contamination • Minimum deformation • Minor cracks in brick work	• Contamination or pollution • Some moss and/or vegetation • Deformations • Cracks in visible brick work	• Extreme contamination or pollution • Extreme moss and/or vegetation • Extreme deformations • Cracks and holes in brick work and other quay wall components
Societal importance			
• Highly accessible for traffic (pedestrians, motor vehicles, boats)	• Good accessible for traffic (pedestrians, motor vehicles, boats)	• Moderately accessible for traffic (pedestrians, motor vehicles, boats)	• Badly accessible for traffic (pedestrians, motor vehicles, boats)

D.2 COSTS AND BENEFITS

D.2.1 Benefits

D.2.1.1 Total benefits

The total benefits (TB) that represent the presence and performance of inner-city quay walls in relation to the quality of public urban areas is stated as in *Eq. 2* and *Eq. 3*.

$$TB = LIV + ACC + REC + S\&H \qquad \text{Eq. 2}$$

With:

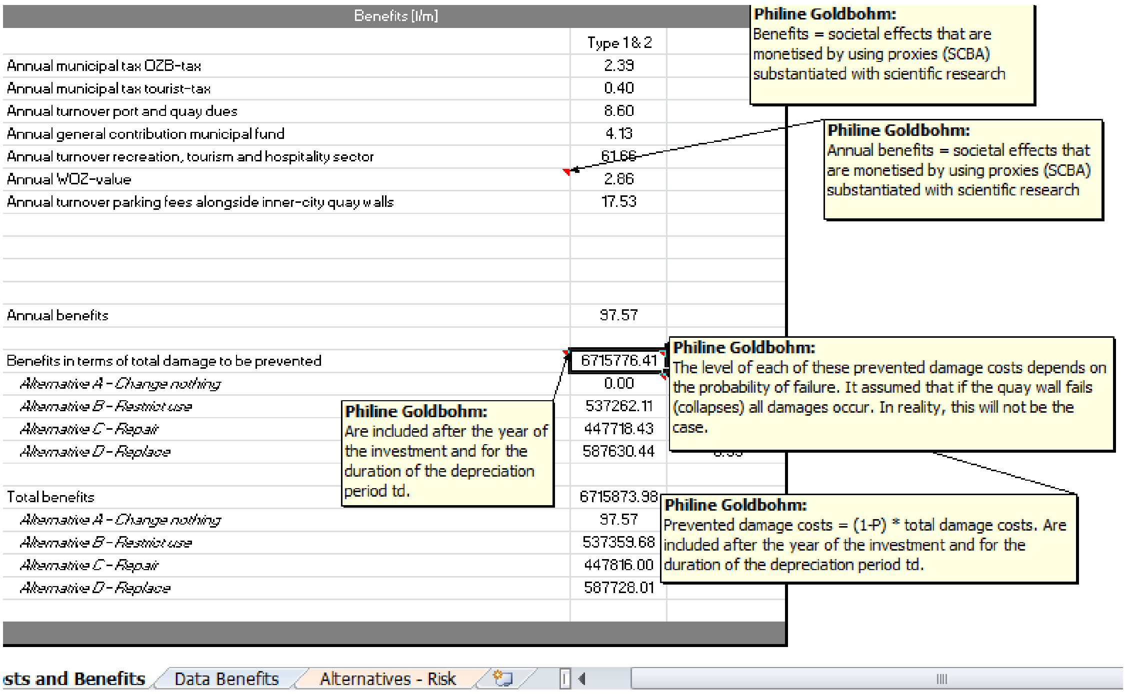
- *LIV* — *Liveability* — *[-]*
- *ACC* — *Accessibility* — *[-]*
- *REC* — *Recreation* — *[-]*
- *S&H* — *Safety and Health* — *[-]*

$$TB = GT + GC + PQ + TR + WOZ + PF + PD \qquad \text{Eq. 3}$$

With:

- *TB* — *Total benefits* — *[€/m]*
- *GT* — *General taxes: OZB (property tax) and tourist tax* — *[€/m]*
- *GC* — *General contribution Municipal Fund* — *[€/m]*
- *PQ* — *Port and quay charges* — *[€/m]*
- *TR* — *Turnover recreation, tourism and hospitality sectors* — *[€/m]*
- *WOZ* — *WOZ (property value)* — *[€/m]*
- *PF* — *Parking fees* — *[€/m]*
- *PD* — *Prevented damage costs* — *[€/m]*
    - *Prevented replacement costs* — *[€/m]*
    - *Prevented water damage costs* — *[€/m]*
    - *Prevented personal damage* — *[€/injury/m]*
    - *Prevented personal damage* — *[€/death/m]*

FIGURE 32 shows the benefits associated with managing inner-city quay walls as a sub-module 'Costs and Benefits' of the model.



Benefits [l/m]	Type 1& 2
Annual municipal tax OZB-tax	2.39
Annual municipal tax tourist-tax	0.40
Annual turnover port and quay dues	8.60
Annual general contribution municipal fund	4.13
Annual turnover recreation, tourism and hospitality sector	61.66
Annual WOZ-value	2.86
Annual turnover parking fees alongside inner-city quay walls	17.53
Annual benefits	97.57
Benefits in terms of total damage to be prevented	6715776.41
Alternative A - Change nothing	0.00
Alternative B - Restrict use	537262.11
Alternative C - Repair	447718.43
Alternative D - Replace	587630.44
Total benefits	6715873.98
Alternative A - Change nothing	97.57
Alternative B - Restrict use	537359.68
Alternative C - Repair	447816.00
Alternative D - Replace	587728.01

FIGURE 32: Benefits associated with managing inner-city quay walls as part of public urban areas.

TABLE 12: Relation-matrices from management strategies → inner-city quay wall functions → quality criteria → benefits public urban area.

		Inner-city quay wall function						
		Retaining	Load-bearing	Storage	Mooring	Traffic	Environment	Impact depends on..
Management strategy	Alternative A - Change nothing	-	-		-		-	..nature and effect of management strategy on degradation mechanism(s) inner-city quay wall
	Alternative B - Restrict use	-	-		-		+	
	Alternative C - Repair	+	+		+		+	
	Alternative D - Replace	++	++		++		++	

		Quality ambition						
		Safety & Health	Functionality	Image	Societal importance	Affordability		Impact depends on..
Inner-city quay wall function	Retaining	++	++	+	+	+		...performance level inner-city quay wall in primary and secondary functions
	Load bearing	++	++	+	+	+		
	Storage							
	Mooring	++	++	+	++	+		
	Traffic							
	Environment	+	+	++	++	+		

		Benefits public urban area						
		General Taxes	Quay and port charges	General contribution Municipal Fund	Functional capacity and traffic safety	Living comfort or Settlement comfort	Recreation	Impact depends on..
Quality criterion	Safety & Health	+	+	+	+	+	+	...quality perception (appreciation quality criteria) of actors and duration of effect
	Functionality	+	+	+	+	+	+	
	Image	+	+	+	+	++	++	
	Societal importance	+	++	+	+	++	++	
	Affordability	+	+	+	+	0	0	

TABLE 13: Identification of effects of management strategies.

Physical effect	Prosperity effect	Real estate (property) price	Monetising through	Management strategy			
				Alternative A	Alternative B	Alternative C	Alternative D
				Change nothing	Restrict use	Repair	Replace
Spatial quality	Living comfort value	yes	Property value existing houses	=	+	++	+
	Settlement value	yes	Property value existing houses	=	+	+	+
	Recreation value	yes	Property value hospitality and retail sector	=	+	+	+
			Turnover data	=	+	+	+
	Recreational amenity value	no	Willingness to pay	-	+	+	+
Cultural heritage	Living comfort value	yes	Property value existing houses	=	+	+	--
	Settlement value	yes	Property value existing houses	=	+	+	--
	Recreation value	yes	Property value hospitality and retail sector	=	+	+	-
			Turnover data	=	-	+	-
	Recreational amenity value	no	Willingness to pay	-	+	+	-
	Philantropical values	no	-	=	+	+	-
	Inheritance values	no	Willingness to pay	=	+	+	-
	Existance values	no		=	+	+	-
Accessibility	Travel time	no	Travel time savings or delays	-	--	-	-
	Traffic safety	no	Prevented damage	--	+	+	+
Tourism	Recreation value	yes	Property value hospitality and retail sector	=	+	+	-
			Turnover data	=	+	+	-
	Recreational amenity value	no	Willingness to pay	=	+	+	-
Maintenance and construction period	Nuisance during maintenance and construction activities	no	Prevented damage or damage claims	++	-	-	--
Safety	Traffic safety	no	Prevented damage	--	+	+	++
Functionality (reliability, availability, maintainability) (among others: change in water management)	Bearing capacity	no	Prevented damage	-	--	+	+
	Retaining capacity	no	Prevented damage	-	-	+	+
	Mooring capacity	no	Prevented damage	-	--	+	+
Ecology or environment	Ecological value	no	Prevented damage	=	=	-	-
Legend: ++ major benefit + benefit = constant - cost -- major cost							

D.2.1.2 General taxes and WOZ-value

Annually, the municipality collects a number of legally approved municipal taxes specified as per municipality. The benefits of general taxes are the input for general means of the municipality. The municipality can decide for which purposes these means can be used. Examples of general taxes are property taxes (OZB), parking taxes and tourist taxes. The specifications of these taxes and associated levels can be found in the municipal database of the CBS. The legal foundation for these charges has been stipulated in the 'Municipality Act' (Dutch: 'Gemeentewet').

As stated before, the WOZ-value is reflected in the annual OZB-tax and therefore it is stated that the quality of the public urban area contributes to the municipal benefits derived from general taxes. The WOZ value depends on different aspects, such as surface, location, lay-out and sales figures regarding similar properties. Each year, the WOZ-value is determined for both residential houses and commercial properties. The municipalities are free to determine the OZB-level as percentage of the WOZ-value (to a maximum: macro standard OZB) (*Eq. 4*).

$$OZB = \cdots \% * WOZ \qquad \text{Eq. 4}$$

With:

-	*OZB*	*Property tax*	*[€/year]*
-	*WOZ*	*Property value*	*[€]*

The WOZ-value for waterfront properties directly connected to the presence of inner-city quay walls, is approximately15% (10% to 40%) higher than comparable properties without this view(Brouwer, Hess, Wagtendonk, & Dekkers, 2007; Dammers et al., 2005; de Boer, 2001). Berkenbosch and Koetsenruijter (2012, p. 31) define several benefit key figures that can be used for calculation of benefits in public urban areas in terms of change in quality level. To monetise the living comfort of the public urban area, *Eq. 5* may be used (Berkenbosch & Koetsenruijter, 2012, p. 32).

$$LIV = \frac{(n * \ \Delta Q * \Delta WOZ * WOZavg)}{20} \qquad \text{Eq. 5}$$

With:

-	*LIV*	*Liveability*	*[€/year]*
-	*N*	*Number of properties with view over …*	*[-]*
-	*ΔQ*	*Quality level increase*	*[-]*
-	*ΔWOZ*	*Increase WOZ per quality level increase*	*[%]*
-	*WOZ*	*Average WOZ*	*[€]*

The tourist tax relates to the quality of the public urban area in terms of number of visitors and tourists; the municipalities are however free to determine the level of both taxes. This research assumes that benefits of tourist taxes are generated in the public urban area of the municipality (*Eq. 6* and *Eq. 7*).

$$TTpa = n * \ \Delta t * TT \qquad \text{Eq. 6}$$

With:

-	*TTpublic area*	*Tourist tax i.r.t. public urban area*	*[€/year]*
-	*n*	*Number of tourists*	*[-/years]*
-	*Δt*	*Duration of stay per visitor*	*[hrs]*
-	*TT*	*Tourist tax*	*[€/visit]*

$$TTiqw = n * \ \Delta t * TT * \frac{Aiqw}{Apa} \qquad \text{Eq. 7}$$

With:

-	*TTiqw*	*Tourist tax i.r.t. inner-city quay wall*	*[€/year]*
-	*n*	*Number of tourists*	*[-/years]*
-	*Δt*	*Duration of stay per visitor*	*[hrs]*
-	*TT*	*Tourist tax*	*[€/visit]*
-	*Aiqw*	*Area inner-city quay wall*	*[m^2]*
-	*Apa*	*Area public urban area*	*[m^2]*

D.2.1.3 Port and quay charges

Inner-city quay walls also contribute to the quality of public urban areas by providing an area to moor and transfer goods and/or people from water to land and vice versa. If a ship berths at a port designated for public service, the Harbour Master collects harbour dues. If an inner-city quay wall intended for public services is temporarily used to load or unload, quay charges should be paid. The legal foundations for these charges are stipulated in the 'Municipality Act' (Dutch: 'Gemeentewet') (Loqius, 2015).

The retaining, load-bearing, storage, traffic and mooring capacity of an inner-city quay wall determines the maximum dimensions of the ships that are allowed to berth. These dimensions affect the port and quay charges. Port charges are calculated taking into account the ship's load capacity, surface and length overall (LOA). Quay charges depend on the volume of transferred goods. The benefits that are annually generated in terms of quay and port charges depend on the amount and types of ships that are annually 'processed' by inner-city quay walls.

This results in the following *Eq. 8* and *Eq. 9*.

$$Qqw = n * \ V * \rho * Q \qquad \text{Eq. 8}$$

With:

- *Qiqw* — *Quay charges quay walls* — *[€/year]*
- *n* — *Number of operational hours* — *[hrs/year]*
- *V* — *Volume of transferred goods* — *[m³]*
- *ρ* — *Occupancy rate* — *[-]*
- *Q* — *Quay charge* — *[€/ship]*

$$Pqw = \sum_{i=1}^{n} L * \Delta t * \rho * P \qquad \text{Eq. 9}$$

With:

- *Piqw* — *Tourist tax i.r.t. quay wall* — *[€/year]*
- *n* — *Number of ships* — *[-/year]*
- *L* — *Length overall ship* — *[m]*
- *Δt* — *Dwell time* — *[days/year]*
- *ρ* — *Occupancy rate* — *[-]*
- *P* — *Port charge* — *[€/ship]*

The capacity factors of inner-city quay walls can be divided into physical factors, directly associated with design, and operational factors which depend on the functioning of inner-city quay walls.

A more superficial approach of the benefits that are actually generated through quay and port charges uses the annual benefits that are collected by the municipality and allocate them to the length of inner-city quay wall (*Eq. 10*):

$$PQiqw = \frac{(Piqw + Qiqw)}{Liqw} \qquad \text{Eq. 10}$$

With:

- *PQiqw* — *Port and quay charges inner-city quay walls* — *[€/year]*
- *Piqw* — *Port charges* — *[€/year]*
- *Qiqw* — *Quay charges* — *[€/year]*
- *Lqw* — *Length inner-city quay wall* — *[m]*

D.2.1.4 General contribution Municipal Fund

The general contribution from the Municipal Fund to a particular municipality depends on an allocation formula. This formula looks at considers different municipal characteristics and tax capacity, and the extent to which a municipality can annually collect annual taxes. There are more than sixty standards according to which the National Government distributes the Municipal Fund over the municipalities. The general contribution can be used for different purposes; however, justification at the municipal council is required. The specifications and level of this annual contribution can be found in the municipal database of the Centraal Bureau voor de Statistiek (CBS). As the quality of the public urban area affects the municipal tax capacity, in terms of WOZ-value and thereby OZB-value, there is a relation between the general contribution from the Municipal Fund and the quality of the public urban area. In this research, it is assumed that the contribution is defined by means of surface-ratio (*Eq. 11*):

$$GCiqw = GC * \frac{Aiqw}{Apa} \qquad \text{Eq. 11}$$

With:

- *GCiqw* — *General contribution Municipal Fund inner-city quay walls* — *[€/year]*
- *GC* — *General contribution Municipal Fund* — *[€/year]*
- *Aiqw* — *Area inner-city quay walls* — *[m²]*
- *Apa* — *Area public urban area* — *[m²]*

D.2.1.5 Turnover recreation, tourism and hospitality sectors

The quality of public urban areas affects the recreation value that is experienced by the users of these areas. This can be monetised using the touristic and recreational expenditures or the turnover that is generated by the sectors of recreation, tourism and hospitality (*Eq. 12*).

$$RECiqw = n * \Delta t * (Eavg\ (R + H + O)) * \frac{Aiqw}{Apa} \quad \text{Eq. 12}$$

With:

- *RECiqw*	*Recreation value inner-city quay walls*	*[€/year]*
- *n*	*Number of visits*	*[-/year]*
- *Δt*	*Average duration of stay*	*[hrs/stay]*
- *Eavg*	*Average expenditures per visit*	*[€/visit]*
- *R*	*Retail sector*	*[%]*
- *H*	*Hospitality sector*	*[%]*
- *O*	*Other sectors*	*[%]*
- *Aiqw*	*Area inner-city quay walls*	*[m^2]*
- *Apa*	*Area public urban area*	*[m^2]*

This research assumes that inner-city quay walls contribute to the quality of public urban areas which can be expressed in terms of recreation value. In order to identify the actual contribution of inner-city quay walls to the quality of a public area, at least two municipalities should be compared: one municipality with inner-city quay walls as part of a public area and one municipality without inner-city quay walls as part of a public area.

D.2.1.6 Parking fees

Inner-city quay walls often provide area for parking vehicles, alongside the canals. The benefits derived from issuing parking permits can be calculated using the number of permit holders and the price of a parking permit (*Eq. 13* and *Eq. 14*). The composition of these permit-holders and the price-level of the permits are variable over time. This should be taken into account. Determining the parking benefits derived from parking visitors is more complicated, because of the number of parking visitors, average parking time and average parking fee, the size and composition of the visitors' vehicle-fleet.

$$PF = n * \Delta t * PFavg * 365 \quad \text{Eq. 13}$$

With:

- *PF*	*Parking fees*	*[€/year]*
- *n*	*Number of parking visits*	*[visits/24hrs]*
- *Δt*	*Average parking time*	*[hrs/visit]*
- *PFavg*	*Average parking fee*	*[€/24hrs]*

$$PF = (np * PFp + nb * PFb) * (\frac{niqw}{npa}) \quad \text{Eq. 14}$$

With:

- *PF*	*Parking fees*	*[€/year]*
- *np*	*Number of parking permits private*	*[-]*
- *PFp*	*Parking fees private*	*[€/permit/year]*
- *nb*	*Number of parking permits business*	*[-]*
- *PFb*	*Parking fees business*	*[€/permit/year]*
- *niqw*	*Number of parking areas along inner-city quay walls*	*[-]*
- *npa*	*Number of parking areas public urban area*	*[-]*

Inner-cities do have complicated parking regulations. Therefore, it is often difficult to determine an unambiguous benefit function. It should be taken into consideration that an inner-city parking system consists of different types of parking areas with associated permits. The required differentiation between these types will be challenging.

D.2.1.7 Prevented damage cost

The influence of the alternatives on the functional capacity of the quay wall(s) are monetised by taking the (prevented) damage cost by executing a management strategy into account. The 'willingness to pay' for an increase in safety can be determined using the "Value Of a Statistical Life" (VOSL), which is defined as the ratio of the monetary value of decrease in mortality rate and the decrease of annual probability (Kind, 2011, p. 40). Estimations of the VOSL are derived through questionnaires or actual behaviour of individuals in situations with mortality risk. The VOSL in European studies vary between €2 million and €14 million. The bandwidth is large due to statistical uncertainty and context-dependency. The value is dependent on terms that are also used in a risk-context: individual controllability, manner of death, scale and initial probability. In case of water safety, the research of Kind (2011, pp. 42,47) resulted in an average VOSL of €6.7 million (bandwidth of €1.4 million to €11.3 million). For immaterial damage due to evacuations or non-replaceable possessions €12 000 for each victim is estimated.

The reducing effect of the management strategies on the damage cost for the surrounding properties, due to functional failure of the inner-city quay walls, can be calculated using *Eq. 15* (Kind, 2011; Ten Veldhuis, 2010).

$$DAM = \Delta P * (nh * DAMh + nb * DAMb + DAMpa) \quad \text{Eq. 15}$$

With:

- *DAM* — *Prevented damage* — *[€]*
- *ΔP* — *Decrease probability* — *[-]*
- *nh* — *Number of houses* — *[-]*
- *DAMh* — *Damage per house* — *[€/house]*
- *nb* — *Number of businesses* — *[-]*
- *DAMb* — *Damage per business* — *[€/business]*
- *DAMpa* — *Damage public area* — *[€]*

D.3 RISKS

D.3.1 Project risks

Despite the fact that the condition of an inner-city quay wall is (positively) affected by the execution of a maintenance alternative, this execution entails also risks. The key objectives of (maintenance) projects are determined in the scope in terms of quality, time and cost. During a project, these objectives are dynamically endangered due to unexpected changes from stakeholders, technical problems or staffing changes. Furthermore, safety and health and legal (and financial) issues are taken into account while considering the execution of a maintenance alternative. Additionally, plotting the identified (and quantified) risks in a risk matrix facilitates the definition of risk acceptation levels and the possible risk-response (avoid, reduce, accept, transfer).

The risk matrix in TABLE 14 provides an understanding of some of the risks that can be encountered during the execution of projects (Appendix C).

TABLE 14: Simplified risk register ((S. van den Assem, J. Brinkman, L. de Jong, C. Krstulovic, & M. Lugten, 2013, p. 33)).

Category	Causes	Risk events	Consequence	Objectives	Probability	Impact
Social	No analysis of public interests	Public opposition	Project delay	Time and Costs	M	L-M
Social	No analysis of political interests	Political opposition	Project delay	Time, Costs and Legal	M	M-H
Organisational	Contrary interests	Internal conflicts	No smooth process	Time and Costs	H	L
Organisational	Lack of experimental data	Incorrect time and cost schedules. Results do not meet expectations	Necessary adjustments during project	Time, Costs and Quality	H	M
Organisational	No HSEQ-plan at the work floor	Accidents and injuries during project	Lives are endangered and there may be a shortfall of employees and major claims	Health and Safety and Costs	L	H
Organisational	Injuries, bankruptcy and strikes	Shortfall of employees	Project delay	Time and Costs	L	L
Organisational	Lack of communication and control between executing team and managing team. Errors in planning	Delay in equipment-supply	Project delay	Time and Costs	H	M
Organisational	Contractor has	Bankruptcy of	Project delay	Time, Costs	L	H

	unstable organisational conditions	contractor		and Legal		
Technical	Lack of communication and control between executing team and managing team. Errors in planning	Construction errors	Project delay and quality decrease	Time, Costs and Quality	M	H
Technical	Lack of quality control	Final result does not meet PoR	Necessary adjustments during or after project	Time and Quality	L	M
Financial	Financial crisis	Cutbacks in funding	Less budget for the execution of the maintenance project	Time, Costs, Quality and Legal	H	H
Financial	Incorrect budget estimation	Higher cost than estimated budget	Less budget for the execution of the maintenance project and possible budget overrun	Time, Costs and Quality	M	L-M
Environment	Geographical location and climate	Extreme weather conditions	Project delay and high costs	Costs and Quality	M	M-H

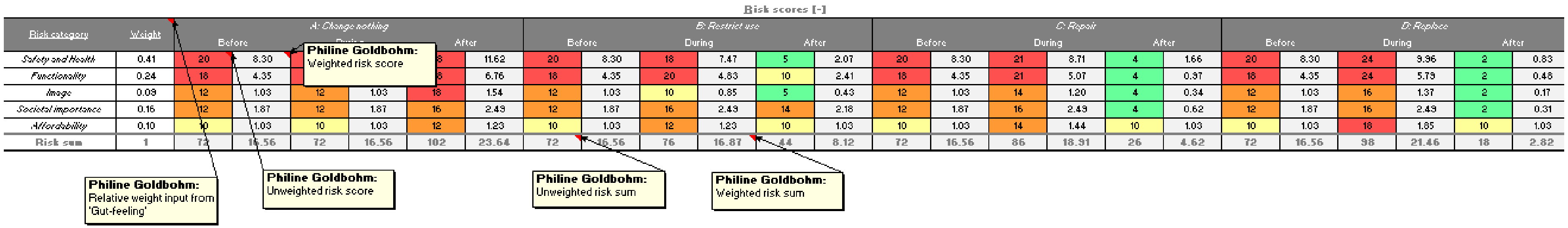
D.3.2 Mapping of asset in risk matrix

After determining the relative weight of the quality criteria ('knowledge and experience'), the relevant quay wall can be plotted into the risk matrix based on its assessed condition regarding these criteria and the expected effects of expected (un)desirable events.

- A possible instrument to analyse this is the Failure Mode Effect Criticality Analysis (FMECA). This FMECA enables the explication and measurement of failures and associated consequences by scoring them. The FMECA is an extension of the Failure Mode and Effect Analysis (FMEA) with the inclusion of criticality analyses (Rausand, 2004). Risks can be made measurable and comparable by using the FMECA.
- It is evident that the largest risk is caused by the product of the largest impact and the largest probability. The acceptation level is dependent on the decision-maker and can be determined numerically. It should be noted that each criterion can have another acceptation level; this is also dependent on the relative weighting (TABLE 15). The risk-approach consists of avoiding, reducing, accepting or transferring. The management strategies can be considered as different risk approaches.
- For each criterion, the unweighted risk score and weighted risk score before performing maintenance ($risk_{before}$) can be determined for the quay wall (asset), by estimating the possible consequences of undesirable events regarding that particular object and its surroundings. The risk score is a quantifiable variable and provides a relative value. The risk scores per criterion can be summarized, resulting in the (un)weighted risk score sum before ($risk\ sum_{before}$).
- Subsequently, the possible maintenance strategies and activities result in a (un)weighted risk score during ($risk_{during}$) for each criterion and a (un)weighted risk sum during ($risk\ sum_{during}$).
- Finally, the (un)weighted risk score after performing maintenance ($risk_{after}$) is determined. Again, the risk scores can be summarised and this results in the (un)weighted risk score sum after ($risk\ sum_{after}$).
- The management strategies are ranked according to (un)weighted $risk\ sum_{before}$, $risk\ sum_{during}$ and $risk\ sum_{after}$ (FIGURE 33 and TABLE 16).
- Finally, the (un)weighted Δ risk sum is determined that is the difference between the (un)weighted risk sum after and (un)weighted risk sum before. A more negative number implies a larger risk reduction. Furthermore, the risk analysis can provide extra input for determination of the costs and benefits (by means of a local SCBA).

TABLE 15: Risk matrix regarding inner-city quay walls.

Impact		Consequence for quality aspects					Probability							
		Safety and Health	*Functionality*	*Prestige*	*Societal importance*	*Affordability*	> 25 years	< 25 years	< 15 years	< 10 years	< 5 years	< 1 year	< 3 months	< 1 month
	Negligible	Failure results directly or indirectly in accidents with non-permanent personal injury and no personal absence	Impairment element function but not primary object functions	Negligible consequences for flora and fauna and living environment	No effects	< €10 000								
	Negligible	In term personal health-nuisance	Short-term nuisance regarding primary object functions. No nuisance regarding system and network functions*	Complaints										
	Negligible		Local repair easy to perform				1	2	3	4	5	6	7	8
	Limited	Failure results directly or indirectly in accidents with non-permanent personal injury with medical assISTance	Impairment primary object functions but not system and network functions*	Limited consequences for flora and fauna (damage generic species) and living environment, no action required	Limited nuisance, short and quick recovery 1-12 h	€10 000 - €50 000								
	Limited	In term temporary personal health-nuisance	Nuisance regarding system is shorter than lower limit	Local loss or municipal loss of image	Minor economic damage									
	Limited		Repair with extra effort				2	4	6	8	10	12	14	16
	Large	Failure results directly or indirectly in accidents with permanent personal injury	Impairment system and network function*	Large consequences for flora and fauna (damage limited rare species) and living environment, actions required	Substantial or persISTent nuisance, recovery 12-48 h	€50 000 - €500 000								
	Large		Nuisance regarding system is between lower and upper limit	Regional loss of image	Municipal economic damage									
	Large		Repair with a lot of extra effort				3	6	9	12	15	18	21	24
	Grave	Failure results directly or indirectly in accidents with permanent (multiple-personal) or fatal personal injury	Impairment system and network functions*	Grave and prolonged consequences for flora and fauna (damage rare species) and living environment, large-scale actions required	Extreme or persISTent nuisance, recovery > 48 h	> €500 000								
	Grave		Nuisance regarding system is longer than upper limit	National loss or international loss of image	Major economic damage									
	Grave		Large-scale replacement											
Impact	*Grave*		*system and network functions: motor- and waterway traffic, recreation, water management etc.				4	8	12	16	20	24	28	32



Risk scores [-]

Risk category	Weight	A: Change nothing						B: Restrict use						C: Repair						D: Replace					
		Before		During		After		Before		During		After		Before		During		After		Before		During		After	
Safety and Health	0.41	20	8.30	[illegible]	[illegible]	[illegible]	11.62	20	8.30	18	7.47	5	2.07	20	8.30	21	8.71	4	1.66	20	8.30	24	9.96	2	0.83
Functionality	0.24	18	4.35	[illegible]	[illegible]	[illegible]	6.76	18	4.35	20	4.83	10	2.41	18	4.35	21	5.07	4	0.97	18	4.35	24	5.79	2	0.48
Image	0.09	12	1.03	12	1.03	18	1.54	12	1.03	10	0.85	5	0.43	12	1.03	14	1.20	4	0.34	12	1.03	16	1.37	2	0.17
Societal importance	0.16	12	1.87	12	1.87	16	2.49	12	1.87	16	2.49	14	2.18	12	1.87	16	2.49	4	0.62	12	1.87	16	2.49	2	0.31
Affordability	0.10	10	1.03	10	1.03	12	1.23	10	1.03	12	1.23	10	1.03	10	1.03	14	1.44	10	1.03	10	1.03	18	1.85	10	1.03
Risk sum	1	72	16.56	72	16.56	102	23.64	72	16.56	76	16.87	44	8.12	72	16.56	86	18.91	26	4.62	72	16.56	98	21.46	18	2.82

FIGURE 33: Risk matrix with (un)weighted risk scores and (un)weighted risk sums.

TABLE 16: Risk matrix with (un)weighted risk scores and (un)weighted risk sums.

Risk scores [-]																									
Risk category	Weight	A: Change nothing						B: Restrict use						C: Repair						D: Replace					
		Before		During		After		Before		During		After		Before		During		After		Before		During		After	
Safety and Health																									
Functionality																									
Image																									
Societal importance																									
Affordability																									
Risk sum																									

E. ANALYTICAL HIERARCHICAL PROCESS (AHP)

AHP and ANP are essentially ways to measure especially intangible factors by using pairwise comparisons with judgments that represent the dominance of one element over another with respect to a property that they share (Chung et al., 2005). The Analytic Network Process is a generalisation of the Analytic Hierarchy Process. While the AHP represents a framework with a unidirectional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and attributes (Yüksel and Dağdeviren, 2007).

E.1 PRIORITISATION METHODOLOGY

In order to determine the importance of the different quality aspects, multiple criteria-weighting models are be used. These are divided in monetary evaluation methods, overview tables and multi-criteria evaluation methods (MCE) (Broesterhuizen, 2012)(TABLE 17).

TABLE 17: Characteristics evaluation methods (Broesterhuizen, 2012, p. 82).

Method	Applicable	Transparent	Flexible	Stable	Effective	User-friendly
CBA and CEA	Only to monetary criteria	Standardised method with logical and simple calculations. Shadow prices can affect transparency	Simple calculation results in flexibility	Standardisation results in stability if shadow prices are correctly determined. Correlation between different criteria is possible	Focused on costs and benefits and efficiency	Simple and short calculation
(Balanced) Score Card	To all criteria	Clear overview, no calculations	Flexible due to simplicity	Difficult comparison between criteria. Correlation between different criteria possible	Balance between criteria is difficult to assess	No quantitative output possible
Weighted Summation Method	To all criteria	Clear overview despite of calculations	Deleting or adding criteria affects entire calculation	Correlation between different criteria possible	Weight factors result sometimes in dis-balance of effects	Simple and clear calculation
Permutation Method	To all criteria	Clear understanding of relative differences between alternatives	Deleting or adding criteria affects entire calculation	Correlation between criteria possible	Limited disadvantageous effect weight factors by using preference sequences	In case of multiple alternatives many calculations required
Concordance Analysis	To all criteria	Relatively comprehensible, multiple calculations	Deleting or adding criteria affects entire calculation	Correlation between criteria possible	Disadvantage weight factors	In case of multiple alternatives many calculations required
Saaty-Method (AHP-Method)	To all criteria	Mathematical method	Deleting or adding criteria affects entire calculation	Output dependent on assessment of effects of alternatives	Information-loss by compensation of strong characteristics of alternatives i.r.t. weak characteristics	Relatively simple to execute
Multi-Dimensional Scale Method	To all criteria	Complex optimisation process	Adding criteria results in new dimensions	Complexity makes sensitivity analysis difficult. No correlation	Reliable output	Complex optimisation process
-- = -2, - = -1, +/- = 0, + = 1, ++ = 2						

TABLE 18 offers the assessment of the different evaluation methods. The monetary methods score relatively 'good' to 'very good', except for the applicability. In order to decide on the different maintenance alternatives a monetary method (CBA for example) can be combined with another method, such as the AHP-method. There is, however, always a correlation between different criteria which is difficult to eliminate. Additionally, each method has its inaccuracies because it is an approximation of the reality. This should be taken into account when using these types of methods in the weighting of the criteria.

TABLE 18: Assessing weighting methods (based on (Broesterhuizen, 2012, p. 83)..

Method	Applicable	Transparent	Flexible	Stable	Effective	User-friendly	Total
CBA and CEA	-	+	++	+	++	++	7
(Balanced) Score Card	++	++	++	-	--	+/-	3
Weighted Summation Method	++	+	+/-	+/-	-	+	3
Permutation Method	++	++	-	+/-	+	-	4
Concordance Analysis	++	+	+/-	+/-	+	+/-	4
Saaty-Method (AHP-Method)	++	+/-	+/-	+/-	+	+	4
Multi-Dimensional Scale Method	++	--	--	+/-	++	--	-2

E.2 AHP AND ANP METHODOLOGY

The ANP-method is a decision finding method. It can model complex decision problems, because it allows for feedback connections and loops (Saaty, 1990). This trade-off or comparison process can be used for the evaluation of different criteria and make a decision regarding optimal maintenance performance. Often, this process is based on expert knowledge and judgement of decision-makers.

Since several maintenance related objectives are interlinked and interdependent, for example reliability and availability (Kutucuoglu, Hamali, Irani, & Sharp, 2001), ANP can be used. ANP is a proven strategic decision support method that is used in many cases (Saaty, 1990, 2005). Expressing preference between different criteria in the decision problem can be reduced by allowing minor inconsistency in pairwise comparisons. The consistency of the decision maker is checked by calculating a consistency ratio. Furthermore, interdependence between criteria is taken into account. Additionally, ANP uses pairwise comparisons to derive priorities amongst the considered criteria in the decision process.

The ANP methodology is applied through the following steps (Kutucuoglu et al., 2001):

1. *Develop team of competent managers*. Since the ANP methodology uses a comparison process, group decision-making may be used to avoid a possible biased attitude of a single decision maker (Dyer & Forman, 1992). In this decision-making process, knowledge and experience of the involved managers are essential (Kutucuoglu et al., 2001; Saaty, 2005).

2. *ANP network and problem formulation*. In the ANP methodology, which is an extension of the AHP (analytical hierarchy process), the decision-problem is transformed into a network structure (Van Horenbeek & Pintelon, 2014). The network structure is based on the comprehension of the decision problem and the different relations between the decision factors. The goal of the decision problem is to find, based on the network structure, the most important maintenance objectives (performance requirements) for a specific 'business' environment. The proposed generic network structure serves for assisting decision makers. It is customizable to the specific 'business' environment of an organisation through adjusting the elements, clusters and defined relation s in the general decision structure.

3. *Pairwise comparisons*. After the decision problem is translated into a network structure, pairwise comparisons between different clusters and elements can be performed to derive overall priorities. The decision-maker

provides a judgement from the fundamental AHP scale (i.e. a ratio scale of 1-9)(Saaty, 1990). In this way, two questions are answered:

- Given a criterion, which of two elements is more dominant with respect to that criterion?
- Which of two elements influences a third element more with respect to a criterion?

All comparisons should be made with regard to one criterion: the goal or control criterion of the ANP network. The number of pairwise comparisons that should be performed for an *n x n* pairwise comparison matrix equals *n x (n-1)/2*. N is the number of elements that must be compared. The pairwise comparison number can be defined as follows:

$$aij = wi/wj$$

4. *Priority vector calculations and consistency check.* After previous step of pairwise comparisons between criteria and clusters, priorities or weights for all criteria should be derived. Many methods can be used for this. However, Saaty (1990) proposes the principal eigenvector method and its uniqueness in deriving priorities form pairwise comparison matrices. The local priority factor is the unique solution to:

$$Aw = \lambda \max * w$$

A:	*matrix of pairwise comparison values*
w:	*priority vector or principal eigenvector*
λmax:	*maximum or principal eigenvalue of matrix A*

Lack of consistency in the pairwise comparisons emphasizes lack of understanding of the problem by decision-makers. This could result in wrong decisions. The consistency ratio helps checking if the judgements of decision-makers follow the logic, rather than filling in random numbers. The consistency ratio should be less than 10% (or 0.1) and is defined as follows (Saaty, 1990). In case of a higher consistency ratio, the decision-makers should fine-tune their pairwise comparisons.

$$CR = \frac{CI}{RI} < 0.1$$
$$CR = \lambda \max - \frac{n}{n-1}$$

CR:	*Consistency Ratio*
CI:	*Consistency Index*
RI:	*Random Index*
n:	*size of matrix*

5. *Super-matrix formation and overall priority calculation.* A super-matrix is a two-dimensional matrix that includes all elements of the different clusters (rows and columns). It represents the influence priority of a row-element on a column-element. Each local priority vector derived from the pairwise comparisons is inserted at the right column of the super-matrix. To establish convergence, the super-matrix should be column stochastic. After normalisation a weighted supermatrix is formed. Finally, the weighted super-matrix ($W_{weighted}$) is raised to large powers (*k*), in order to reach synthesis.

$$Wlimit = \lim_{x \to \infty} (Wweighted)^x$$

$$(Wweighted)^{2k+1}$$

The resulting matrix is the limit super-matrix, which contains the global priority vector. All transitive relationships between clusters and elements in the network structure are synthesised. The global priority vector represents all effects of interdependence in the network (Kutucuoglu et al., 2001, p. 41).

F. EFFECTS OF MANAGEMENT STRATEGIES

F.1 PROSPERITY EFFECTS

F.1.1 Living comfort value

This is defined as the added value of an agreeable and attractive environment for the inhabitants, entrepreneurs, visitors and recreants. This is represented in the WOZ-value (property-value) of the houses in the inner-city of Delft. The difference in the living comfort of the project-alternatives is established through the difference in spatial quality and rehabilitation of cultural heritage. The existing houses gain a higher value through performing maintenance to the inner-city quay walls, because the presence of beautiful canals and clean quays contributes to the living comfort. For the existing houses, the differences can be determined through key figures related to the WOZ-value.

F.1.2 Settlement value

This value considers the attraction of the inner-city of Delft for potential inhabitants and entrepreneurs to settle their houses and businesses at that specific location. Also this value is represented in the WOZ-value; the more 'popular' the location, the more expensive the property. The settlements value is mainly related to commercial services and offices. For the hospitality and retail sector, this value will be elaborated as part of the recreation value. The location in the spatial network (accessibility parking areas), the spatial quality and the marketability of the business determine the property value. Therefore, the spatial quality of the inner-city public area is not the most important price indicator. Whether the business is located at or nearby the (canal) quay or not, the important thing is that it is located in the centre of Delft (Van Velzen, 2009). The presence of cultural heritage does influence the settlement value to a minor and uncertain extent.

F.1.3 Recreation value

The added value for the recreation sector; it can be seen as the settlement value for the recreation, hospitality and retail sectors. The presence of cultural heritage and 'clean'-looking quay walls should result in a higher recreation value than when absent. This value can calculated through turnover-data of the hospitality and recreation facilities at different location in the inner-city of Delft. The WOZ-value in this sector is related to turnover which can also be used as indication. It must be decided in which way the benefit will be monetised, because when both values are used it is double-counting.

F.1.4 Recreational amenity value

This is the amenity value of the recreant of the visitor and it is not market-conform. A visitor of the inner-city of Delft can enjoy his visit without spending money. An accurate indicator of this value can be the 'willingness to pay' for the visit; this is covered by the travel cost (and time). However, the recreational amenity value consists of a benefit for those who are visitors and no inhabitants of Delft. The benefits are therefore outside the scope of the local SCBA. The value does apply to the attraction of extra tourists, but these benefits are already represented in the recreation value.

F.1.5 Non-user values cultural heritage

The non-user values do only relate to the fact that the inner-city quay walls of Delft are part of 'protected cityscape' and therefore highly-potential cultural historic heritage. The maintenance of the quay walls and in particular the repair of them considers non-user values. Resistance of interest groups, inhabitants and other parties regarding the execution of maintenance activities indicate that the quay walls alongside the inner-city canals do represent an added value in the terms of non-user values. To determine these values, the Contingent Valuation Method (CVM) can be used. Due to the time and data-consuming nature of this method, the non-user values of each project-alternative will be integrated as positive Pro Memori (PM-) item. Because each alternative considers the same quay wall construction, it will be difficult to determine the mutual difference regarding cultural heritage.

F.1.6 Travel time

Due to the fact that one project-alternative (A) considers the constructional devaluation of the particular inner-city quay wall, it is plausible that the adjacent roads are narrowed or limited to a maximum speed and adjacent parking areas will be blocked. This will be disadvantageous for local traffic (congestion, no parking opportunities, and slower flow). Furthermore, all project-alternatives (0, A t/m C) consider maintenance activities that affect the traffic situation around the quay wall. However, the effects will be minim, because the current traffic condition is already pressing. Thereby, this cost item will not be monetised.

F.1.7 Traffic safety

Because the traffic condition will be improved (after a period of possible maintenance or (re)construction risks), the risk of accidents is reduced. This reduced probability can be seen as prevented damage and therefore as beneficial. However, it is assumed that all project-alternatives are intended (in order to meet legislation) to reach the same safety-level. Therefore, this benefit will not make the difference in the result and it will not be monetised. It should be noted that the execution of each project-alternatives is associated with different risks regarding the (traffic) safety. This value will be taken into account through nuisance during maintenance and construction activities.

F.1.8 Nuisance during maintenance and construction activities

Some project-alternatives consider more radical maintenance and construction activities. This results in greater inconvenience during maintenance and (re)construction. The 'costs' are for the local inhabitants and entrepreneurs and to a smaller extend for the recreants and visitors of the inner-city of Delft. Since the major part of the benefits can be assigned to these parties (inhabitants, entrepreneurs, recreants and visitors), it is decided that no benefit taxes are incurred as compensation for the nuisance. These costs are not monetised, but integrated in the SCBA as negative PM-item.

F.1.9 Functional capacity

Most project-alternatives add a positive contribution to the functional capacity of the inner-city quay walls: recovery of the load-bearing, earth- and water- retaining and mooring function. Thereby, the risk of failure is diminished. The value of this benefit can be monetised through additional prevented damage cost. It should be noted that the project-alternatives should reckon with the water management of the inner-city canals and its surroundings. The water board should be involved (consulted) in the decision-making process.

F.1.10 Ecology

The ecological value indicates the influence of the project-alternatives on the ecology or the environment. More green (flora) implies more nature and carbon fixation. It is expected that more environmentally-conscious inspection, monitoring and maintenance measures and resources could neutralise or positively affect the ecological structure of the inner-city public area of Delft. Contamination or pollution of soil, water and adjacent pavements should be prevented. Monetising this ecological benefit appears to be difficult, because there are no example-cases.

F.2 MONETISING OF EFFECTS

F.2.1 Functional capacity, traffic safety and ecology or environment – prevented damage costs

The influence of the alternatives on the functional capacity of the quay wall(s) can be monetised by taking the (prevented) damage cost by executing a project-alternative into account. To determine whether executing one of the project-alternatives makes sense, the direct repair costs associated with an undesirable event are analysed.

Briefly, it comes to repair costs in the public space which the local authority or municipality pays for undesirable events. Cost of private and individual parties are not included. For sewerage management many indicators are available in the areas of maintenance, repair and replacement of the sewage system. These numbers can be found in the "Guidelines of sewage" from RIONED (Stowa & Stichting Rioned, 2014). Also data resulting from tendered works are available via various online subscriptions. However, it appears that very little information is available for direct repair costs of various undesirable events. That is why use will be made of different cost categories for smaller or larger events (Stowa & Stichting Rioned, 2014, p. 13).

Since the project-alternatives and associated possible undesirable event(s) have more effects than only the direct repair cost, the SCBA can provide an improved understanding of the effects of nuisance for the inhabitants and entrepreneurs. For each project-alternative, including the zero-alternative, the financial (direct) and social costs (direct and indirect) for the repair of the possible occurrence of undesirable events should be determined (Stowa & Stichting Rioned, 2014). Therefore, the risk-analysis can provide input.

Besides damage to the build environment, also damages to the public area and public utilities could occur. These damages are difficult to quantify; however, roughly estimated cost categories are provided as mentioned previously. Furthermore, indirect consequent damages of water-on-the-street could occur, such as a decrease in working hours due to traffic congestion. These damages are not yet quantified. It should be noted that water-on-the-street can be caused by different (sometimes interrelated) factors such as excessive rainfall, quay wall failure (collapse) and/or a broken pipeline.

F.2.2 Living comfort or settlement value – property value

In infrastructure projects benefits are often calculated in terms of travel time savings. Area development can be translated into a largely unpredictable increase in property or real estate prices. A large amount of data regarding value development of property is available, which can be retrieved at NVM or in terms of WOZ-data at municipalities. These WOZ-values are based on surface, location and the lay-out of the building. Also the sales figures of comparable properties do play a role. It should be noted that these data are all based on past developments; key figures regarding future developments are missing. It is possible to validate the data and the influence on property value after executing a project (ex-post). However, these analyses are insufficiently executed. This complicates the determination of societal values and therefore many assumptions are done. A nationally developed framework with key figures could be helpful but also extremely complex and time consuming. Differences in property values are location-dependent.

Research suggests that properties nearby water or green in have a higher WOZ-potential than similar properties without water (+10% to +15%) and green (+4% to +30%) in their surroundings (Bade, Smid, & Tonneijck, 2011; Berkenbosch & Koetsenruijter, 2012; Dammers et al., 2005; Ruijgrok et al., 2004). Not only are the effects of the management strategies of inner-city quay walls indicated by a change in WOZ-value, the WOZ-value is also based on the presence of inner-city water in the canals. Since canals are inextricably linked with inner-city quay walls (and vice versa), the demolition of the quay walls means indirectly that the canals should be damped and that the water (storage) is removed. This will result in (Bade et al., 2007; Bade et al., 2011; J. van Rooijen, 1995): decreased WOZ-values and municipal benefits from OZB-taxes of the surrounding properties; more problems regarding (inner-city) water management, due to limited water drainage and storage; and decreased touristic and recreational attraction of the inner-city.

An increase in the living comfort value through a better spatial quality is represented in the WOZ-value. The zero-alternative and the project-alternatives should be compared in relation to the development of the WOZ-value. It can be stated that all maintenance alternatives aim to increase the spatial quality to the same level. However, each alternative can be associated with a particular increase of living comfort value through contributing to more attractive living environment in a specific way. Because it is most likely that the property-value (WOZ-value) will increase, calculation through the use of key-figures is justified. This benefit is the difference between the zero-alternative and management strategy and it will accrue mostly to the property owners; however, the municipality will receive a part of this benefit through levying OZB-tax. The benefit can be incurred once at the end of the execution of the associated project-alternative.

F.2.3 Recreation value – turnover recreational, tourist, hospitality and retail sectors

It is difficult to assess the average value-increase in terms of turnover for the hospitality and retail sector as an effect of a project-alternative, because the turnover is dependent of many different factors. It is assumed that this increase will be relatively small or even 'negligible', due to the fact that the project-alternatives do not initially consider the execution of complete area development plans, but the maintenance of a single 'asset' that is part of the inner-city public area. In this case, the local SBCA will not be a suitable instrument to monetarise or provide an accurate qualitative indication of the influence of these project-alternatives on the recreation value.

A municipality uses its characteristic, historic inner-city and its quay walls as a 'marketing-tool' to attract tourists and day-recreants. It is assumed that the project-alternatives influence this number of tourists and day-recreants, because a percentage of the recreation value can be assigned to the quay walls and their appearance. However, as stated previously, this effect will be relatively small since the total area of quay walls is approximately X% of the inner-city area. A questionnaire focussed on the reason(s) for tourists to visit the (inner) city may be used to determine the actual percentage. Monetising these benefits requires data regarding the development of the number of visitors and the movement patterns (incl. 'strolling environment'). In TABLE 19 the effects of the alternatives on the recreation value of the inner-city (quay walls), effectual after completion, are displayed. Since the effects are income-dependent they may be annually adjusted with the prosperity-growth.

TABLE 19: Effects of strategies on the recreation value of inner-city quay walls.

	Zero-alternative A	*Alternative B*	*Alternative C*	*Alternative D*
Effect on 'strolling environment'	-	-/=	+	+
Longer duration of stay visitors	-	=	+	+
Increase average expenditures per visit	-/=	=	+	+
Increase turnover	-/=	-/=	+	+

G. SIMULATION

Are municipalities with historic inner-cities, such as Delft, capable to compete with modern city-centres where less investments are needed to maintain inner-city quay walls? There are many strategies and solutions to maintain historic inner-city quay walls. The municipality of Delft is looking for the best financial and social solution for their typical situation. They could even apply for a subsidy from the National Government, but only then when they can prove that the money will be spent responsibly. The asset management framework could facilitate this process.

G.1 PERFORMANCE - 'IST' AND 'SOLL' SITUATION

Part of the infrastructural historic assets in the inner-city of Delft reach the end of their technical or functional life span. After incidents of a collapsing quay wall in Utrecht and threatening or pressing quay wall situations in Dordrecht, the municipality of Delft wants to switch from occasional (corrective) maintenance and replacement actions towards more structured (and preventive) maintenance and replacement of inner-city quay walls and other civil works. The corrective actions as consequence of calamities result in sudden and therefore unexpected investments. The municipal council and urban management face a dilemma: technical necessity versus social disruption.

G.1.1 Municipal Objectives regarding Quality Level Public Urban Areas

Municipality, Mayor and Aldermen, define the 'Vision Public Area' (Dutch: 'Visie Openbare Ruimte'). This document contains ambitions and tasks for design, construction and management of the spatial structure for the public area. The vision defines support for the three spatial structures of Delft:

- Cultural historic: the inner-city canal system, the Schie, the bosom waterways and historic routes.
- Modern: the main motor- and railways and boulevards with and without public transport routes.
- Continuous: the continuously present network of green, blue and slow traffic.

In 2009, Delft started using a new approach to inspect the performance of inner-city quay walls as to the quality of public urban areas. Quay walls and banks are combined in a civil works cluster and inspected once every five years (FIGURE 34). Thereto information from other sources, like inspections, inhabitants, entrepreneurs, other municipalities or other externals will be collected to update the performance status of these assets. These notifications are now processed ad-hoc and are not included in the municipal multi-annual budget. FIGURE 35 shows an overview of the owners of areas quays, banks and other line-objects (noise walls) in Delft. This research covers 14.3 km of quay walls that are owned by the municipality and located in the inner-city area. This is approximately 6% of the total length of quays, banks and line-objects owned by municipality (FIGURE 36). It is assumed that all existing quay walls are located in the inner-city of Delft (marked red in FIGURE 34). When determining the value of a 'random' inner-city quay wall [€/m] all inner-city quay walls are taken into consideration.

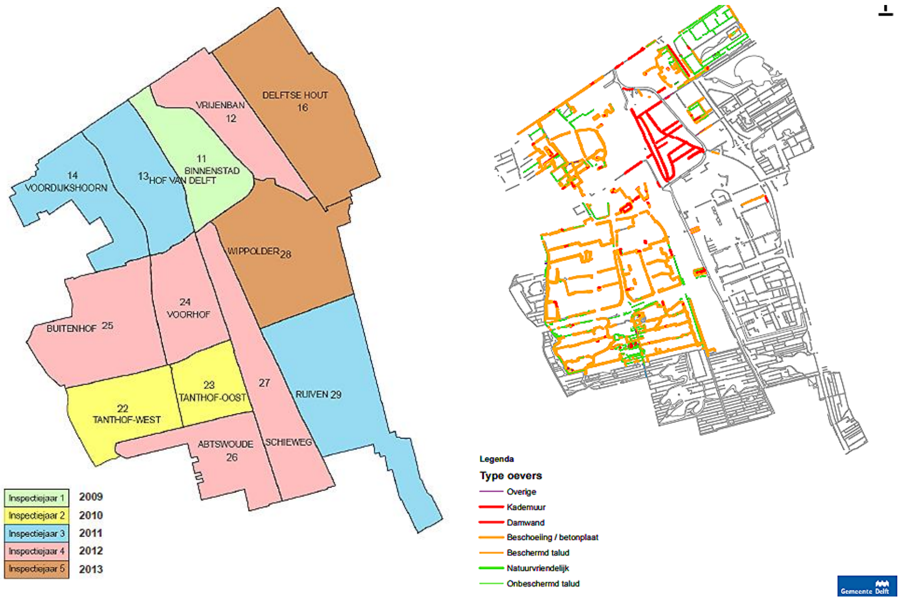


FIGURE 34: l) Inspection cycle bridges, quay walls and banks and r) Bank types in Delft (Gemeente Delft, 2012, p. 37).

Type Kade (alles in m[1])	Gemeente Delft	Derden	DSM	GGZ	GZH	HHD	Provincie Zuid-Holland	RWS	NS	TU Delft
Beschermd Talud	1.200			100	200	2.000		0		200
Beschoeiing	103.900	800	300	2.800	1.900	5.500		3.300	1.400	
Damwand	3.400	600		600	600	4.100	1.000		100	100
Gebouw		1.100								
Geluidsscherm	3.200		500					3.600		
Kademuur	14.300	400		0	700	200	1.300	1.800		
Natuurvriendelijke oever	90.300	500	1.300	2.000	2.200	1.600		5.400	3.300	700
Schanskorf - land	1.100									
Schanskorf - oever	300									
Overig/onbekend	32.100	17.000	600	500	126.000	1.900	14.000	7.800	4.300	24.400
Totaal	**249.800**	**20.400**	**2.700**	**6.000**	**131.600**	**15.300**	**16.300**	**21.900**	**9.100**	**25.400**

FIGURE 35: Overview area quays, banks and other line-objects in Delft (Gemeente Delft, 2012, p. 36).

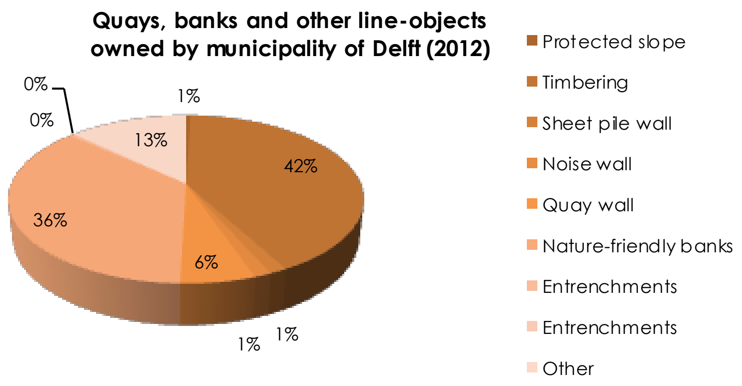


FIGURE 36: Quays, banks and other line-objects owned by the municipality of Delft.

The asset inspections result in a global assessment of the performance and remaining life time of the entire construction. The performance is also referred to as the quality and is expressed in the policy objectives (Gemeente Delft, 2012) which can be connected to the model's quality ambitions.

When it comes to major maintenance the aspects safety and sustainability are perceived as the most important. The aspect image is of particular importance in relation to monumental quay walls or quays and banks in conservation areas, such as the inner-city quay walls. To assess a quay wall, a matrix comparable with the 'performance ruler' from the asset management framework is used (TABLE 11). However, the aspect safety is represented by three quality levels and sustainability and image by four quality levels. Societal importance is not taken into consideration at all.

In the municipal document "Beheerplan Kunstwerken 2011-2014" May 2011, the municipality of Delft has formulated multiple objectives with regard to the management of civil works as part of the public area. They advocate a structured approach through prioritisation of monitoring, inspections, risks and calamities and aligning maintenance activities of different capital assets. Safety and functionality of the inner-city quay walls prevail. However, the image and accessibility of the inner-city area is of utmost importance for the economy (e.g. tourism, recreation). These aspects should meet the quality-standards that are agreed upon: A+, A, B, C or D. For the inner-city of Delft the levels A and B are desired (Gemeente Delft, 2015e).

The inner-city quay walls of Delft should perform multiple functions, such as: retaining, load-bearing, mooring, traffic, storage and environment. The extent to which these functions should be fulfilled depends on the inner-city quay wall and its surroundings.

Based on above information, the quality ambitions are weighted from the perspective of the municipality of Delft using the AHP-method. Regardless of the absence of the criteria regarding societal importance (accessibility) and affordability, these are nevertheless – for the sake of completeness - included in the asset management framework. FIGURE 37 provides an overview of the weighting of the criteria: safety and health; functionality, image, societal importance and affordability. These weights are also the weights or importance of the risk categories in the risk matrix.

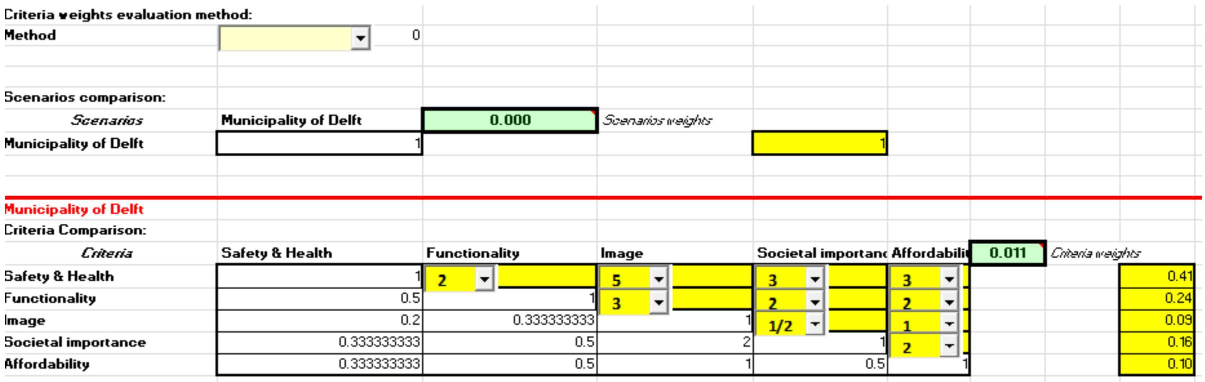


FIGURE 37: AHP - weighting of quality criteria by the municipality of Delft (using Excel, DAME 2015).

The results represent the relative 'knowledge and experience' weights expressed in value for money (VFM) (TABLE 20). As can be seen in TABLE 20, the criteria safety and health and functionality are considered to be the most important quality aspects in managing inner-city quay walls in public urban areas.

TABLE 20: Municipal relative weights of quality criteria [VFM].

Quality criterion	VFM
Safety and Health	0.41
Functionality	0.24
Image	0.09
Societal importance	0.16
Affordability	0.10
Inconsistency index < 0.10	0.011

G.1.2 'IST' Situation

The technical performance of the inner-city quay walls in respect to the quality level of public urban areas is reflected in the criteria safety and sustainability.

In the inner-city of Delft, quay walls have sustained much damage over time. This damage is generally limited to irregularities in the brick work, such as cracks, broken or missing bricks, and sloping embankments. Roots from trees along the canal or too large loads by placing trucks or waste containers on the quay have also inflicted damage. On top of that, some embankments are subject to fungi or moss. As a result, many quays in the city score poorly on safety, sustainability and wealth (image) (TABLE 21) and are eligible for major maintenance (TABLE 22).

TABLE 21: Data on safety, sustainability and image regarding quays and banks in Delft [m] (Gemeente Delft, 2012, p. 18).

Quality criterion	Unknown [m]	Very Good [m]	Good [m]	Medium [m]	Bad [m]
Safety	41400	75100	-	11600	15400
Sustainability	41500	54900	96400	41700	15400
Image	41800	68000	91600	33300	15100

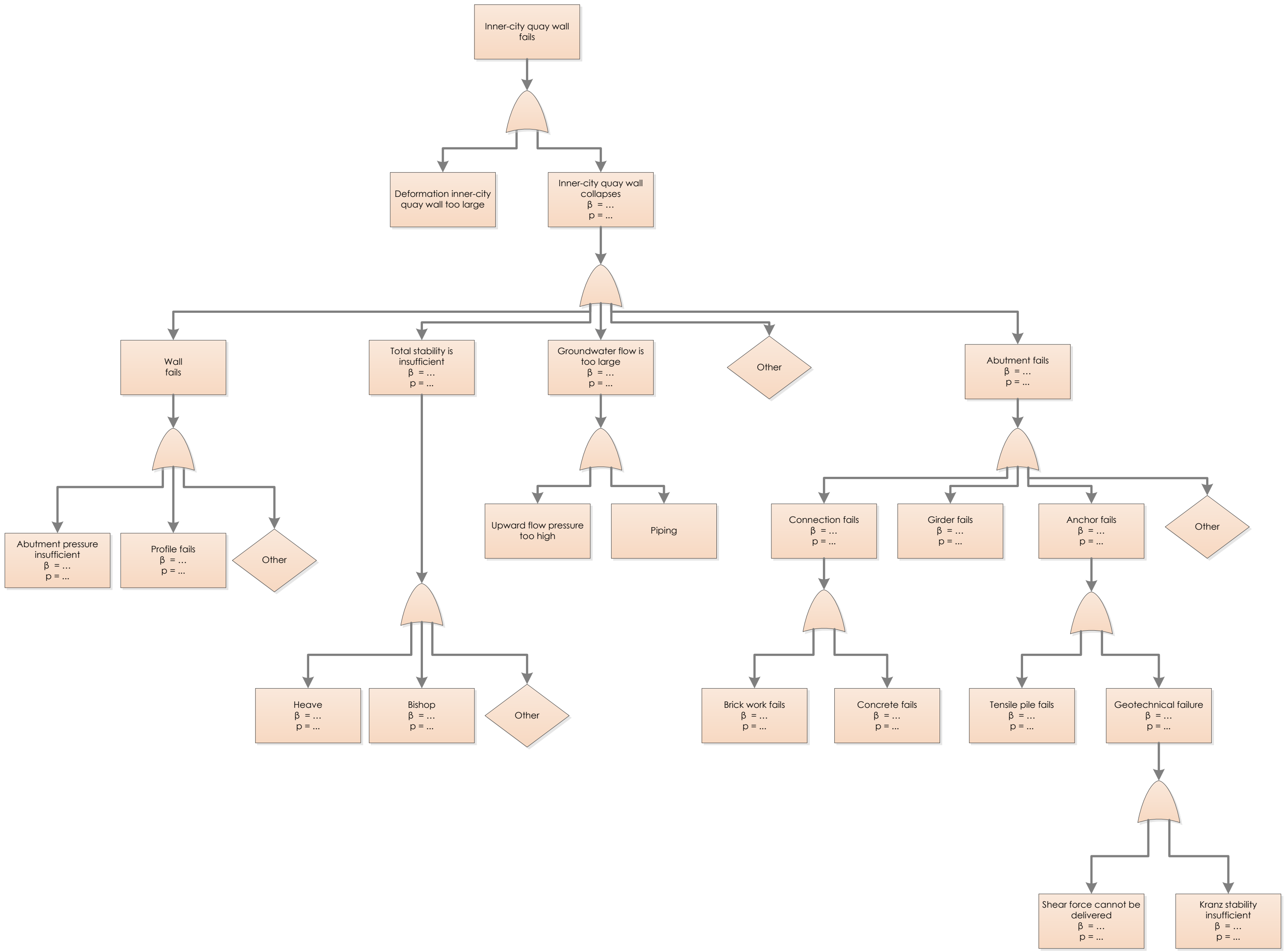
TABLE 22: Length of banks and quays eligible for major maintenance [m] (Gemeente Delft, 2012, p. 19)

Type	Length [m]
Protected slope	41400
Timbering	41500
Sheet pile wall	41800
Quay wall	4500
Nature-friendly bank	3100
Total	21500

Regular monitoring, inspection and testing of its constructional performance is required to determine risks related to a particular inner-city quay wall. Furthermore, a Failure Mode Effect Criticality Analysis (FMECA) can be performed to analyse possible technical failure mechanisms of the inner-city quay wall structure. By means of a fault tree analysis these failure mechanisms can be exposed with their probability (p) and reliability-index (β) (FIGURE 39). TABLE 29 illustrates the plotting of the 'Oude Delft', a historic quay wall alongside the canals in the inner-city of Delft.

FIGURE 38: Location 'Oude Delft' in the inner-city of Delft (Google Maps, 2015).

In 2005, 13 km of quay wall length in the inner-city of Delft has been inspected. It appeared that approximately 376 m of inner-city quay wall was in 'bad' shape of which 25 m consisted of the 'Oude Delft'(Gemeente Delft, 2008, p. 21). The risk analysis considers this length of the inner-city quay wall. Meanwhile, it should be noted that 14.3 km of inner-city quay wall length is inspected and assessed (TABLE 23 and TABLE 24).



Inner-city quay wall fails
Deformation inner-city quay wall too large
Inner-city quay wall collapses β = ... p = ...
Wall fails
Total stability is insufficient β = ... p = ...
Groundwater flow is too large β = ... p = ...
Other
Abutment fails β = ... p = ...
Abutment pressure insufficient β = ... p = ...
Profile fails β = ... p = ...
Other
Upward flow pressure too high
Piping
Connection fails β = ... p = ...
Girder fails β = ... p = ...
Anchor fails β = ... p = ...
Other
Heave β = ... p = ...
Bishop β = ... p = ...
Other
Brick work fails β = ... p = ...
Concrete fails β = ... p = ...
Tensile pile fails β = ... p = ...
Geotechnical failure β = ... p = ...
Shear force cannot be delivered β = ... p = ...
Kranz stability insufficient β = ... p = ...

FIGURE 39: Fault-tree inner-city quay wall (based on (J.G. de Gijt & Broeken, 2013, p. 628).

TABLE 23: Risk scores before implementation of management strategies incl. relative weight of quality criteria.

Risk category	Weight	*A: Change nothing*						*B: Restrict use*						*C: Repair*						*D: Replace*					
		Before		During		After		Before		During		After		Before		During		After		Before		During		After	
Safety	0.41	20	8.29					20	8.29					20	8.29					20	8.29				
Functionality	0.24	18	4.34					18	4.34					18	4.34					18	4.34				
Image	0.09	12	1.02					12	1.02					12	1.02					12	1.02				
Societal importance	0.16	12	1.87					12	1.87					12	1.87					12	1.87				
Affordability	0.10	10	1.04					10	1.04					10	1.04					10	1.04				
Weighted sum	1	72	16.6	0	0	0	0	72	16.6	0	0	0	0	72	16.6	0	0	0	0	72	16.6	0	0	0	0

TABLE 24: Risk matrix with risk scores.

		Probability							
		> 25 years	< 25 years	< 15 years	< 10 years	< 5 years	< 1 year	< 3 months	< 1 month
Impact	*Negligible*	1	2	3	4	5	6	7	8
	Limited	2	4	6	8	10	12	14	16
	Large	3	6	9	12	15	18	21	24
	Grave	4	8	12	16	20	24	28	32

G.1.3 'SOLL' Situation

A basic principle regarding the desired quality level of the public urban area and in particular quay walls and banks is to maintain these assets so that their functional use is guaranteed at the lowest possible cost. This quality level is the minimum standard for quay walls and banks.

- For a safe and sustainable living environment or public urban area the quay walls and banks should NOT score 'bad' (quality level D) in respect to safety and sustainability (Gemeente Delft, 2012, p. 18).
- For a safe and sustainable living environment or public urban area 'good' (quality level B) is desired and 'medium' (quality level C) is allowed for the inner-city quay walls and banks in (Gemeente Delft, 2012, p. 18).

Since 2011, the inner-city of Delft, the 'Agnetapark' and the 'Nieuwe Plantage' are regarded as conservation area. Banks and in particular quay walls are a large part of the public urban area. For this part of Delft a minimum guaranteed standard in respect to image has a higher priority than in other parts of Delft (Gemeente Delft, 2012).

- For a comfortable living environment or public urban area the quay walls and banks should NOT score 'bad' (quality level D) in respect to image (Gemeente Delft, 2012, p. 19).
- For a safe and sustainable living environment or public urban area 'good' (quality level B) is desired and 'medium'(quality level C) is allowed for the inner-city quay walls and banks in (Gemeente Delft, 2012, p. 18).

To establish this quality level both preventive and corrective maintenance should be performed. The quay walls that score 'bad' in respect to safety, sustainability and image are eligible for (major) maintenance. Besides these three quality criteria other quality objectives or criteria could be important for the multi-annual management plan. Postponement of maintenance endangers the utility of the quay wall or bank and could even result in a final collapse with all the associated (financial) consequences. In addition, deferred maintenance is relatively more expensive which often leads to capital destruction.

G.1.4 Boundary Conditions

The management of quay walls in Delft is limited by the following boundary conditions (Gemeente Delft, 2012, pp. 33-35):

- Wall plants are protected by the 'Nature Protection Act' (Dutch: 'Natuurbeschermingswet)', the 'Flora and Fauna Act' (Dutch: 'Flora en faunawet') and the 'Nature Act' (Dutch: 'Natuurwet'). Measures should be taken to protect these plants during maintenance activities of quays and bridges. This will lead to higher maintenance costs.
- Building Aesthetics provides an understanding of the contents of the building aesthetics assessment, which is based on different criteria. The Committee for Building Aesthetics and Monuments advises the Mayor and Aldermen on building permits relating to special constructions. She tests the plans to the Building Aesthetics and monumental criteria. Building Aesthetics emphasises only on aesthetic aspects of the exterior of constructions (beauty and ensemble). Monumental care considers the internal and external historic quality of the existing constructions. Building Aesthetics can result in functional undesired design which is often associated with higher maintenance costs.
- Delft has three or four conservation areas: the historic inner-city, the 'Agnetapark', the 'Nieuwe Plantage' and the 'TU-noord' area. These are protected cityscapes because of their integrity and strong cohesion. As a consequence, all assets (regardless of monumental status) and assetinterventions within the protected cityscapes are subject to licensing. These required permits are associated with longer preparation periods.
- Water plans ("Een blauw netwerk" and "Herpolderingsovereenkomst") define objectives of the municipality of Delft and the 'Hoogheemraadschap Delfland' regarding the water management, such as agreements on water quality, water levels, water storage and waterway management. These objectives do also affect the management of quays and banks in Delft and particularly the inner-city. The municipality of Delft is responsible for the performance of the quays and banks in relation to the quality of public urban areas. Additionally, she has multiple obligations regarding the management of surface water in Delft, such as: dredging activities, purifying municipal waterways and cleaning divers. Surface water is directly associated with (inner-city) quay walls. The water board 'Hoogheemraadschap Delfland' is responsible for monitoring the quality of this water. Management measures to guarantee the water quality are performed in collaboration with the municipality.

G.1.5 Assumptions

- Inner-city quay walls are inseparably linked to the urban water management system and to the recreation, tourism, hospitality and retail sectors. Furthermore they are part of the public urban area and therefore of the living environment of the citizens of Delft.
- The inner-city of Delft and the inner-city quay walls are 'protected cityscape'. Therefore, the management of inner-city quay walls should meet specific legislation. Before major maintenance works can be performed, construction permits must be obtained.
- If inner-city quay walls will be demolished they should be replaced at all times. Either by the same type of inner-city quay walls or by another type. The primary function (earth and water retaining) in relation to the surroundings of the quay wall is crucial. It is stated that a quay wall cannot be "exchanged" with a different type of object.
- Urban management, in consultation with other interested (municipal) parties, decides on the Program of Requirements. This is based on the (constructional) capacity of the current or repaired quay wall. This Program of Requirements should be divided into two parts: one with technical requirements and the other with functional requirements. Among other things the actual use of the quay should be translated into load schematisations, maximum dimensions of surrounding trees and maximum excavations or dredging depths of the subsoil in front of the quay wall.
- Currently, an integral management system is used to process GIS and inspection data (Gemeente Delft, 2011).
- The deterioration and degradation process should be monitored and analysed in order to predict or give an indication of the remaining life span of the quay structure. The presence of brick work material complicates this prediction.
- There is a current periodically measurement program to monitor changes to quay wall and interfaces such as fluctuating groundwater levels, change of design loads, vibrations and construction flaws. Some examples regarding deformation measurements are measurements using satellite, fibre techniques and laser (Kruithof, 2015; Ophof, 2015; Ravenzwaaij, 2015; Wienia, 2015).
- If inner-city quay walls fail to exist and perform no benefits are generated. Furthermore, endangered inner-city quay wall functions are associated with fewer or lower benefits.
- Quality aspects regarding the management of the public area are: safety (safety and health), sustainability (functionality) and image (image). They should meet the requirements that are associated with the quality levels B (inner-city) and C (entire municipality).
- The current bank (incl. quay wall) structures have variable conditions of which a major part is known (84% ≈ 209 km). The quality of the brick work varies quite a lot and approximately 21 km does not meet the quality requirements. Due to the fact that the desired quality level of the inner-city public area is lowered to category B instead of A (Gemeente Delft, 2011; Gemeenteraad Delft, 2015), there are no maintenance backlogs.
- There are plans to replace the surrounding pavements and the five monumental bridges. This offers a window of opportunity to combine the maintenance activities of the inner-city quay wall with those of the adjacent pavement and bridges.
- For each quay wall a visual inspection and inspections generated by monitoring should provide a proper assessment of the current condition of the structure in terms of quality. This could lead to the allocation of particular risk score which indicates the level of urgency. Thereby the actual condition will be taken as a starting point/baseline for the decision-making process. Nevertheless, future scenarios should be taken into account in order to anticipate certain events. This will be additional input for the sensitivity analysis.
- It is assumed that minor and major maintenance are not life time extending and therefore these types of maintenance cannot be included as investment on the municipal balance sheet. They will be seen as regular maintenance and are already included in the annual operation and maintenance costs (exploitation). It can be decided to charge the costs for major maintenance as a 'preconceived' provision during the entire exploitation period. The exact level of this provision is determined based on a multi-annual management plan. In this way, major fluctuations in annual costs can be prevented. Due to these considerations the annual operation and maintenance costs will vary between a minimum and maximum level (between 4% and 8% of the construction costs).
- The execution of a management strategy lasts a maximum of one year. All management strategies except the zero-alternative consider investments which should be activated in year t = 0.
- The analysis period starts from the year of investment (t = 0) and goes until the end of the life span (t = tr).
- Additional qualitative data considering the inner-city of Delft and the quay walls are summarised in TABLE 25.

TABLE 25: Qualitative data inner-city quay walls Delft.

Qualitative characteristics		
Urban conservation area / protected cityscape	yes / no	yes (13^{th} and 14^{th} century)
(Motorised) traffic free	yes / no	no
Parking areas	yes /no	yes
Quality aspects defined by municipality and urban management	yes / no	yes
Desired quality level public area inner-city	A^+, A, B, C, D	A and B → B
Current quality level public area inner-city	A^+, A, B, C, D	B and C

G.2 MANAGEMENT STRATEGIES

In the next step of the asset management framework the management strategies for the aging inner-city quay walls of Delft are elaborated.

G.2.1 Zero-Alternative A - Change Nothing

The zero-alternative is initially the most inexpensive maintenance strategy that consists of changing nothing to the current situation. This means that there still will be regular maintenance on e.g. daily basis, including visual inspection, monitoring and minor maintenance (mostly aesthetical) in order to assess and guarantee the quality-aspects: safety (safety), sustainability (functionality) and image (prestige and societal importance).

Maintenance activities that are performed are for example (Gemeente Delft, 2011, 2012; Gemeente Utrecht, 2012) :

- Repair minor damages
- Cleaning, removing and applying wear-resistant coatings
- Removing graffiti
- Painting railings and boulders
- Remove and / or replace loose parts
- Replace piling shelves
- Remove vegetation
- Repairs to embankments

The zero-alternative can be extended by a) performing several test loads to assess the constructional safety of the particular inner-city quay wall or b) performing additional research.

In case nothing will be changed to the current management of the particular inner-city quay wall, this research assumes that the remaining life span of the structure is 10 years. In the 10^{th} year, the quay wall will collapse and corrective maintenance should be performed in order to restore its operation. In this year, no benefits are generated by the inner-city quay wall. In the first 10 years, the regular operation and maintenance cost are incurred and benefits are generated.

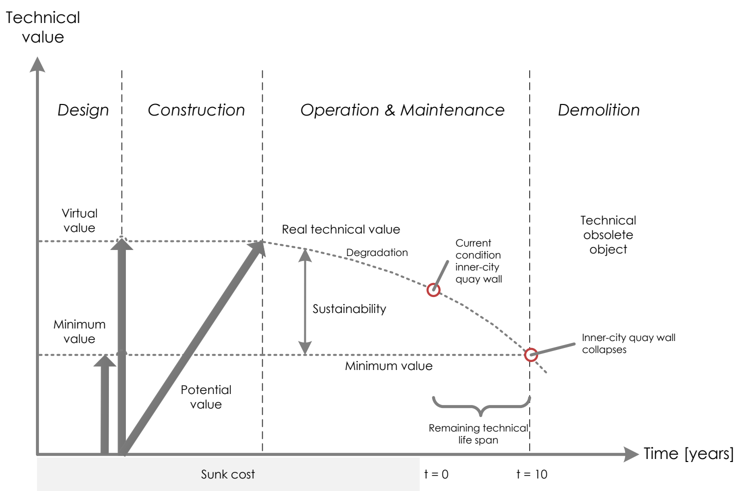


FIGURE 40: Life cycle inner-city quay wall – management strategy A.

G.2.2 Alternative B - Restrict Use (constructional devaluation)

Project Alternative B considers the constructional devaluation of the particular inner-city quay wall. The current functions of the quay wall structure, regarding bearing, retaining, mooring and traffic, will be eliminated. The function that remains is purely aesthetical and therefore the maintenance activities are only limited to aesthetic 'patching'. The quay wall becomes unavailable and inaccessible for driving or parking vehicles and mooring boats. Furthermore, the quay wall and its surroundings cannot be used for storage and transhipment, terraces and events. There are multiple possibilities to realise this and it depends on the specification of the sub-variant if it will be costly.

In case of constructional devaluation of the particular inner-city quay wall, this research assumes that the remaining life span of the structure is 50 years. After the 50^{th} year, the quay wall will collapse and corrective maintenance should be performed in order to restore its operation. In that year, no benefits are generated by the inner-city quay wall. In the first 50 years, the regular operation and maintenance cost are incurred and benefits are generated. The investment costs of this management strategy consist of a percentage of the construction cost incurred in the implementation year.

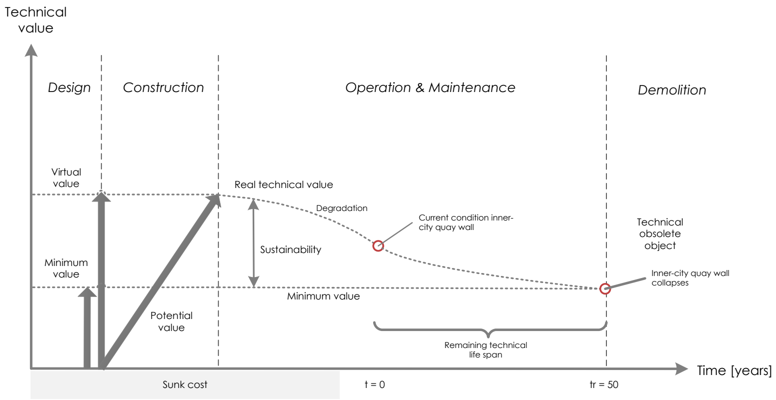


FIGURE 41: Life cycle inner-city quay wall – management strategy B.

G.2.3 Alternative C - Repair (major maintenance - restoration)

Project Alternative C is the execution of major maintenance or restoration activities of (some components of) the particular inner-city quay wall. This could be of corrective or preventive nature. The purpose of this type of (major) maintenance activities is to restore the quay to its original functional and technical condition. It considers for example the replacement of a particular section of the quay wall, such as the brick work and concrete under-structure, the anchoring components or the foundation. These major operations are systematically executed.

In case of repair of the particular inner-city quay wall, this research assumes that the remaining life span of the structure is 30 years. In the 30^{th} year, the quay wall will collapse and corrective maintenance should be performed in order to restore its operation. In this year, no benefits are generated by the inner-city quay wall. In the first 30 years, the regular operation and maintenance cost are incurred and benefits are generated. The investment costs of this management strategy consist of a percentage of the construction cost and are incurred in the implementation year.

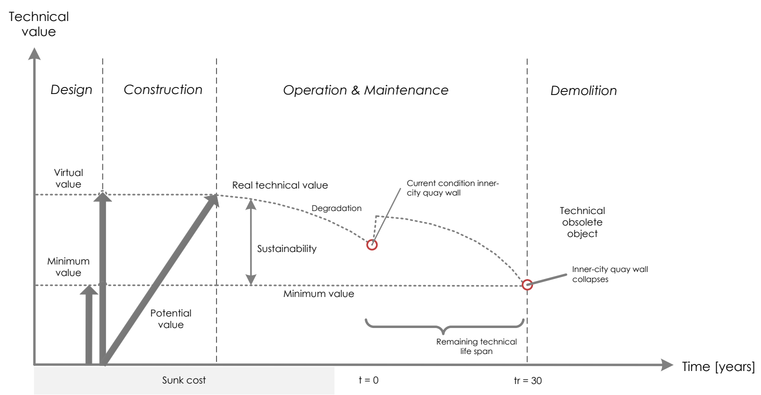


FIGURE 42: Life cycle inner-city quay wall – management strategy C.

G.2.4 Alternative D - Demolish and Renew (renovation or replacement with new construction)

Project Alternative D considers the demolition of the current quay wall and replacement by a new construction. For realisation of this alternative there are multiple possibilities which are decisive for the final construction cost. As the inner-city is conservation area, some of these options will not be permitted or feasible. For example, a prefab concrete or steel sheet-pile quay wall structure will never be chosen or even allowed.

When the inner-city quay wall is demolished and replaced, this research assumes that life span of the replaced structure is 80 years. Because the inner-city of Delft is 'protected cityscape', the new quay wall structure is similar to the one that is replaced. The investment costs of this management strategy C consist of demolition, planning design and engineering and construction and are incurred in the implementation year.

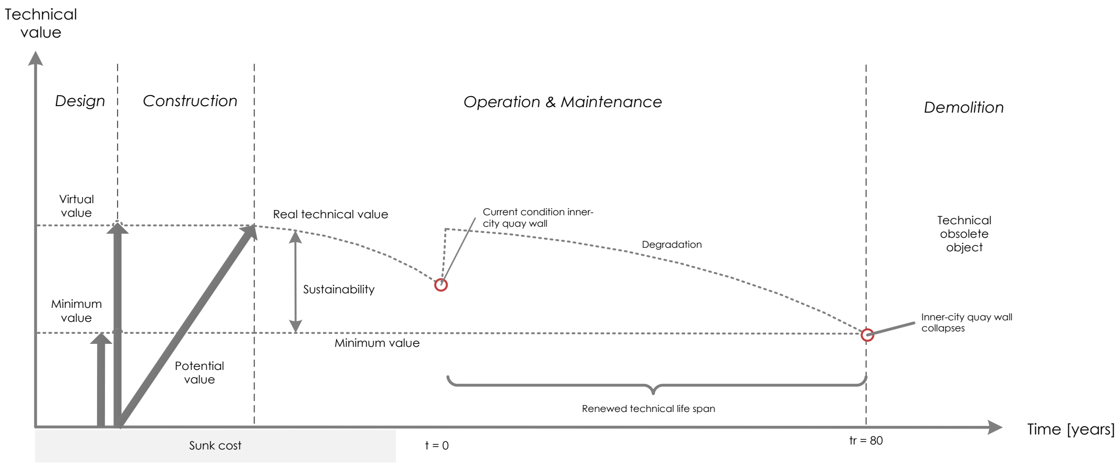


FIGURE 43: Life cycle inner-city quay wall – management strategy D.

G.3 KNOWLEDGE AND EXPERIENCE

The quality criteria that are weighted by the municipality of Delft, based on 'knowledge and experience', and the proposed management strategies represent the input of the 'knowledge and experience' prioritisation of these alternatives. In order to achieve VFM-scores for the four alternatives, the quality-criteria should be compared with each alternative (FIGURE 44).

Evaluation of Variants According to Individual Criteria:					
Safety & Health	Alternative A - Change noth	Alternative B - Restrict	Alternative C - Repa	Alternative D - Re	0.007
Alternative A - Change nothi	1	1/5	1/6	1/7	
Alternative B - Restrict use	5	1	1	1/2	
Alternative C - Repair	6	1	1	1/2	
Alternative D - Replace	7	2	2	1	
Functionality	Alternative A - Change noth	Alternative B - Restrict	Alternative C - Repa	Alternative D - Re	0.085
Alternative A - Change nothi	1	1/4	1/5	1/6	
Alternative B - Restrict use	4	1	1/6	1/7	
Alternative C - Repair	5	6	1	1/2	
Alternative D - Replace	6	7	2	1	
Image	Alternative A - Change noth	Alternative B - Restrict	Alternative C - Repa	Alternative D - Re	0.019
Alternative A - Change nothi	1	1/7	1/7	1/5	
Alternative B - Restrict use	7	1	1/2	2	
Alternative C - Repair	7	2	1	2	
Alternative D - Replace	5	0.5	0.5	1	
Societal importance	Alternative A - Change noth	Alternative B - Restrict	Alternative C - Repa	Alternative D - Re	0.033
Alternative A - Change nothi	1	1	1/3	1/4	
Alternative B - Restrict use	1	1	1/2	1/2	
Alternative C - Repair	3	2	1	2	
Alternative D - Replace	4	2	0.5	1	
Affordability	Value				
Alternative A - Change nothi	29				
Alternative B - Restrict use	145				
Alternative C - Repair	580				
Alternative D - Replace	3655				

FIGURE 44: AHP - weighting of management strategies i.r.t. individual quality criteria (using Excel, DAME 2015).

This results in the relative 'knowledge and experience' weights of the alternative in respect to the quality criteria, expressed in value for money (VFM). These can be seen in TABLE 26.

TABLE 26: Municipal weights of management strategies in respect to individual quality criteria [VFM].

	Safety and Health [VFM]	Functionality [VFM]	Image [VFM]	Societal importance [VFM]	Affordability [VFM]
A - Change nothing	0.05	0.05	0.05	0.12	0.79
B - Restrict use	0.24	0.09	0.31	0.16	0.16
C - Repair	0.26	0.34	0.44	0.41	0.04
D - Replace	0.45	0.52	0.20	0.31	0.01
Inconsistency index < 0.10	0.007	0.085	0.019	0.033	-

The total synthesised evaluation of management strategies results in FIGURE 45.

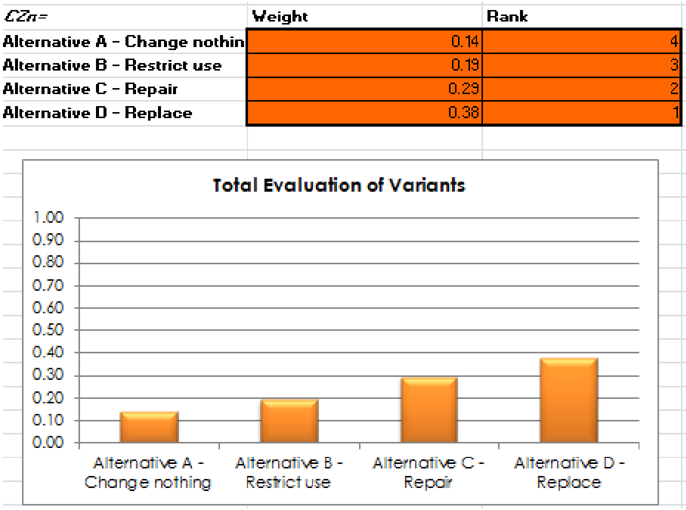


FIGURE 45: AHP - total evaluation of management strategies (Excel, DAME 2015).

As illustrated in the ranking of the proposed management strategies in relation to the quality criteria (TABLE 27), the municipality of Delft prefers Alternative D to replace inner-city quay wall structures (0.38 VFM). Thereafter, Alternative C to repair is preferred (0.30VFM), followed by respectively Alternative B (0.20 VFM) and Alternative A (0.12 VFM). Since the criteria safety and health and functionality are considered the most important (in VFM) and Alternative D is preferred in respect to this criterion, it seems logically that this Alternative is ranked as number 1.

TABLE 27: Ranked management strategies weighted by municipality of Delft [VFM].

Alternative	Weight [VFM]	Rank
A - Change nothing	0.14	4
B - Restrict use	0.19	3
C - Repair	0.29	2
D - Replace	0.38	1

G.4 COSTS AND BENEFITS

Now that the' IST' and 'SOLL' situation are mapped and various management strategies are proposed, the cost and benefit functions of the inner-city quay walls in Delft should be determined. Therefore, the data presented in TABLE 28, TABLE 29 and TABLE 30 should be taken into consideration and serve as input for the calculation of the NPV of inner-city quay walls in Delft.

TABLE 31 provides the input data that are used in the model-supporting Excel-spreadsheet.

TABLE 28: Quantitative data inner-city quay walls Delft (Gemeente Delft, 2012, 2015a, 2015d).

Quantitative characteristics		
Surface inner-city (water and land)	m^2	24 080 000
Surface inner-city (land)	m^2	2 700 000
Total number of banks of in management of municipality of Delft	-	2 201
Total length of banks in management of municipality of Delft	m	283 755
Technical life time of quay wall structures	year(s)	80
Number of inner-city quay walls	-	340
Total length of quay walls	m	21 425
Total length of inner-city quay walls in ownership of municipality of Delft	m	14 300
Percentage quay walls of inner-city area	%	1
Percentage quay walls of banks	%	6
Average retaining height of quay walls	m	2

TABLE 29: Financial data inner-city quay walls Delft (Gemeente Delft, 2012, 2015a, 2015d).

Financial characteristics regarding management and maintenance		
Annual budget minor and major maintenance civil works (2016-2019)	€	1 900 000
Annual budget management and maintenance banks (incl. quay walls) (2012-2015)	€	105 000
Annual budget minor (regular) maintenance banks (incl. quay walls) (2012-2015)	€	60 000
Budget extra research quay walls	€	25 000
Budget reservation (2012-2013)	€	36 000
Annual budget minor and major maintenance quay walls (2012-2015)	€	645 316
Annual budget inspections by external party (2012-2015)	€	30 000
Annual budget administration management plans by external party (2012-2015)	€	50 000
Entire duration of phases planning design and engineering, construction and demolition	year(s)	1
Single cost planning design and engineering	% CON	6
Single cost construction	€/m^2	$1719.5\,H^{0.9791}$
Annual costs operation and maintenance (regular)	% CON	1
Single cost demolition	% CON	17.5
Investment cost management strategy At t=0		
Single cost repair	% CON	20
Single cost restricted use	% CON	5
Single cost replacement	% CON	DEM + PDE + CON 17.5 + 6 + 100
Original investment cost	-	Sunk cost

TABLE 30: Societal data Delft (Gemeente Delft, 2012, 2015a, 2015d).

Societal characteristics		
Number of inhabitants (2008)	-	96 200
Number of monuments (2006)	-	1 465
Total turnover recreation and tourism sector (2006)	€	66 179 000
Total turnover hospitality sector (2006)	€	61 435 000
Total turnover retail sector (2006)	€	294 443 000
Total turnover commercial services sector (2006)	€	531 835 000
Total number of visitors attractions (2005)	-	901 815
Total number of houses (2013)	-	45 415
Number of houses inner-city (2013)	-	6 060
Average WOZ-value of houses (2013)	€	199 950 (average WOZ + 17%)
Average WOZ-value of houses inner-city (2013)	€	265 736
Total number of businesses and enterprises (2013)	-	5 638
Number of businesses and enterprises inner-city (2013)	-	1 535
Total number of shops (incl. vacancy) (2013)	-	630
Number of shops inner-city (incl. vacancy) (2013)	-	349

TABLE 31: Input Excel-model (Gemeente Delft, 2012, 2015a, 2015d).

Annual budget average management and maintenance costs inner-city quay walls (2012-2015) [€]	686116
Annual budget average management and maintenance costs inner-city quay walls (2012-2015) [€/m2]	48
Surface municipality [m2]	24080000
Surface inner-city [m2]	1270000
Surface inner-city quay walls [m2]	14300
Surface ratio of inner-city and municipality [%]	5
Surface ratio of inner-city quay walls and inner-city [%]	1
Surface ratio of inner-city quay walls and municipality [%]	0.06
Length of inner-city quay walls [m]	14300
Retaining height of inner-city quay walls [m]	2
Length of quay walls [m]	14300
Number of inhabitants (2012)	99000
Number of inhabitants inner-city (2012)	12000
Average WOZ-value inner-city [€]	266000
Average WOZ-value municipality [€]	200000
Difference in average WOZ-value [€]	66000
Increase in average WOZ-value [%]	33

G.4.1 Costs

As owner of the inner-city quay walls, the municipality of Delft incurs owner costs when managing these assets as part of the public urban area. It is assumed that the historic inner-city quay walls are gravity quay walls (type 1 & 2) and have a total length of 14.3 km and an average retaining height of 2 m.

The owner costs are presented in TABLE 32. The average, minimum and maximum values are provided, as (changeable) percentages from the construction cost equation (J.G. de Gijt, 2010, p. 157) (*Eq. 16*):

Gravity wall

$$Ccon\ [{}^{€}/_{m}] = 1719.5\ 2^{0.9791} \approx 2901 \quad \text{Eq. 16}$$

And the total cost (TC) function (*Eq. 17*, *Eq. 18* and *Eq. 19*):

$$TC = PDE_{t0} + CON_{t0} + O\&M_{t1} + O\&M_{t2} + O\&M_{ti} + DEM_{tr\ of\ te} + U_{ti} + DAM_{tr\ of\ te} \quad \text{Eq. 17}$$

$$TC = I_{t0} + [0.005\ to\ 0.015 CON_{t1..ti}]_{rand} + 0.175 CON_{tr\ or\ te} + 0.2 CON_{ti} + DAM_{tr\ or\ te} \quad \text{Eq. 18}$$

With:

-	*TC*	*Total costs*	*[€/m]*
-	*PDE_t*	*Planning, design and engineering costs in year 0*	*[€/m]*
-	*I_{t0}*	*Initial costs in year 0*	*[€/m]*
-	*$O\&M_{t1}$*	*Operation and maintenance costs in year i*	*[€/m]*
-	*$DEM_{tr\ of\ te}$*	*Demolition costs in final operating year r*	*[€/m]*
-	*U_{ti}*	*Unforeseen costs in year i*	*[€/m]*
	$DAM_{tr\ of\ te}$	*Damage costs in final operating year r*	*[€/m]*

$$DAM = Pf\ (Z \le 0) * Pd\ (DAM > 0) * DAM \quad \text{Eq. 19}$$

With:

-	*DAM*	*Damage costs*	*[€/m]*
-	*P_f*	*Failure probability (Reliability $Z \le 0$)*	*[1/x]*
-	*P_d*	*Probability occurrence damage (Damage DAM > 0)*	*[1/x]*

It should be taken into account that the risk component in the owner costs depends on the risk profile of the particular quay wall. In case the risk sum before, during and after implementation of a management strategy is relatively high (red zone), the costs for managing these risks will increase.

TABLE 32: Owner costs the life cycle of an inner-city quay wall with retaining height of 2 m (J.G. de Gijt, 2010, p. 157).

	% CC	*Type 1 & 2*	%CC	*Min Type 1 & 2*	% CC	*Max Type 1 & 2*
PDE	6%	174.05	4%	116.03	8%	232.07
Construction	100%	2900.82	90%	2610.74	110%	3190.90
Operation and Maintenance	1%	29.01	0.5%	14.50	1.5%	43.51
Alternative A - Change nothing	1%	29.01	0.5%	14.50	1.5%	43.51
Alternative B - Restrict use	5%	145.04	2.5%	72.52	7.5%	217.56
Alternative C - Repair	20%	580.16	15%	435.12	25%	725.20
Alternative D - Replace	126%	3655.03	109%	3161.89	143%	4148.17
Demolition	17.5%	507.64	15%	435.12	20%	580.16
Unforeseen	20%	580.16	10%	290.08	30%	870.25
DEM+PDE+CON+UNF	143.5%	4162.68	119.0%	3451.98	168.0%	4873.38
Total damage @ tr	Pf (Z ≤ 0)	71376.41	FPd(D > 0)	71376.41		
Alternative A - Change nothing	0.10	7137.64	1.00	7137.64		
Alternative B - Restrict use	0.02	1427.53	0.80	1142.02		
Alternative C - Repair	0.03	2379.21	1.00	2379.21		
Alternative D - Replace	0.01	892.21	1.00	892.21		
Retaining height H [m]	2					

G.4.2 Benefits

G.4.2.1 Total benefits (TB)

TABLE 33: Overview benefits inner-city quay walls in Delft.

Benefits [€/m]			
	Type 1 & 2		
Annual municipal tax OZB-tax	2.39		
Annual municipal tax tourIST-tax	0.40		
Annual turnover port and quay dues	86.01		
Annual general contribution municipal fund	4.13		
Annual turnover recreation, tourism and hospitality sector	61.66		
Annual WOZ-value	2.86		
Annual turnover parking fees alongside inner-city quay walls	27.62		
Annual benefits	185.07		
Benefits in terms of total damage to be prevented	71376.41	Pnf (Z>0) = 1 - Pf	Pd (D > 0)
Alternative A - Change nothing	0.00	0.90	1.00
Alternative B - Restrict use	4568.09	0.98	0.80
Alternative C - Repair	4758.43	0.97	1.00
Alternative D - Replace	6245.44	0.99	1.00
Total benefits	71561.49		
Alternative A - Change nothing	185.07		
Alternative B - Restrict use	4753.16		
Alternative C - Repair	4943.50		
Alternative D - Replace	6430.51		

G.4.2.2 General taxes and WOZ-value (GT and WOZ)

G.4.2.2.1 OZB

Annually, the municipality collects a number of municipal taxes allowed by law and are specified for each municipality. The benefits of general taxes are the input for general means of the municipality. The municipality decides for which purposes these means may be used. Examples of general taxes are property taxes (OZB), parking taxes and tourist taxes. The specifications of these taxes and associated levels are found in the municipal database of the CBS.

The WOZ-value is reflected in the annual OZB-tax and therefore it is stated that the quality of the public urban area contributes to the municipal benefits derived from general taxes. The WOZ value depends on different aspects, such as surface, location, lay-out and sales figures regarding similar properties. Each year, the WOZ-value is determined for both residential houses and commercial properties. The municipalities are free to determine the OZB-level as percentage of the WOZ-value (to a maximum: macro standard OZB).

For Delft, the following rates apply (Gemeente Delft, 2015g):

• OZB residential properties	[€/year]	0.15% of WOZ
• OZB non-residential properties owners	[€/year]	0.26% of WOZ
• OZB non-residential properties users	[€/year]	0.26% of WOZ

The average WOZ-value of the properties in the inner-city of Delft is €266 000, which is approximately 17% above the average WOZ-value of the entire municipality of Delft: €200 000 FIGURE 46: Average WOZ-value of properties in Delft (2012) (Gemeente Delft, 2015c).) (Gemeente Delft, 2015d).

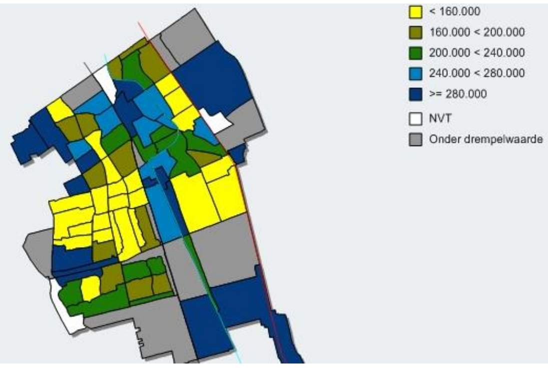


FIGURE 46: Average WOZ-value of properties in Delft (2012) (Gemeente Delft, 2015c).

Therefore, the average levels of the annual OZB in the inner-city of Delft are the following:

Residential properties $OZB = 0.15\% * 266\,000\,€ \approx 399\,€/year$

Non-residential properties owners $OZB = 0.26\% * 266\,000\,€ \approx 692\,€/year$

Non-residential properties users $OZB = 0.26\% * 266\,000\,€ \approx 692\,€/year$

The average levels of the annual OZB in the entire municipality of Delft are the following:

Residential properties $OZB = 0.15\% * 200\,000\,€ \approx 300\,€/year$

Non-residential properties owners $OZB = 0.26\% * 200\,000\,€ \approx 520\,€/year$

Non-residential properties users $OZB = 0.26\% * 200\,000\,€ \approx 520\,€/year$

TABLE 34 presents the annual OZB benefits that are generated by the presence of inner-city quay walls (*Eq. 20*):

$$OZBiqw = \frac{OZBiqw}{Liqw} = \frac{34\,174}{14\,300} \approx 2.39 \qquad \textit{Eq. 20}$$

With:

- *OZBiqw* *Annual OZB benefits in relation to presence inner-city quay walls* *[€/year]*
- *OZBiqw* *Annual OZB benefits in relation to presence inner-city quay walls* *[€/year]*
- *Liqw* *Length inner-city quay wall* *[m]*

TABLE 34: OZB benefits i.r.t. presence inner-city quay walls in respect to entire municipality of Delft.

	Number of properties inner-city [-]	Number of properties municipality [-]	Annual OZB inner-city [€/year]	Annual OZB municipality [€/year]	Annual OZB benefits inner-city [€/year]	Annual OZB benefits municipality [€/year]	OZB-benefit ratio inner-city vs municipality [%]	Annual OZ/yearB benefits derived from presence inner-city quay walls (≈ 1%) [€/year]	Annual OZB benefits derived from presence inner-city quay walls (≈ 1%) [€/year]	Annual OZB benefits derived from presence inner-city quay walls
Residential properties	7000	51000	399	300	2793000	15300000	18%	172276	31449	2.39
Non-residential properties	350	630	692	520	242060	327600	74%	3689	2726	
Total	7350	51630	1091	820	3035060	15627600	19%	175964	34174	

G.4.2.2.2 Tourist tax

The tourist tax relates to the quality of the public urban area in terms of number of visitors and tourists; the municipalities are however free to determine the level of both taxes. This research assumes that benefits of tourist taxes are generated in the public urban area of the municipality.

According to the Centraal Bureau voor de Statistiek (CBS) (2015) the benefits derived from tourist tax in the entire municipality of Delft (2013) were €514 000. This results in *Eq. 21* and *Eq. 22*.

$$TTiqw = TTmun * \frac{Aiqw}{Amun} \qquad \textit{Eq. 21}$$

$$TTiqw = 514\,000 * \frac{14\,300}{1\,270\,000} \approx 5788$$

$$TTiqw = TTiqw * \frac{Aiqw}{Liqw} \qquad \textit{Eq. 22}$$

$$TTiqw = \frac{5788}{14\,300} \approx 0.40$$

With:

- *TTiqw* *Tourist tax i.r.t. inner-city quay wall* *[€/m/year]*
- *TTmun* *Tourist tax i.r.t. municipality* *[€/year]*
- *Aiqw* *Area inner-city quay wall* *[m^2]*
- *Amun* *Area municipality* *[m^2]*
- *Liqw* *Length inner-city quay wall* *[m]*

G.4.2.2.3 WOZ-value

The value of cultural heritage is also reflected in the property value (WOZ-value). The average WOZ-value of properties at the Schieweg (€283 000 (2012)) is higher than the average WOZ-value of the inner-city of Delft (€265 736 (2012)). However, the average WOZ-value of the inner-city is also 17% above-average (€199 950 (2012)). Within the inner-city district, the neighbourhoods with the largest part of historic quay walls alongside the canals (west-side) do have the highest average WOZ-value (> € 270 000). This cannot be explained by the fact that all properties are larger than those in other neighbourhoods (which is not the case), but this is caused by the unique location and surroundings (ensemble). In addition to their technical value (reflected in safety and functionality) quay walls also contribute to the amenity and user values of the inner-city public area (protected cityscape) of Delft.

The WOZ-value for waterfront properties in combination with the presence of inner-city quay walls, is approximately15% (10% to 40%) higher than comparable properties without (Brouwer et al., 2007; Dammers et al., 2005; de Boer, 2001). Berkenbosch and Koetsenruijter (2012, p. 31) define several benefit key figures that can be used for the calculation of benefits in public urban area in terms of change in quality level.

The living comfort of the inner-city area of Delft is determined by the average WOZ-value of that area (€266 000) (TABLE 30). The higher WOZ-value of the inner-city of Delft can be explained by multiple factors, among others the view over water. It is assumed that all properties in the inner-city of Delft benefit from a view over water. This results in the change in living comfort of the inner-city area as a consequence of a quality increase of one level (C → D) (*Eq. 23*, *Eq. 24* and *Eq. 25*):

$$LIV = \frac{(n * \ \Delta Q * \ \Delta WOZ * WOZavg)}{20} \qquad \text{Eq. 23}$$

With:

- *LIV*	*Liveability*	*[€/property/year]*
- *N*	*Number of properties with view over …*	*[-]*
- *ΔQ*	*Quality level increase*	*[-]*
- *ΔWOZ*	*Increase WOZ per quality level increase*	*[%]*
- *WOZ*	*Average WOZ*	*[€]*

$$LIVmunicipality = \frac{(1 * \ 15\% * \ 200\,000)}{20} \approx 1500$$

$$LIVinner\ city = \frac{(1 * \ 15\% * \ 266\,000)}{20} \approx 1995$$

$$\Delta LIViqw = (LIVinner\ city - LIvmunicipality) * \frac{Aiqw}{Aic} \qquad \text{Eq. 24}$$

With:

- *ΔLIViqw*	*Liveability added by inner-city quay wall*	*[€/property/year]*
- *LIVinner-city*	*Liveability inner-city*	*[€/property/year]*
- *LIVmunicipality*	*Liveability municipality*	*[€/property/year]*
- *Aiqw*	*Area inner-city quay wall*	*[m²]*
- *Aic*	*Area inner-city*	*[m²]*

$$\Delta LIViqw = (1995 - 1500) * \frac{14\,300}{1\,270\,000} \approx 5.57$$

$$\Delta LIViqw = \Delta LIViqw * \frac{n}{Liqw} \qquad \text{Eq. 25}$$

With:

- *ΔLIViqw*	*Liveability added by inner-city quay wall*	*[€/property/m/year]*
- *n*	*Number of properties*	*[-]*
- *Liqw*	*Length inner-city quay wall*	*[m]*

$$\Delta LIViqw = 5.57 * \frac{7\,350}{14\,300} \approx 2.86$$

G.4.2.3 General contribution Municipal Fund (GC)

The general contribution of the Municipal Fund is provided by the National Government and assigned to the municipality of Delft. Decisive are two factors (Gemeente Delft, 2014):

- The size of the Municipal Fund is positively linked to the expenditures of the National Government.
- The Municipal Fund is distributed over the municipalities according to multiple benchmarks (e.g. number of inhabitants) and an amount per unit. Both municipal-specific development and national development of these benchmarks affect the size of the general contribution of Delft.

According to the Gemeente Delft (2015a, p. 1), the annual general contribution of the Municipal Fund assigned to the municipality of Delft is €99 382 000. The surface of the municipality is 24 080 000 m^2 and the entire surface of inner-city quay walls is 14 300 m^2 ((Gemeente Delft, 2015c)) (*Eq. 26* and *Eq. 27*).

$$GCiqw = GC * \frac{Aiqw}{Apa}$$ *Eq. 26*

With:

- *GCiqw* — *General contribution Municipal Fund inner-city quay walls* — *[€/year]*
- *GC* — *General contribution Municipal Fund* — *[€/year]*
- *Aiqw* — *Area inner-city quay walls* — *[m²]*
- *Apa* — *Area public urban area* — *[m²]*

$$GCiqw = 99\ 382\ 000 * \frac{14\ 300}{24\ 080\ 000} \approx 590$$

$$GCiqw = \frac{GCiqw}{Liqw}$$ *Eq. 27*

With:

- *GCiqw* — *General contribution Municipal Fund inner-city quay wall* — *[€/m/year]*
- *Liqw* — *Length inner-city quay wall* — *[m]*

$$GCiqw = \frac{590}{14\ 300} \approx 0.04$$

G.4.2.4 Port and quay charges (PQ)

Inner-city quay walls also contribute to the quality of public urban areas by providing an area to moor and transfer goods and/or people from water to land and vice versa. If a ship berths at a port designated for public service, the Harbour Master collects harbour dues. If an inner-city quay wall intended for public services is temporarily used to load or unload, quay charges should be paid. The legal foundations for these charges are stipulated in the 'Municipality Act' (Dutch: 'Gemeentewet') (Loqius, 2015).

In case of the port and quay charges that are collected in the inner-city of Delft, a superficial approach is used. The benefits that are actually generated through quay and port charges uses the annual benefits that are collected by the municipality and allocate them to the length of inner-city quay wall. It is assumed that these annual benefits are 'continuous' over time.

According to Gemeente Delft (2015b) the collected port and quay charges in 2014 were €123 000. The total length of quay wall owned by the municipality of Delft is 14 300 m and this is also the length of inner-city quay walls in Delft (*Eq. 28*).

$$PQiqw = \frac{(Piqw + Qiqw)}{Liqw}$$ *Eq. 28*

With:

- *PQiqw* — *Port and quay charges inner-city quay walls* — *[€/year]*
- *Piqw* — *Port charges* — *[€/year]*
- *Qiqw* — *Quay charges* — *[€/year]*
- *Lqw* — *Length inner-city quay wall* — *[m]*

$$PQiqw = \frac{123\ 000}{14\ 300} \approx 8.60$$

According to Gemeente Delft (2015b) the collected port and quay charges in 2014 were €123 000. The total length of quay wall owned by the municipality of Delft is 14 300 m and this is also the length of inner-city quay walls in Delft.

G.4.2.5 Turnover recreation, tourism and hospitality sectors (TR)

G.4.2.5.1 Recreation expenditures

The quality of public urban areas affects the recreation value that is experienced by the users of these areas. This can be monetised using the touristic and recreational expenditures or the turnover that is generated by the sectors of recreation, tourism and hospitality (*Eq. 29*).

$$RECiqw = n * \Delta t * (Eavg\ (R + H + O)) * \frac{Aiqw}{Apa} \qquad \text{Eq. 29}$$

With:

- *RECiqw*	*Recreation value inner-city quay walls*	*[€/year]*
- *n*	*Number of visits*	*[-/year]*
- *Δt*	*Average duration of stay*	*[hrs/stay]*
- *Eavg*	*Average expenditures per visit*	*[€/visit]*
- *R*	*Retail sector*	*[%]*
- *H*	*Hospitality sector*	*[%]*
- *O*	*Other sectors*	*[%]*
- *Aiqw*	*Area inner-city quay walls*	*[m^2]*
- *Apa*	*Area public urban area*	*[m^2]*

This research assumes that inner-city quay walls contribute to the quality of public urban areas which is among others expressed in terms of recreation value. In order to identify the actual contribution of inner-city quay walls to the quality of a public area, at least two municipalities should be compared: one municipality with inner-city quay walls as part of a public area and one municipality without inner-city quay walls as part of a public area.

The municipality of Delft uses its characteristic and historic inner-city, and its quay walls, as a 'marketing-tool' to attract tourists and day-recreants. It is assumed that the project-alternatives influence this number of tourists and day-recreants; therefore, a percentage of the recreation value can be assigned to the quay walls and their appearance. As stated previously, this effect will be relatively small since the total area of quay walls is approximately 1% of the inner-city area. A questionnaire focussed on the reason(s) for tourists to visit Delft may be used to determine the actual percentage. Monetising these benefits requires data regarding the development of the number of visitors and the movement patterns (incl. 'strolling environment'). It is stated that "the prosperity of a municipality is stimulated by an increase in the number of visitors, an increase of the visit-frequency and/or prolongation of the duration of stay results in an increase of the economic expenditures and employment" (Gemeente Breda, 2008).

TABLE 35: Recreation in Delft (Gemeente Delft, 2015f)

Number of visits (2010) [-]	1 948 000	
Average duration of stay [hours]	6	
Average expenditures [€/visit]	100%	39
Retail sector [€/visit]	46%	18
Hospitality sector [€/visit]	40%	15.5
Other [€/visit]	14%	5.5
Total expenditures tourism and recreation visits [€/year]	75 972 000	
Inner city area [€/year]	100%	75 972 000
Inner city quay walls [€/m2/year]	1%	53.13

G.4.2.5.2 Cultural heritage

Since inner-city quay walls contribute to the quality of the urban public area, it can be assumed that they also play a role in municipal competiveness (Bade et al., 2007). In order to determine the 'profitability' of the presence of historic inner-city quay walls in Delft, it should be analysed what benefits are earned in the inner-city, as a consequence of experiencing cultural heritage, and which part of those can be traced back to the existing historic quay walls. To concretise the results, they are compared to a nearby inner-city public area with no (historic) quay walls and protected 'cityscape': Rijswijk.

In 2006, the historic inner-city of Delft incurred revenues of approximately €1.1 billion, which is €1136 per inhabitant. In the city centre the most successful sectors were commercial services, retail and non-commercial services (Bade et al., 2007). In the same year, the total turnover in the inner-city of Rijswijk covered approximately €557 million, which is €1182 per inhabitant. Taking the recreation and tourism sector into account, Delft received a turnover of around €66 million (€668 per inhabitant – 99 000 inhabitants) and Rijswijk of circa €12.5 million (€267 per inhabitant – 46 990 inhabitants). Essentially, the tourism and recreation sector and the hospitality sector are for Rijswijk of less importance than it is for Delft. This is also reflected in the employment figures of this sector, 22% and 20% (Delft) versus 10% and 8% (Rijswijk), in both municipalities of TABLE 36. .

TABLE 36: Turnover and employment per sector (Kamers van Koophandel, MKB-resultatenberekening, Rabobank Cijfers & Trends, (Bade et al., 2007, p. 28).

Sector	Inner-city of Delft		Inner-city of Rijswijk	
	Turnover [*€1000]	Employment [fte]	Turnover [*€1000]	Employment [fte]
Construction	13 349	81	10 053	61
Retail	294 443	766	199 498	519
Hospitality	61 345	1 028	10 787	179
Industry	31 793	132	79 000	328
Agriculture	1 076	9	718	6
Non-commercial services	118 239	1 144	22 221	215
Transport	31 570	223	29 730	210
Commercial services	531 835	1 953	205 055	753
Total	1 083 650	5 326	557 061	2 271
Recreation and tourism	66 179	1 163	12 576	221

The recreation and tourism sector and the hospitality sector in Delft have relatively high 'turnovers' and attracts many visitors (Bade et al., 2007). The (cultural) heritage of the municipality and in particular of the inner-city can be one of the main explanations. As mentioned before, cultural heritage and visitor attractions are inseparably related.

bezienswaardigheid	2005
Nieuwe Kerk en/of Oude Kerk	238.091
Koninklijke Porceleijne Fles	150.000
De Delftse Pauw	135.000
Legermuseum	61.000
Stedelijk Museum Het Prinsenhof	59.869
Rondvaartboot	48.000
Toren Nieuwe Kerk	40.066
Reptielenhuis SERPO	32.547
Botanische tuin TU Delft	32.000
De Candelaer	25.000
Techniek Museum Delft	20.944
Volkenkundig Museum Nusantara	20.162
Museum Lambert van Meerten	18.638
Winkeltje van Kouwenhoven	7.724
Museum Paul Tétar van Elven	6.687
Molen De Roos	2.500
Mineralogisch-Geologisch Museum	1.550
Medisch Farmaceutisch Museum	780
Museum Psychiatrisch Centrum Joris	500
Gereedschapmuseum Mensert	462
Tabaks Historisch Museum	275
Het Steen (toren Stadhuis)	20

bron: Delft Marketing

FIGURE 47: Visitors attractions Delft (Gemeente Delft, 2006).

As stated before, the turnover for recreation and tourism and hospitality in Delft is significantly higher than in the same sector of Rijswijk: €127 million versus €23.5 million (in 2006). This is for Delft approximately €1288 per inhabitant and for Rijswijk €497 per inhabitant. This difference of €791 per inhabitant can be mainly explained by the historic inner-city of Delft, which is circa 5% of the total surface of the municipality of Delft. The share of (historic) quay walls in the inner-city of Delft is approximately 1% (Gemeente Delft, 2015c). It is therefore assumed that the monetary contribution of inner-city quay walls to the difference in turnover in the recreation and tourism sector in Delft in 2006 was €8.91 per inhabitant and in total €0.88 million per year (*Eq. 30*).

$$\Delta TRiqw = \frac{\Delta TRmun}{Liqw} = \frac{880\ 000}{14\ 300} = 62 \qquad \textit{Eq. 30}$$

With:

- *ΔTRiqw* — *Added turnover i.r.t. inner-city quay walls* — *[€/m/year]*
- *ΔTRmun* — *Added turnover municipality i.r.t. inner-city quay walls* — *[€/year]*
- *Liqw* — *Length inner-city quay walls* — *[m]*

G.4.2.6 Parking fees (PF)

Inner-city quay walls often provide area for parking vehicles, alongside the canals. The benefits derived from issuing parking permits can be calculated using the number of permit holders and the price of a parking permit. The composition of these permit-holders and the price-level of the permits are variable over time. This should be taken into account.

The number of available permits depends on the amount of available parking areas. The number of parking areas alongside the inner-city quay walls can be determined using *Eq. 31* and *Eq. 32*.

$$PF = \frac{(np * PFp + nb * PFb) * \left(\frac{niqw}{npa}\right) * \rho}{Liqw} \qquad \text{Eq. 31}$$

With:

- *PF*	*Parking fees*	*[€/m/year]*
- *np*	*Number of parking permits private*	*[-]*
- *PFp*	*Parking fees private*	*[€/permit/year]*
- *nb*	*Number of parking permits business*	*[-]*
- *PFb*	*Parking fees business*	*[€/permit/year]*
- *niqw*	*Number of parking areas along inner-city quay walls*	*[-]*
- *npa*	*Number of parking areas public urban area*	*[-]*
- *ρ*	*Occupancy rate*	*[%]*
- *Liqw*	*Length inner-city quay walls*	*[m]*

$$niqw = \frac{Aparking}{Aiqw} * \left(\frac{Liqw}{Lparking}\right) \qquad \text{Eq. 32}$$

With:

- *niqw*	*Number of parking areas along inner-city quay walls*	[-]
- *Aparking*	*Parking area municipality*	[m^2]
- *Aiqw*	*Area inner-city quay walls*	[m^2]
- *Liqw*	*Length inner-city quay walls*	[m]
- *Lparking*	*Average length parking area (≈ 6m)*	[m]

$$niqw = \frac{(14\,300 - 0.3 * 14\,300)}{6} \approx 1668$$

$$PF = \frac{(1168 * 160 + 500 * 245) * 81}{14\,300} \approx 17.53$$

Determining the parking benefits derived from parking visitors is more complicated, because of the number of parking visitors, average parking time and average parking fee, the size and composition of the visitors' vehicle-fleet. Inner-cities do have complicated parking regulations. Therefore, it is often difficult to determine an unambiguous benefit function. It should be taken into consideration that an inner-city parking system consists of different types of parking areas with associated permits. The required differentiation between these types will be challenging.

G.4.2.7 Prevented damage cost (PD)

The influence of the alternatives on the functional capacity of the quay wall(s) can be monetised by taking the (prevented) damage cost by executing a management strategy into account. To determine whether executing one of the project-alternatives makes sense, the direct repair costs associated with an undesirable event are analysed. These prevented costs are considered as benefits in terms of prevented damage costs, generated by the inner-city quay wall after implementation of an alternative. The 'willingness to pay' for an increase in safety can be determined using the "Value Of a Statistical Life" (VOSL), which is defined as the ratio of the monetary value of decrease in mortality rate and the decrease of annual probability (Kind, 2011, p. 40). Estimations of the VOSL are derived through questionnaires or actual behaviour of individuals in situations with mortality risk. The VOSL in European studies vary between €2 million and €14 million. The bandwidth is large due to statistical uncertainty and context-dependency. The value is depends on terms that are also used in a risk-context: individual controllability, manner of death, scale and initial probability. In case of water safety, the research of Kind (2011, pp. 42,47) resulted in an average VOSL of €6.7 million (bandwidth of €1.4 million to €11.3 million) (*Eq. 33*). For immaterial damage due to evacuations or non-replaceable possessions €12 000 for each victim is estimated (*Eq. 34*).

$$DAMvosl = \frac{VOSL}{Liqw} = \frac{6\,700\,000}{14\,300} \approx 468.53 \qquad \text{Eq. 33}$$

With:

- *DAMvosl*	*Prevented damage VOSL*	*[€/victim/m]*
- *Liqw*	*Length inner-city quay walls*	*[m]*

$$DAMimm = \frac{DAMimm}{Liqw} = \frac{12\ 000}{14\ 300} \approx 0.84$$ *Eq. 34*

With:

- *DAMimm* — *Prevented immaterial damage* — *[€/victim/m]*

The costs regarding water damage to properties as a consequence of flooding are estimated by Ten Veldhuis (2010). For houses the damage costs lie between €1 000 and €30 000 per house, for businesses the damage costs lie between €2 000 and €30 000 per business (van Riel, Tollenaar, & van de Ven, 2011). The number of houses and businesses alongside the inner-city quay walls can be estimated using data regarding the Ground Space Index (GSI) and Floor Space Index (FSI), which are indicators for surface ratios (B. Oostdijk & L. Zenger, 2015). The national standard for building density is 50 to 60 houses per ha. For the inner-city of Delft, the building density for houses is approximately 5 754 houses per km^2 (≈ 58 houses per ha ≈ 0.0058 houses per m^2) (Gemeente Delft, 2015d) . The total amount of business-surface is approximately 354 businesses at 54 864 m^2 (≈ 65 businesses per ha ≈ 0.0065 businesses per m^2) (Gemeente Delft, 2015c). This results in the estimation that alongside the total surface of the inner-city quay walls (14 300 m^2) approximately 83 houses and 93 businesses are located.

The reducing effect of the management strategies on the damage cost for the surrounding properties, due to functional failure of the inner-city quay walls, can be calculated using *Eq. 35* (Kind, 2011; Ten Veldhuis, 2010).

$$DAM = \frac{\Delta P * (83 * 15\ 500 + 93 * 16\ 000 + DAMpa)}{14\ 300}$$ *Eq. 35*

$$\approx\ minimum\ \Delta P * 194$$

With:

- *DAMiqw* — *Prevented damage functional failure i.r.t. inner-city quay wall* — *[€/m]*
- *ΔP* — *Decrease in probability* — *[-]*
- *DAMpa* — *Damage public area* — *[€]*

Besides damage to the built environment, also damages to the public area and public utilities could occur. These damages are difficult to quantify; however, roughly estimated cost categories are provided as mentioned previously. Furthermore, indirect consequent damages of flooded streets could occur, such as a loss of working hours due to traffic congestion. These damages are not yet quantified. It should be noted that flooded streets can be caused by different (sometimes interrelated) factors such as excessive rainfall, quay wall failure (collapse) and/or a broken pipeline. This case only considers the prevented damage costs in terms of VOSL and immaterial damage. Furthermore, prevented replacement costs can be seen as benefits for the municipality. These costs consist of demolition cost, planning design and engineering and construction cost.

G.4.3 Future Scenarios

External developments (e.g. demographic developments, economic developments, climate changes, regulation and legislation, political developments) with high impact but low predictability represent the input for future scenarios. Only the factors that influence the effects in the different management strategies (including the zero-alternative) are considered. Future scenarios consider three different approaches: a bad scenario with the most negative developments, a good scenario with the most positive developments and a moderate scenario that is situated in the middle. These data form part of the input for calculations. Additionally, (internal) scenarios should be developed. They include different possibilities for the actual (constructional) condition of the particular quay wall (TABLE 37). These internal scenarios are also considered in the risk analysis.

TABLE 37: Internal scenarios regarding the inner-city quay walls, in relation to the management of inner-city quay walls.

BAD	MODERATE	GOOD
Extremely bad technical and functional condition inner-city quay wall: the structure is about to collapse. The degradation process is far-developed.	Neutral technical and functional condition inner-city quay wall: structure is relatively stable. It meets the minimum requirements (performance levels). There are some uncertainties regarding the degradation process.	Good technical and functional condition inner-city quay wall: the structure is stable. It meets the desired requirements (performance levels). Although there are some uncertainties regarding the degradation process, the structure generates the maximum benefits as part of the public urban area.
Low benefits High costs	Moderate benefits Moderate costs	High benefits Low costs

G.4.4 Management Summary - NPV

The cost and benefits of inner-city quay walls as part of the public area can be captured in one overview, which is shown in TABLE 38. The annual benefits derived from the inner-city quay walls in Delft are largely determined by their contribution to the annual turnover in terms of port and quay dues, parking fees and the annual turnover of the recreation, tourism and hospitality sector. These contributions depend on the total area of inner-city quay walls in relation to the total public urban area. For each municipality the benefits derived from inner-city quay walls probably differ. The most decisive benefits are derived from the prevented damage costs, regardless of the fact that these benefits are not actual cash inflows. By identifying prevented damage costs (risk) as benefits, the prosperity effects of managing inner-city quay walls in terms of safety and health are monetised.

It is noted that the generated benefits are hardly ever related to one particular inner-city quay wall, due to the surrounding interfaces and their influences on the quality of public urban areas. Therefore, only a certain percentage of the benefits in the public urban area is attributed to inner-city quay walls. This percentage depends on the nature of the benefit.

TABLE 38: Overview costs and benefits inner-city quay walls in Delft.

	% CC	*Type 1 & 2*		Type 1 & 2		
PDE	6%	174.05	Annual municipal tax OZB-tax	2.39		
Construction	100%	2900.82	Annual municipal tax tourist-tax	0.40		
Operation and Maintenance	1%	29.01	Annual turnover port and quay dues	86.01		
Alternative A - Change nothing	1%	29.01	Annual general contribution municipal fund	4.13		
Alternative B - Restrict use	5%	145.04	Annual turnover recreation, tourism and hospitality sector	61.66		
Alternative C - Repair	20%	580.16	Annual WOZ-value	2.86		
Alternative D - Replace	126%	3655.03	Annual turnover parking fees alongside inner-city quay walls	27.62		
Demolition	17.5%	507.64				
Unforeseen	20%	580.16				
DEM+PDE+CON+UNF	143.5 %	4162.68	Annual benefits	185.07		
Total damage @ tr	Pf (Z ≤ 0)	71376.41	Benefits in terms of total damage to be prevented	71376.41	Pnf (Z>0) = 1 - Pf	FPd (D > 0)
Alternative A - Change nothing	0.10	7137.64	*Alternative A - Change nothing*	0.00	0.90	1.00
Alternative B - Restrict use	0.02	1427.53	*Alternative B - Restrict use*	4568.09	0.98	0.80
Alternative C - Repair	0.03	2379.21	*Alternative C - Repair*	4758.43	0.97	1.00
Alternative D -	0.01	892.21	*Alternative D - Replace*	6245.4	0.99	1.00

Replace				4		
			Total benefits	71561.49		
			Alternative A - Change nothing	185.07		
			Alternative B - Restrict use	4753.16		
			Alternative C - Repair	4943.50		
			Alternative D - Replace	6430.51		
Retaining height H [m]	2					

TABLE 39: Depreciation periods investments in public space (Gemeente Delft, 2011).

Asset or element	Depreciation period [years]
Concrete and steel bridges	40
Pavements	
Public Lighting	
Parking areas	25
Quay walls	
Wooden and steel bridges	
Traffic control installations	12
Green facilities	10
Major maintenance or renovation activated in the period until 2003	25
Renovation activated in the period since 2004	Remaining (technical) life time
Planning Design & Engineering	5

TABLE 40 provides the ranking of the management strategies based on the NPV, taken into account the depreciation period of inner-city quay walls as used by the municipality of Delft. The management strategy that is preferred is Alternative D: replace the inner-city quay wall. Alternative B and C are also considered feasible alternatives (NPV > 0). Since the inner-city quay walls in Delft are part of 'protected city-scape', they cannot be demolished and replaced. Therefore, a choice should be made between Alternative B and Alternative C. Alternative A is not feasible (NPV < 0) and is therefore discouraged.

TABLE 40: NPV for t = tr.

NPV [€/m] for t=	tr	Type 1 & 2	Rank
Alternative A	*Change nothing*	-0.4 million	4
Alternative B	*Restrict use*	0.2 million	3
Alternative C	*Repair*	0.1 million	2
Alternative D	*Replace*	0.3 million	1

G.4.5 Sensitivity and Actor Analysis

In the sensitivity analysis the robustness of the results are tested. The different assumptions in monetisation do affect the result to a certain extent. They should be determined and tested. By taking all scenarios into account, the variables regarding the prosperity-growth and the number of those who seek recreation and visitors are already analysed. By adjusting these values in the SCBA the effects on the final result can be assessed.

The sensitivity analysis can take multiple factors in consideration. These have been described earlier in scenarios 'bad', 'moderate' and 'good'. Due to simplification, this research emphasises the following sensitivity factors:

- Varying discount rate: this provides an understanding of the impact of the discount rate on the cash flow. By means of the spreadsheet model, the cash flow is simulated for a discount rate varying from 0% to 11%. Alternative A and D show the highest NPV-sensitivity to a change in discount rate. The NPV of Alternative A (change nothing) becomes less negative with an increasing discount rate. Alternative A considers a short remaining life span (duration period tr = 10 years) and therefore the (timing of) changes in the cash flows do have a large impact on the NPV. The NPV of Alternative D (replace) decreases with an increasing discount rate. Since Alternative D covers a large remaining life span (duration period tr = 80 years), changes in the discount rate result in a relatively large change in NPV. By applying a higher discount rate, the costs and benefits are assigned a lower present value as they occur further on in the future. Alternative B (restrict use) and Alternative C (repair) show the largest robustness in their NPVs as function of the discount rate. Alternative C has the lowest sensitivity to the discount rate, which implies the lowest uncertainty in NPV, and is therefore preferred.

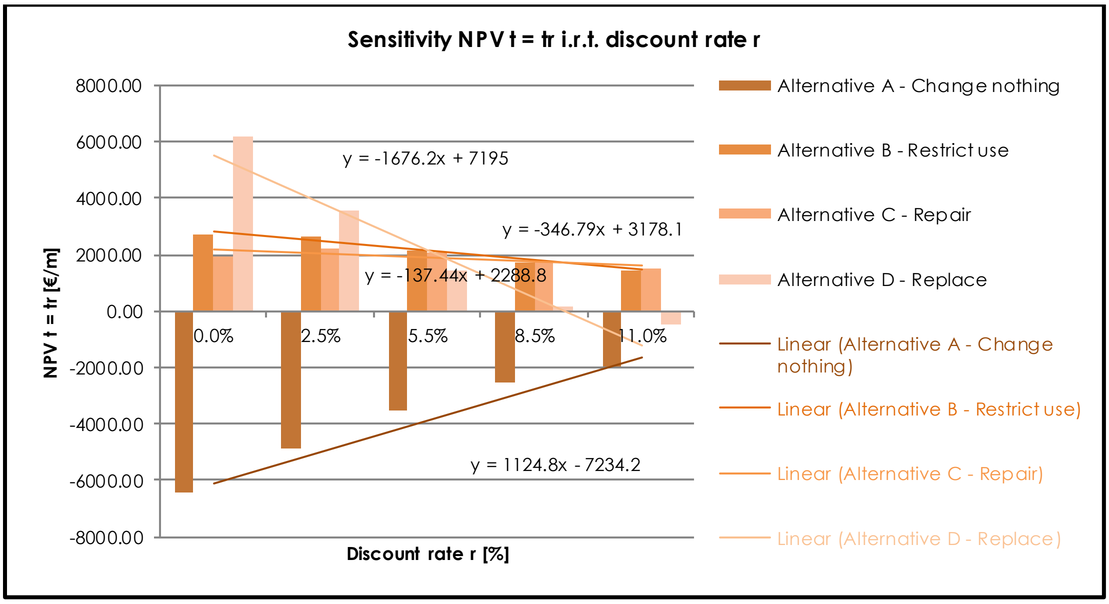


FIGURE 48: Sensitivity NPV i.r.t. discount rate.

- Maximum and minimum cost-benefit input: this provides an understanding of the band width of the determined cost and benefit function. By taking into consideration a maximum cost function and a minimum benefit function in combination with a minimum cost function and a maximum benefit function, both extreme situations are calculated. TABLE 41 presents the upper and lower boundaries of the cost and benefit functions. Alternative D shows the largest bandwidth, which can be explained by the fact that this alternative consists of the entire replacement of the inner-city quay wall. This is the largest investment, but results also in the largest (remaining or renewed) life span. Alternative B and Alternative C are relatively close to each other, although Alternative B has a lower maximum NPV than Alternative C. They represent the 'mid-alternatives' and the associated investments of respectively 5% and 20% of the construction cost are significantly smaller than the investment cost of Alternative D. The bandwidth of Alternative A is also close to those of Alternative B and Alternative C. Taking into consideration that this alternative does not include any investment, this bandwidth is remarkably large.

TABLE 41: Upper and lower boundary NPV (r = 5.5%).

Alternative	Maximum NPV [€/m]	Minimum NPV [€/m]	Bandwidth [€/m]
Alternative A - Change nothing	874	-4443	5317
Alternative B - Restrict use	2775	-2037	4812
Alternative C - Repair	3414	-1433	4847
Alternative D - Replace	5464	-4148	9612

- Varying retaining height as input for the cost function: this provides an understanding of the impact of the retaining height on the cost function and thereby on the NPV output. As can be seen in FIGURE 49, there exists a negative relation between the NPV and the retaining height the inner-city quay wall. Alternative A, B and C are relatively "insensitive" for changes in retaining heights. Alternative D shows a large sensitivity for changes in the retaining height. This can be explained by the fact that this alternative considers the entire replacement of the inner-city quay wall. This investment consists of 126% of the construction cost (demolition, planning + design + engineering and construction) in comparison to the investments of Alternative B (5%) and Alternative C (20%).

Alternative D becomes unfeasible (NPV < 0) with retaining heights of more than 3.50 m. Alternative A is considered unfeasible for all retaining heights.

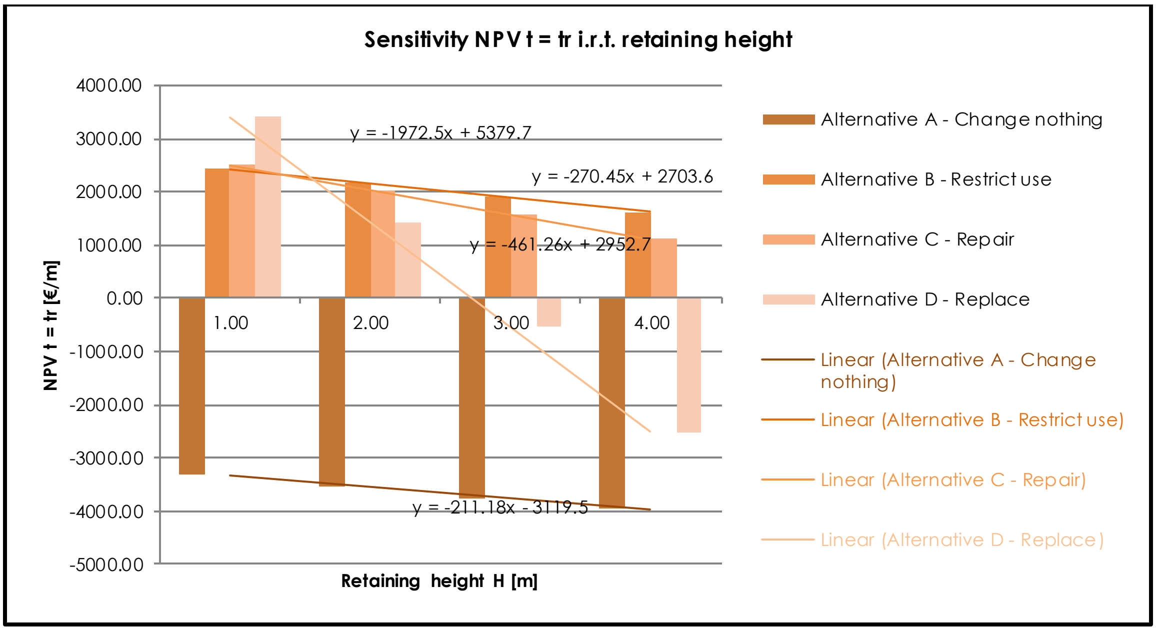


FIGURE 49: Sensitivity NPV (t=tr) in relation to retaining height H .

- Varying benefit and cost function: this provides an understanding of the impact of the different benefit and cost aspects on the benefit (FIGURE 50) and cost function (FIGURE 51) and thereby on the NPV output.

  FIGURE 50: When changing the benefit level in relation to a constant cost level (100%), it appears that Alternative C and Alternative D show the largest sensitivity. This can be explained by the fact that the NPVs of these alternatives are largely affected by the prevented damage costs which represent the largest part of the benefits. The damage costs are defined as a function of the probability of failure and the probability of occurrence. Since Alternative C and Alternative D do have the largest impact on these probabilities, the sensitivity of the NPV function in relation to the benefit level is also the highest for these alternatives.

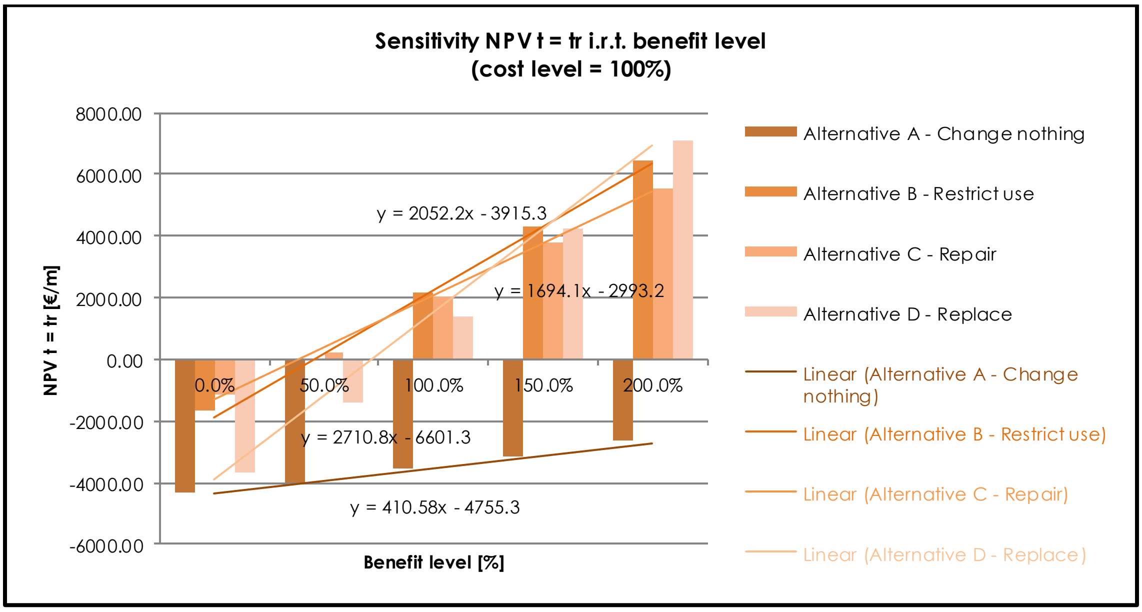


FIGURE 50: Sensitivity NPV (t = tr) in relation to benefit level.

FIGURE 51: When changing the cost level in relation to a constant benefit level (100%), it appears that Alternative A and Alternative D show the largest sensitivity. This can be explained by the fact that the NPVs of these alternatives are largely affected by the life cycle costs in terms of replacement costs (Alternative D) and damage costs (Alternative A). The sensitivity of the NPV function in relation to the benefit level is therefore the highest for these alternatives.

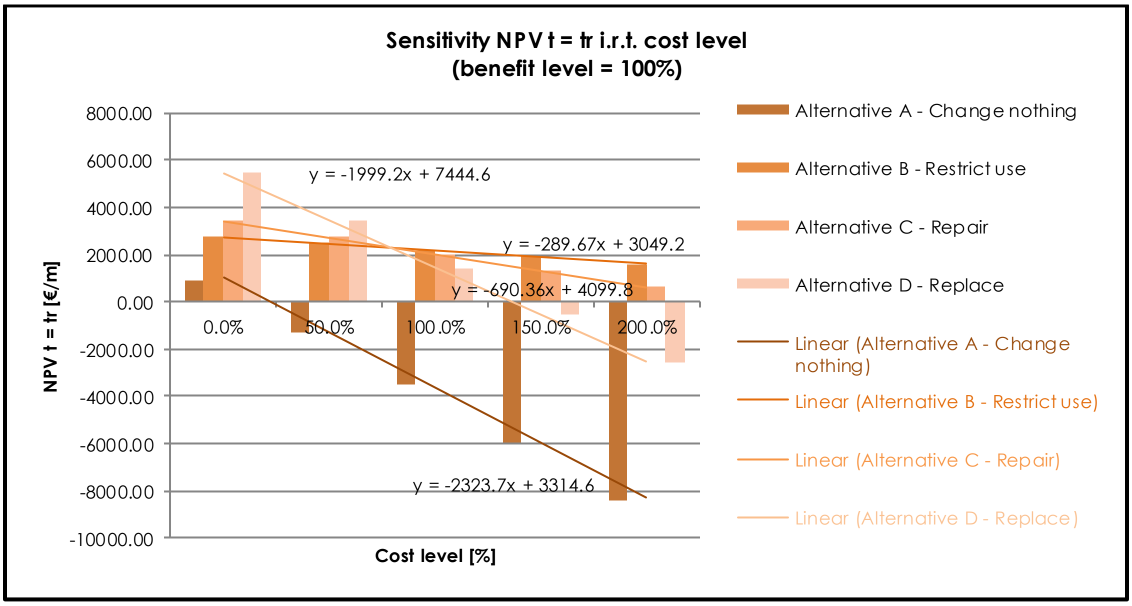


FIGURE 51: Sensitivity NPV (t = tr) in relation to cost level.

The input parameters consist of the different cost items, benefit items and the discount rate. As it appears, the NPV-function shows for all management strategies the 'highest' sensitivity for variation in construction costs and benefits in terms of prevented damage costs. The construction costs affect the other costs and the benefits in terms of prevented damage costs, which are among others derived from prevented replacement costs. Because all costs are assumed to be a percentage of the construction cost, this is reflected in the entire NPV-function.

It should be noted that the higher the profitability requirement (processed in the discount rate), the lower the PV's of the cash flows and the NPV. Furthermore, the NPV-method does not consider the difference in maturity between the alternatives. The alternatives with a longer maturity period are therefore more beneficial. On a shorter term, e.g. 25 years, it is illustrated that the NPV of both Alternative B and Alternative C is higher than the NPV of Alternative D. In the end it will be the decision of the municipality which alternative is desired in relation to their short- and long term objectives.

Furthermore, an actor-analysis is done by taking into account the medium scenario ('Moderate'). As stated before, only the owner-costs (in terms of investment cost of in management strategies) are taken into account. The benefits generated by the presence of inner-city quay walls will accrue to different actors (within the municipal boundaries).

G.5 RISKS

The execution of management strategies for inner-city quay walls requires special attention as environment factors are very complex. When considering the execution aspects elaborated in Appendix C, results will show an estimation of the risk scores during the execution of the proposed management strategies.

Historic inner-city quay walls consist of material from which the degradation process is relatively difficult to predict. Incoherent brick work in combination with wooden foundation piles is often associated with many technical uncertainties. The risk analysis should consider both technical and functional performance of inner-city quay walls. Therefore, the quality criteria of public urban areas are represented as risk categories. Each category has its own relative weight which affects the risk score.

For the municipality of Delft, safety (0.41 VFM) is priority number one, followed by functionality (0.24 VFM), societal importance (0.16 VFM), affordability (0.10 VFM) and image (0.08 VFM). In order to determine the effectiveness of the management strategies in regard to the quality-risks as described previously, a part of the inner-city quay wall "Oude Delft" will be plotted in the risk matrix. The risk scores after the execution of the management strategies are rough estimations. In reality, the municipality, together with experienced consultancy and engineering firms and contractors, should analyse and assess the risks as accurately as possible.

TABLE 43 presents the ranking of the management strategies according to their risk sums before, during and after implementation. In the short term the municipality could be tempted to change nothing to the current management of inner-city quay walls. However, the performance of the inner-city quay wall and the quality of the public urban area cannot be guaranteed with certainty. The municipality should be willing to take a large risk. According to the risk-ranking of the management strategies, Alternative D is preferred. However, the implementation of this alternative is associated with multiple difficulties that threaten the quality of the public urban area. Alternatives B and C are close to each other, both during and after their implementation.

Alternative B, to restrict use, is associated with a decreased functional performance of the inner-city quay wall and a decreased functionality and accessibility of the public urban area. However, in respect to safety, image and affordability, Alternative B scores relatively low on risk during implementation. The execution activities of this alternative have a low risk for surrounding public area. Alternative C, to repair, scores relatively low on risk after execution, as the performance of the inner-city quay wall in terms of quality criteria of the surrounding area will be restored.

It should be noted that the risk sum during the implementation of a management strategy covers a shorter duration than the risk sum after the implementation. Adding a time axis would provide a more accurate indication of risk 'volume'.

Risk analysis and risk monitoring is a continuous process and must be taken seriously. Risks should be identified, analysed, assessed and controlled by avoidance, prevention, reduction, transfer or acceptation (Port of Rotterdam, 2013; Ten Veldhuis, 2010). Awareness is raised through timely identification of risks and opportunities around (historic) inner-city quay walls in Delft. Currently, innovative monitoring tools are developed to detect inner-city quay wall deformations in an early stage (Hansje Brinker B.V., 2012; Horstmann, Schimmels, & Oumeraci, 2012; Ophof, 2015).

As described in Appendix B, interface and environment are important factors in managing inner-city assets in public urban areas. Inner-city areas are dynamic environments in which individuals and organisations have their own requirements, desires and interests. When these stakeholders are insufficiently involved and/or informed in the management processes the risk exists that they will use their veto. By recognising these different interests and possible consequences for the stakeholders, adequate communication and nuisance reducing measures can be used.

TABLE 42: Risk scores after implementation of management strategies incl. relative weight of quality criteria.

Risk category	Weight	A: Change nothing						B: Restrict use						C: Repair						D: Replace					
		Before		During		After		Before		During		After		Before		During		After		Before		During		After	
Safety and Health	0.41	20	8.30	20	8.30	28	11.62	20	8.30	18	7.47	5	2.07	20	8.30	21	8.71	4	1.66	20	8.30	24	9.96	2	0.83
Functionality	0.24	18	4.35	18	4.35	28	6.76	18	4.35	20	4.83	10	2.41	18	4.35	21	5.07	4	0.97	18	4.35	24	5.79	2	0.48
Image	0.09	12	1.03	12	1.03	18	1.54	12	1.03	10	0.85	5	0.43	12	1.03	14	1.20	4	0.34	12	1.03	16	1.37	2	0.17
Societal importance	0.16	12	1.87	12	1.87	16	2.49	12	1.87	16	2.49	14	2.18	12	1.87	16	2.49	4	0.62	12	1.87	16	2.49	2	0.31
Affordability	0.10	10	1.03	10	1.03	12	1.23	10	1.03	12	1.23	10	1.03	10	1.03	14	1.44	10	1.03	10	1.03	18	1.85	10	1.03
Risk sum	1	72	16.56	72	16.56	102	23.64	72	16.56	76	16.87	44	8.12	72	16.56	86	18.91	26	4.62	72	16.56	98	21.46	18	2.82

TABLE 43: Ranking of management strategies based on risk sums.

Unweighted (U) and Weighted (W) Risk sum [-]		U_Before	W_Before	Rank	U_During	W_During	Rank	U_After	W_After	Rank	Δ_U	Δ_W	Rank
Alternative A	*Change nothing*	72	16.56	1	72	16.56	1	102	23.64	4	30	7.07	4
Alternative B	*Restrict use*	72	16.56	1	76	16.87	2	44	8.12	3	-28	-8.44	3
Alternative C	*Repair*	72	16.56	1	86	18.91	3	26	4.62	2	-46	-11.95	2
Alternative D	*Replace*	72	16.56	1	98	21.46	4	18	2.82	1	-54	-13.74	1

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